The Own-Race Bias for Face Recognition in a Multiracial Country

by

Wong Hoo Keat

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Abstract

The own-race bias (ORB) is a well-documented phenomenon whereby people are more accurate at recognising faces from their own-race group compared to faces from different race groups (Meissner & Brigham, 2001). While empirical studies have reported the robustness of the ORB across racial groups, the finding that the ORB is negatively related to exposure to other-race individuals suggests that may not necessarily apply to individuals who were born and have lived in a multiracial society. This thesis fills a gap in the ORB literature by examining the role of multiracial immersion experience as well as potential perceptual/attentional mechanisms in modulating the ORB by employing a series of face memory and face perceptual tasks on different racial groups (i.e. Malaysian-Malay, Malaysian-Chinese, Malaysian-Indian, African and Western-Caucasian individuals).

In Experiment 1, I demonstrated that the ORB in face memory was pronounced not only in Western-Caucasian participants, but also in Malaysian participants (Malay, Chinese, and Indian) who were raised in a racially diverse environment, implying that growing up in a profoundly multiracial society does not eliminate the ORB. In Experiment 2, I found significant correlations between memory performance for learned target faces and facial distinctiveness; most importantly, own-race faces benefited more from this distinctiveness effect than other-race faces across the four race groups. These findings fit well with Valentine's (1991) face-space model that dimensions of face space are optimised for own-race faces, and the ORB is likely to be attributable to the inefficiency in the use of norm-based coding for other-race faces.

Using a procedure identical to Experiment 1, I observed a significantly greater increment in recognition performance for other-race faces than for own-race faces when the external features (e.g., facial contour and hairline) were presented along with the internal

features in Experiment 3. This finding supports the notion that different processing mechanisms are involved for own- and other-race faces, with internal features of own-race faces being processed more effectively whereas external features dominate representations of other-race faces.

In Experiment 4, I adopted a cross-cultural design where Malaysian-Chinese, African, European-Caucasian and Australian-Caucasian participants performed four different tasks: (1) yes-no face recognition, (2) composite, (3) whole-part and (4) global-local tasks. Each face task was completed with unfamiliar own- and other-race faces. Although I detected a robust ORB effect in recognition accuracy, the occurrence of holistic processing for other-race faces did not lead to a smaller ORB in any of the four race groups. These unexpected results cast doubt on the holistic account of the ORB and support an alternative interpretation that the ORB cannot be fully accounted for by a reduced inability to process other-race faces holistically.

Experiment 5a and 5b were designed to test the hypothesis that directing first fixations to diagnostic features would reduce the ORB while taking the race of both face stimuli and of observers into account. Results showed that cueing participants to fixate more on the other-race diagnostic features that they would not normally fixate upon does not remove the ORB, suggesting that the ORB is not solely attributable to general lack of attention towards diagnostic features.

By the means of a gaze-contingent stimulus presentation, Experiment 6 investigated whether, and if so, to what extent restricting facial information outside/inside central vision affects face matching accuracy for own- and other-race faces. Results showed that, regardless of the race of the input face, participants' performance level decreased when they were forced to extract the facial information feature-by-feature than when they could process all features at once holistically. This favours the view that the looking strategies (holistic vs. featural)

dedicated to the extraction of facial information from own-race and other-race faces are flexible in the face matching task.

Contrary to the contact hypothesis, it appears that Malaysians' substantial everyday exposure to different races does not lead to a broadly-tuned representation that accommodates multiple other-race faces. Collectively, my results converge with recent literature to suggest that perceptual experience shapes our ability to recognise own- and other-race faces but there is relatively little plasticity in face recognition in adulthood (e.g., Singh, Loh, & Xiao, 2017; Tree, Horry, Riley, & Wilmer, 2017). That is, interracial contact in adulthood is ineffective for improving other-race face recognition. The current findings imply that the cause of the ORB, at least for Malaysian young adults living in a multiracial environment, is a relative lack of perceptual experience in childhood, rather than a lack of motivation to individuate other-race people. Future research is required to directly address whether, and if so, how early perceptual experience with own- versus other-race faces and development interact to modulate the plasticity of ORB in adulthood.

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Chapter 1

Face Recognition

Face recognition is one of the most crucial skills in our daily social interactions. By looking at a face, people are able to extract sufficient information to infer properties such as race (Michel, Corneille, & Rossion, 2007; Tanaka & Pierce, 2009), gender (Gul & Humphreys, 2014), age (Kwon & Lobo, 1999), and emotions (Ekman, 1993). In everyday life, identifying and discriminating between individuals based on their faces is essential for maintaining relationships and for effective communication with others. The ability to recognise familiar faces in a fraction of a second (Barragan-Jason, Lachat, & Barbeau, 2012) is a remarkable feat given the tremendous number of different individuals encountered in a lifetime. Recognising friends, family members and famous celebrities can be an effortless task despite numerous variations that can interfere with face recognition, such as changes in viewpoint, expression, lighting, shape, and texture (due to aging).

Through extensive experience with individuating faces, humans may develop advanced capabilities for processing faces. Evidence from behavioural, brain lesion, and neuroimaging studies suggests that, in adults, face processing involves specific face processing strategies (i.e., functional specialization, Loffler, Yourganov, Wilkinson, & Wilson, 2005) carried out by dedicated brain areas (i.e., structural or neural specialization) (Eimer, 2000; Huang et al., 2014; Huang et al., 2017; Kanwisher, 2010; Kanwisher & Yovel, 2006). These observations are entirely compatible with the view that the human brain is equipped with neural circuitry specialised for face processing (Haxby & Gobbini, 2010; Haxby, Hoffman, & Gobbini, 2002). Although all faces share the same basic features (i.e. two eyes positioned above a nose with two coupled lips underneath), most people are highly

adept at detecting subtle differences within the set of all faces. Faces are a unique class of visual stimuli with high inter-item similarity that require within-category recognition at the individual level. Hence, many cognitive psychologists are interested in face recognition as it may represent the "ultimate within-category discrimination".

While it has been widely accepted that early experience plays a crucial role in the development of face processing (Rennels & Davis, 2008; Su, Tham, Bremner, & Hay, 2015; Walker & Hewstone, 2006a), relatively little is known about how and when faces become special stimuli (e.g., how view-invariant recognition of familiar faces is achieved) and start to be processed differently from objects. Moreover, there still exists some controversy on the nature of humans' face processing abilities; while some evidence suggests that faces are a special class of stimuli operated by a specialised neocortical circuitry (Kanwisher, 2000; McKone et al., 1993), other research suggests that human superior face processing abilities are reflective of learned expertise that relies on general object recognition pathways (Diamond & Carey, 1986; Kanwisher, 2000; Newport, Wallis, Reshitnyk, & Siebeck, 2016).

1.1 Are Faces Special?

Like many visual stimuli, faces must be accurately recognised over a wide range of orientations, lighting and spatial scales. Unlike non-face object recognition, the ability to extract a large amount of facial information from just a glance plays a crucial role in our daily communication. Do faces seem special only because people have had more extensive experience of individuating them as compared to other homogeneous object categories? Two major rival theories have been proposed to explain how humans recognise faces: First, face recognition is innate, involving face-specific cognitive and neural processes ('domain specificity hypothesis'). Second, recognition is a learned expertise that relies on general object recognition pathways ('the expertise hypothesis').

1.1.1 Domain Specificity Hypothesis

The domain-specificity hypothesis suggests that the processing of faces is a highly specialised function that is separate from the processing of other types of objects. From an evolutionary perspective, the existence of specific brain areas and of specific strategies for face processing concurs with the evolutionary view that they provide an important adaptive advantage for survival. Therefore, they are hypothesised to be domain-specific and likely innate (McKone & Boyer, 2006; Wilmer et al., 2010; Zhu et al., 2010). Face perception abilities emerge very early in infancy with an innate attraction to faces. Newborn babies, despite their lack of experience, orient preferentially towards face-like stimuli rather than to other equally complex visual stimuli (Arcaro, Schade, Vincent, Ponce, & Livingstone, 2017; Farroni, Csibra, Simion, & Johnson, 2002). After just a few days, they can recognise their mother's face (Bushnell, Sai, & Mullin, 1989) and distinguish between a schematic face stimulus and a scrambled face (Morton, Johnson, Dziurawiec, & Ellis, 1991). Yet, early face deprivation leads to a highly selective cortical processing deficit (Arcaro et al., 2017).

Interestingly, non-humans also show an early predisposition to orient to faces. For instance, newly-hatched chicks attend to patterns similar to the head region of their caregivers (Salva, Farroni, Regolin, Vallortigara, & Johnson, 2011). A recent monkey study provides even stronger evidence for a genetic predisposition for face processing (Sugita, 2008). Sugita raised infant monkeys in a visually rich environment but with no exposure to faces (human caregivers wore full face masks) for up to 24 months. They tested face discrimination of these monkeys using a visual paired-comparison procedure and a preferential looking paradigm during and after the face-deprivation period. While the control monkeys raised in a normal environment showed a selective preference for monkey faces compared to non-face objects, the face-deprived monkeys also showed strong preferences for both human and monkey faces despite no exposure to faces. This evidence of discrimination between individuals of both

species suggests that face recognition is an innate capability that is not species-specific. Taken together, not only do these findings provide strong evidence of the presence of pre-wired domain-relevant attentional biases toward faces from birth, but also indicate that face recognition is supported by evolved mechanisms as well as sensitive periods during development (Scott & Nelson, 2007; but see Arcaro et al., 2017).

1.1.1.1 Configural, Holistic and Featural Processing

It has been well established in the literature that faces are processed more configurally than any other object types (Gauthier, Behrmann, & Tarr, 1999; Robbins & Mckone, 2007; Rossion et al., 2000; Watson & Robbins, 2014; for a review, see Bruyer, 2011). However, there is still a lack of consensus on what "configural" processing actually means (Maurer, Le Grand, & Mondloch, 2002; Richler, Palmeri, & Gauthier, 2012). The term is sometimes used interchangeably with holistic processing (Mckone, 2009) and sometimes taken as a central term including holistic processing as a subtype. For example, Maurer et al. (2002) advocate that there are three different types of configural processing: (1) perceiving first-order relations of all faces (i.e. two eyes above a nose and a mouth; e.g., Diamond & Carey, 1986); (2) processing second-order facial relations (i.e., spatial relations among features such as the distance between eyes; e.g., Diamond & Carey, 1986); and (3) holistic processing (i.e., processing the face as an integrated perceptual "whole" rather than a collection of separable facial features; e.g., Tanaka & Farah, 1993). On the other hand, featural processing (sometimes termed "component" or "piecemeal" processing) is a qualitatively different process from configural processing, whereby faces are processed in terms of their independent component parts (e.g., Diamond & Carey, 1986; Tanaka & Farah, 1993).

It is important to note that the terminology differs among researchers. Some use *holistic* versus *featural* processing, whereas others refers to *configural* versus *piecemeal* processing, and still others refer to feature-based processing as *component* processing.

Recently, it has been emphasised that these different terminologies are not interchangeable and that configural and holistic processing have particular and distinguishable definitions (for more discussion, see McKone & Yovel, 2009; Richler et al., 2012). Nevertheless, these different terms share a broad focus on the processing of second-order characteristics (i.e., the relationship between the facial features) versus the processing of first-order characteristics (i.e., the facial features themselves).

Support from prior investigations suggests that there is a qualitative shift in the main type of processing used for recognition throughout development (Schwarzer & Zauner, 2003). Some researchers attribute this idea to the role of experience in shaping children's face processing expertise (Ellis, Bruce, & De Schonen, 1992; Hayden, Bhatt, Reed, Corbly, & Joseph, 2007). To recognise faces, people employ different strategies that require processing different information: the shape of local facial features (i.e., featural processing), the spacing between internal facial features (i.e., configural processing) and the global structure of the face (i.e., holistic processing). Unlike most everyday objects, faces are thought to be processed in a more holistic or integrated manner than other objects. That is, human faces are perceived as indecomposable wholes, rather than as collections of independent parts (Maurer et al., 2002; Piepers & Robbins, 2012; Rossion, 2013).

Evidence in support of holistic face processing derives partly from studies that examine the effect of inversion on face recognition performance (Yin, 1969). As face inversion disrupts the familiar first-order spatial relationships between the facial features (Ellis, Deregowski, & Shepherd, 1975), face recognition performance is more heavily impaired by inversion than recognition of other types of objects (Diamond & Carey, 1986). This suggests that face recognition may use more holistic processing than general object recognition (Le Grand, Mondloch, Maurer, & Brent, 2004). Besides, the claim that faces are special in terms of holistic/configural processing is also well-supported by the lack of holistic

effects when non-face objects were tested in specific holistic processing paradigms, such as the classic whole-part paradigm (Tanaka & Farah, 1993; Tanaka, Simonyi, Tanaka, & Simonyi, 2016b) and the composite-face paradigm (Meinhardt, Meinhardt-Injac, & Persike, 2014; Richler, Cheung, & Gauthier, 2012; Young, Hellawell, & Hay, 1987) (see Chapter 6 for more discussion). In the whole-part task, holistic processing is measured as better recognition of a feature when that feature is presented in the context of a whole face compared to when it is presented in isolation. In the sequential matching composite-face task, observers judge whether one face half (e.g., top) of two sequentially presented faces is the same or different while ignoring the other task irrelevant face-half (e.g., bottom). The degree to which the irrelevant half interferes with the judgment is considered an index of holistic processing. Altogether, the inversion effect, the composite-face effect and the whole-part effect distinguish face-specific processing from general object processing (Robbins & Mckone, 2007).

According to the domain-specificity hypothesis, holistic processing is face-specific (Kanwisher, 2010; McKone et al., 2006; Robbins & Mckone, 2007) due to an innate face template (Morton et al., 1991) that is used to encode the basic structure of a face (e.g., two eyes above a nose and a mouth), or due to experience in discriminating faces at the individual-level during the sensitive period (McKone, Brewer, MacPherson, Rhodes, & Hayward, 2007; Tsao & Livingstone, 2009). Consistent with this hypothesis, a study reported that holistic face processing breaks down if there is a lack of exposure to faces during early infancy (Le Grand et al., 2004). Le Grand et al. (2004) investigated the role of early visual experience in the development of holistic face processing by using the composite-face task to test patients deprived of visual experience of faces during infancy. Visually normal controls manifested the expected composite-face effect: they had difficulty deciding whether the top halves of two faces were the same when the top halves were aligned with different bottom

halves. They showed better performance when holistic processing was disrupted by misaligning the top and bottom halves. On the other hand, deprived patients performed significantly better than control subjects when top and bottom halves were aligned, showing no evidence of holistic processing. These findings suggest that early visual experience is important for the development of holistic face processing.

There is also evidence for some sort of holistic face processing based on observations made on patients who suffer from *acquired* or *developmental prosopagnosia* – neurological conditions in which people are unable to identify familiar faces (Behrmann & Avidan, 2005; Behrmann, Avidan, Marotta, & Kimchi, 2005; Belle et al., 2011; Le Grand et al., 2006; Verfaillie, Huysegems, De Graef, & Van Belle, 2014). Compared to typical observers, individuals with this condition often exhibit deficits when viewing upright faces, but relatively typical discrimination of inverted faces (Busigny & Rossion, 2010; Klargaard, Starrfelt, & Gerlach, 2018). Instead of employing a holistic strategy, they seem to primarily process faces in a piecemeal manner (feature-by-feature analysis). While the inability to take advantage of holistic processing for upright faces may explain the lack of an inversion effect in prosopagnosia patients, their selective impairments for recognising individual faces provides the neuropsychological evidence for the specific domain of face recognition (Belle et al., 2011; White, Rivolta, Burton, Al-Janabi, & Palermo, 2017).

1.1.1.2 Fusiform Face Area (FFA)

More recently, much evidence has shown that the fusiform face area (‘‘FFA’’; Kanwisher & Yovel, 2006), a small region of the right middle fusiform gyrus (located in the neocortex; see *Figure 1.1*), is heavily involved in human face processing. Although it seems that there is domain specificity for face processing, it remains unclear whether the neurons in the fusiform gyrus responds selectively to facial information, and hence whether faces represent a unique object class, or if the neurons performing face processing are merely

general-object responsive neurons tuned to faces via extensive exposure (i.e. perceptual expertise). At the neural level, the temporal aspects of face-specific neural processing have been investigated using ERP components, such as N170 (structural encoding; e.g., Eimer, 2000; Rossion et al., 2000), N250 (familiar faces), and N450 (semantic face processing). Additionally, fMRI studies showed a greater face selectivity in the fusiform face area and occipital face area (Huang et al., 2014) and the fMRI signal change seen in the FFA is greater for upright faces than for inverted faces (Yovel & Kanwisher, 2005), suggesting a dedicated brain region for face processing.

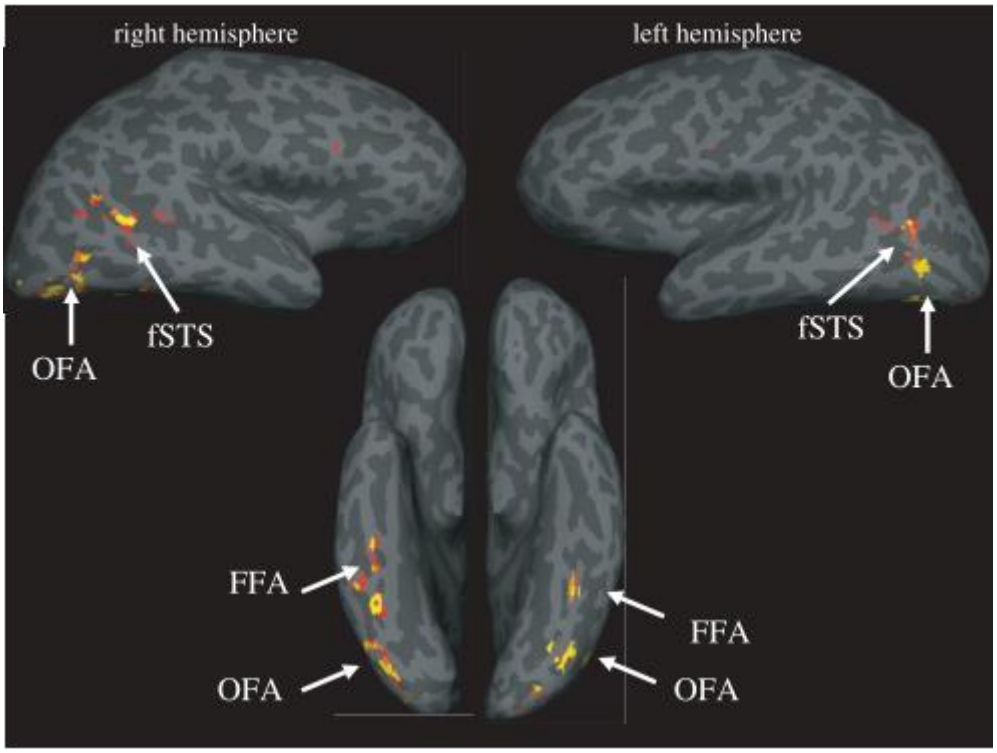


Figure 1.1. Face-selective activation on an inflated human brain, shown from lateral and ventral views of the right and left hemispheres. Three face-selective regions are illustrated: (1) the FFA in the fusiform gyrus along the ventral part of the brain, (2) the OFA in the lateral occipital area and (3) the fSTS in the posterior region of the superior temporal sulcus (Kanwisher & Yovel, 2006, p. 2114).

Greater fMRI responses to faces in the FFA compared to other non-face objects have been reported for a variety of facial stimuli, such as schematic faces (Loffler et al., 2005), full frontal and profile image (Tong, Nakayama, Moscovitch, Oren, & Kanwisher, 2000), line drawings (Spiridon & Kanwisher, 2002), and "Mooney faces" (see *Figure 1.2*; Rhodes, Byatt, & Michie, 1997). Taken together, these consistent results obtained from facial stimuli of different properties indicate that this face-selective region is responsible for the greater response observed in the FFA for faces compared to non-face stimuli. Further support for the face-preferential region derives from empirical studies that used bi-stable visual stimuli (Andrews & Schluppeck, 2004; Hasson, Hendler, Bashat, & Malach, 2001; Williams, Moss, & Bradshaw, 2004). For instance, Hasson (2001) reported that signals from FFA are greater during the perception of a face in the Rubin vase-face illusion (see *Figure 1.2*).



Figure 1.2. Example of a Mooney face (left) and the Rubin Vase (right)

Neuroimaging evidence appears to suggest that mammalian brain structures with highly specialised neural regions acquired through evolution are necessary for face processing (Kanwisher, 2000; Maurer et al., 2002). However, it has been recently reported that other vertebrates like pigeons (Stephan, Wilkinson, & Huber, 2012), sheep (Goncalves,

Jennifer, & Morton, 2017), or archerfish (Newport et al., 2016) seem to be able to discriminate and recognise human faces. Furthermore, the idea that a large mammalian brain structure is required for face processing and individual recognition has been challenged by an astonishing finding that an insect, the wasp *Polistes fuscatus*, can individually recognise nest mates from their facial visual mask (Tibbetts, 2002). The question at issue, however, is whether these forms of perceptual learning are actually comparable to human face recognition? Nevertheless, it is now widely believed that face recognition forms a unique ability that is relatively independent from domain-general factors such as general cognitive ability, motivation, or attention (Wilhelm et al., 2010; Wilmer et al., 2010; Zhu et al., 2010), providing clear support for the domain-specificity hypothesis.

1.1.2 Expertise Hypothesis

People spend much of their lives looking at faces. Intuitively, it would seem that, given the enormous number of faces encountered, acquired expertise in perceiving and recognising faces would be gained naturally. In fact, this idea has become one of the most widely used theoretical framework in face recognition studies. Perceptual expertise has also been claimed to account for the own-race bias (see Chapter 2) in face recognition, for the emergence of holistic processing (see Chapter 6), and for similarities and differences between the recognition of faces and other types of visual stimuli such as birds (Gauthier, Skudlarski, Gore, & Anderson, 2000), cars (Gauthier et al., 2000), dogs (Diamond & Carey, 1986) and Greebles[1] (Gauthier & Tarr, 1997).

According to the expertise hypothesis (Diamond & Carey, 1986), upright faces come to be processed specially in adults only because of lifetime exposure to the upright orientation. It has also been suggested that holistic processing is based on a learned

[1] The Greebles refers to an invented class of novel 3D objects which have a small number of parts in a common configuration like human faces. As most people have never seen them before, they serve as a useful experimental tool for measuring visual discrimination or even memory.

automatized attention to whole objects, which is shaped by extensive individuating experience (Diamond & Carey, 1986; Gauthier & Tarr, 1997; Richler, Wong, & Gauthier, 2011). In this perspective, faces are processed holistically because recognition performance could be benefited by attending to diagnostic information distributed over whole faces (Chua, Richler, & Gauthier, 2016). Studies consistent with this notion have shown that extensive training in individual-level discrimination leads to the emergence of holistic processing for non-face objects (Chua et al., 2016; Palmeri, Wong, & Gauthier, 2004; Zhao, Bülthoff, & Bülthoff, 2016b). For instance, Chua et al. (2016) trained their participants to individuate faces or non-face-like novel stimuli ("Greebles") wherein one half contained most of the information diagnostic for identification. When later asked to selectively attend to just part of those objects, participants could not ignore parts that were previously diagnostic, indicating the emergence of holistic processing.

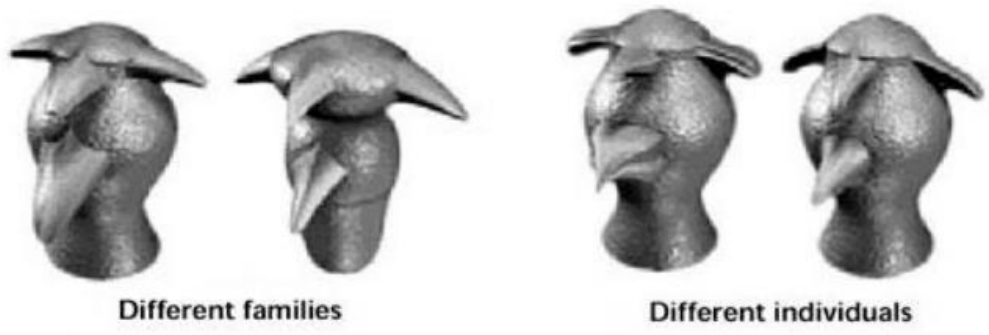


Figure 1.3. Example of Greebles (Gauthier et al., 1999)

In another study, Gauthier and Tarr (1997) extensively trained participants to be greeble experts, encouraging them to process these novel stimuli with the use of cognitive and neural mechanisms involved in face recognition. Their results showed Greeble experts are more sensitive than non-experts to configural changes and they identify Greeble parts more holistically to achieve within-category identification. Importantly, the training selectively activated the FFA (Gauthier, Behrmann, & Tarr, 1999), which is commonly

thought to be involved in face processing. Greater activation in the right FFA was also observed only for Greebles experts when responding to upright compared to inverted stimuli (Gauthier et al. 1999). Consistent with the expertise hypothesis, there was a larger activation within the FFA region for own-race faces relative to other-race faces (Golby, Gabrieli, Chiao, & Eberhardt, 2001).

However, a few studies failed to replicate these patterns of results. For example, Rhodes, Byatt, Michie, & Puce (2004) examined the fMRI activation patterns within the FFA in butterfly experts and compared them to those of faces. First, they detected a greater neural activation to faces compared to butterflies. Second, during individuation of butterflies, a large proportion of activated voxels (83%) were outside the fusiform gyrus region and only 15% of activated voxels were within the fusiform gyrus. While these results seem incompatible with those supporting the expertise hypothesis, the outcome should be interpreted with caution. It is arguable that the level of expertise these individuals have with faces is still greater than that with butterflies. This argument is supported by the observed greater activation for the face stimuli relative to the butterfly stimuli. Furthermore, although the overlap between the cortical areas activated by faces and butterflies within the fusiform gyrus region was reported to be small, such overlap was larger for butterfly experts than for controls. These findings point towards the strong involvement of the FFA in face processing; meanwhile, it seems to indicate that this area is recruited in expertise to some extent.

To date, whether these face-specific brain regions are better considered as regions dedicated to within-category identification is still a matter of ongoing debates. Nevertheless, the vast majority of neuroimaging studies (Gauthier et al., 1999; Kanwisher, 2000; Rossion et al., 2000) suggests that faces are in fact special since they contain a large amount of social cues, such as identity information, emotional expression and gaze direction, which are crucial for daily interpersonal interactions.

1.2 Familiar versus Unfamiliar Face Recognition

Recognising faces that we are familiar with across a wide range of viewing conditions seems to be an effortless task. Yet, psychological research over the past 40 years has clearly demonstrated that our ability to recognise familiar people does not generalise well to unfamiliar faces, not only in laboratory (Shepherd, & Davies, 1979; Valentine & Bruce, 1986), but also in real life settings (for a recent review, see Young & Burton, 2017).

It is well-established in the memory literature that recognition of familiar and unfamiliar faces differs in a number of ways (for reviews see Johnston & Edmonds, 2009; Young & Burton, 2017). For instance, familiar faces are recognised faster and more accurately than unfamiliar faces in studies of recognition memory (Ellis et al., 1979). In more recent studies of perceptual face matching, participants also perform better at identifying familiar faces than unfamiliar faces when asked to judge whether two images depict the same person, indicating that this difference is unlikely to be purely a memory effect (e.g., Bruce, Henderson, Newman, & Burton, 2001; Megreya & Burton, 2006).

O'Donnell & Bruce (2001) investigated whether the internal features (e.g., eyebrows, eyes, nose and mouth) carry different weights in the recognition of familiar faces compared to unfamiliar faces. Their results showed that in faces in which the eyes had been altered, this change was detected more accurately for familiarised faces than for the unfamiliar faces, suggesting that the eyes play a greater role in the recognition process as a face becomes more familiar. However, the authors did not address the question of whether the eyes and eyebrows make equal contributions to the representation of facial identity. To fill this gap, Sadr, Jarudi, & Sinha (2003) studied recognition performance for famous faces after the face had either the eyes or eyebrows removed. They reported a significantly greater disruption in recognition performance of familiar faces when the eyebrows were removed, and this decrement was larger than when the eyes were removed. In addition, evidence from eye-movement data

showed that the internal region of familiar faces was fixated more frequently than unfamiliar faces in a standard recognition memory task (Stacey, Walker, & Underwood, 2005). Collectively, these studies demonstrate that people rely more on the internal features for recognition memory as faces become familiar. Yet, it is important to note that most of the early reports of an external feature advantage for unfamiliar face recognition were mostly derived from Caucasian samples (Bruce et al., 1999, Haig, 1986, Nachson and Shechory, 2002, Veres-Injac and Persike, 2009). Hence, it remains uncertain whether the relative contribution of internal and external features to face recognition of Western Caucasians generalises to people of other ethnicity; for example, East Asians who tend to perceive faces more holistically than Western-Caucasians (e.g. Blais et al., 2008). Given that the hair may serve as an indicator of race, perceived out-group faces (e.g. other-race faces) may also be associated with a stronger reliance on the external features (see Chapter 5).

On the other hand, the external features do contain one particularly distinctive and memorable cue – the hair. However, hair and hairstyles are features that can be altered easily, and therefore are potentially unreliable cues to face identity. It has been found that external features may dominate face-matching decisions when recognising unfamiliar faces compared to familiar faces. By employing a classic old-new recognition paradigm, Ellis et al. (1979) tested Caucasian participants' memory on Caucasian faces. Half of the participants were asked to remember 15 familiar faces, and the other half to remember 15 unfamiliar faces, with each face presented for 6 seconds. In the test phase, target faces were presented with 15 new 'distracter' faces. Participants were asked to indicate whether they had seen each face in the learning phase. One group of participants was presented with the full faces again at test, a second group was presented with just the internal features, and a third group were required to identify faces from the external features only. They found that unfamiliar faces were remembered equally well from their external features as from their internal features.

However, if participants were given internal features at test as opposed to external features, their recognition memory was significantly better for familiar faces.

Endo, Takahashi, & Maruyama (1984) replicated the original study using Japanese faces and observers. Whilst Ellis et al. (1979) found the recognition advantage of the internal features over the external features for familiar faces, they found no recognition advantage of the external features for unfamiliar faces. However, Bruce et al. (1999) reported inconsistent results. They asked participants to match an image taken from high-quality video footage against a photographic array showing studio portraits of young adults of similar appearance to the target. Two different pictures of the same identity were used (one in the target array of faces and one for the probe image), to prevent low-level image matching strategies to memorise face identities. The unfamiliar faces were either presented as whole faces, the internal features only or the external features only. Their results showed that even when the image grabbed from video matched the expression and orientation of the array photos, the error rates were high. More interestingly, it was found that presenting only the external features led to significantly better recognition accuracy than the internal features did; however, presenting the whole face did not lead a better performance than when only external features were available. The authors therefore concluded that familiar face recognition is mediated by more abstract structural codes that define facial identity, allowing generalization across different expressions, viewpoints, and lighting conditions. In contrast, unfamiliar face memory is dominated by pictorial cues (e.g., hairstyle, freckles).

1.3 Cognitive Models of Face Processing

Developing face recognition models has been useful in understanding and even predicting performance on face recognition tasks. Moreover, modelling the cognitive processes underlying face recognition allows us to formulate theories about how we represent, store and retrieve facial information. To date, the cognitive models proposed by

Bruce & Young (1986) and (Valentine, 1991) have been the predominant theories used to formulate how humans store and perceive faces.

1.3.1 Bruce and Young (1986) Model.

Bruce and Young (1986) proposed a structural model of face recognition which remains highly influential to date. At a functional level, Bruce and Young's cognitive model suggests that face processing can be split into two distinct paths (see *Figure 1.4*). Face detection, (i.e., the ability to perceive a visual stimulus as a face) forms the first stage of this process, the so-called structural encoding stage. This initial stage, which produces view-centred descriptions and expression-independent descriptions, is refined in three ways: *expression analysis, facial speech analysis* and *directed visual processing*. While the facial expression analysis allows for the emotional recognition by capturing the configurational aspects of facial features, facial speech analysis enables a person to understand speech by analysing the movements of the mouth and tongue. Directed visual processing plays an important role in comparing or remembering unfamiliar faces by directing selective attention to the visual form of the face. These three processes are applicable to both familiar and unfamiliar faces.

Recognising familiar faces, on the other hand, depends mainly on the second pathway, which is from the *face recognition units* (FRU), through to the *person identity nodes* (PIN) and finally the *name generation stage*. Bruce and Young (1986) claimed that the expression-independent descriptions produced by from the speech and expression analysis are fed into face recognition units. Since FRUs contain the structural information of known faces, a single FRU is activated when a known face is presented. Person identity nodes (PIN) then provide the perceiver with semantic information regarding the individual, e.g. their occupation, interests, siblings etc., allowing for the subsequent retrieval of the person's name,

while the PINs can be activated via the cognitive system (e.g., via voice cues) as well as the FRUs without requiring a face input.

The model explains why people fail to recognise faces under certain circumstances. A typical example would be the everyday failures to recall any information about an individual despite knowing that the face is familiar. This can be accounted by the FRU not activating the corresponding PIN for that person. Another difficulty that people often encounter when trying to recall someone's name is the "tip-of-the-tongue" state (Young, Hay, Mcweeny, Flude, & Ellis, 1985), whereby a face is correctly recognised and identity information is retrieved (e.g. saying "I know he's an actor") but being unable to recall the person's name (e.g. being unable to say "It's Tom Cruise"). This kind of error indicates that both FRU (e.g. Tom Cruise's face) and PIN have been activated to enable recall of the fact that he is an actor. However, his name is not generated because there is no access to the name generation stage. Further support came from Young, Hay, & Ellis (1985) who asked their participants to keep diaries about their face recognition problems. They found that there are many instances of people failing to name someone but recalling other information; however, among 1008 incidents in total, none of them reported knowing a person's name without any specific identifying information about the person. This supports the theoretical concept that there are nodes that store names, and they can only be accessed through the PIN.

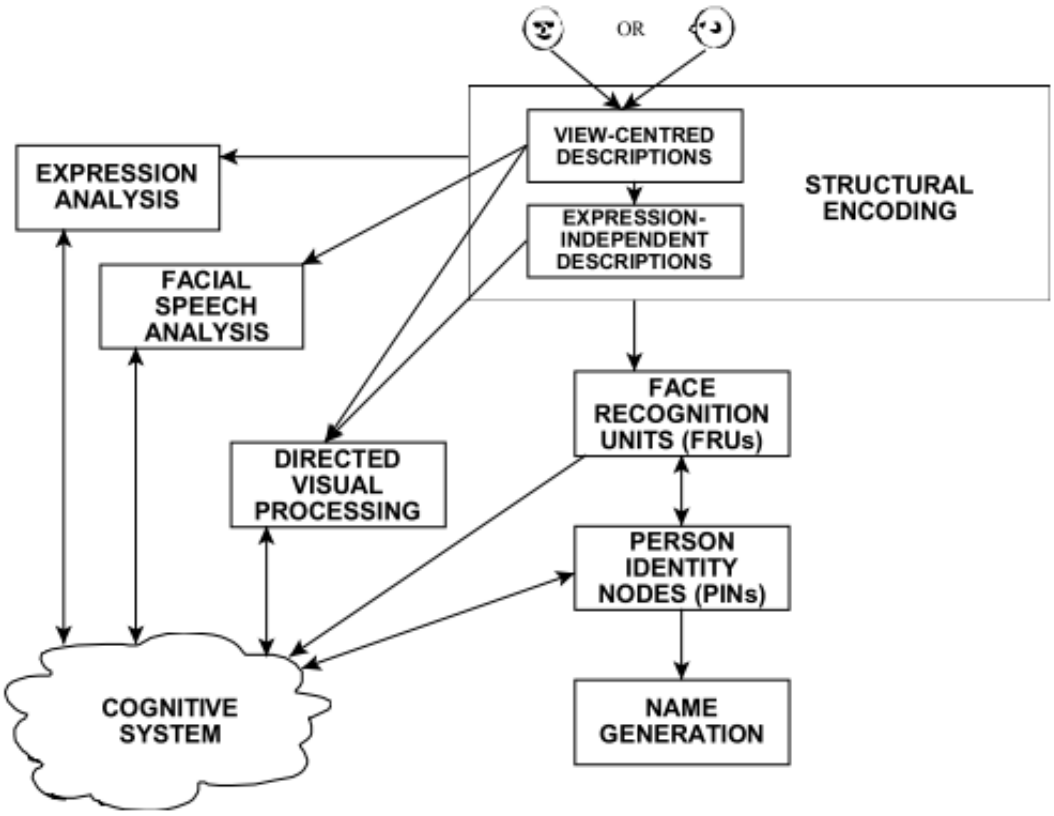


Figure 1.4. Bruce and Young's model of face recognition (adapted from Bruce and Young, 1986). It contains separate parallel routes for recognising facial identity, facial expression and lip speech.

Neuropsychological evidence also lends support to Bruce and Young's model that separate routes are involved in the processing of facial identity (i.e. face recognition) and facial expression. For example, Humphreys, Avidan, & Behrmann (2007) found that participants with developmental prosopagnosia had poor ability to recognise faces, but their ability to recognise facial expressions was comparable to that of healthy controls. In another study, Campbell, Landis, & Regard (1986) studied a woman with prosopagnosia who could not recognise faces but could identify which phonemes were being mouthed when looking at photographs of faces. This supports the prediction that there are separate processes for facial speech analysis and facial identity. Malone, Morris, Kay, & Levin (1982) reported two cases

of a dissociation between prosopagnosia and impaired capacity to match familiar faces. The first patient could recognise familiar faces well but could not match unfamiliar faces, whereas the second patient could match unfamiliar faces but could not recognise familiar people. Such a disassociation can be explained by the model as familiar and unfamiliar face recognition involves separate pathways. Consistent with the different connections illustrated in the Bruce and Young model (Figure 1.4), Malone et al.'s (1982) findings demonstrated that previous experience with a face may influence the intermediate and last stages of recognition; that is from FRUs and onwards. In other words, familiar face recognition does not necessarily involve the first stage of structural encoding.

Despite these convincing empirical supports, this model has limitations. It does not provide a comprehensive account of unfamiliar face recognition. The description given by Bruce and Young (1986) is oversimplified and does not fully explain the complexities of unfamiliar face recognition (e.g. perceptual processes involved in the initial face detection stage). Secondly, the model is quite inflexible in the assumption that the processing of names always comes after the processing of other identify information about faces. Also, the assumption that facial identity and expression involve separate processing routes may be too extreme. The assumption that name processing always occurs after processing of other personal information may also be too rigid. Names can, however, also be used as input information to recognize a person: for example, when we hear the name "Barack Obama", we can immediately recall his face, voice, and person related semantic information. Recent evidence from behavioural, neuroimaging, and patient studies questions the serial and bottom-up processing view of the original Bruce and Young's model (Bruce and Young, 1986). In fact, for faces as well as voices, there is evidence that recognition is based on representations of stored 'prototypes'. Prototypes can be averaged facial representations within a multidimensional space (Rhodes and Jeffery, 2006). Recognition is accomplished by

comparing the incoming stimulus to the stored representation and reflects the interaction of bottom-up and top-down processes. Such a procedure contradicts strict serial processing that proceeds from the sensory input level to more abstract cognitive levels, because the representation of the sensory input is influenced by the stored prototype.

1.3.2. The Interactive Activation and Competition (IAC) model

The IAC model (Burton et al., 1990) is often considered as the improved version of the Bruce and Young model. Although both models make similar predictions, the IAC model is more specific regarding the underlying mechanisms and the relationships between the different conceptual components. Figure 2 illustrates the framework of the IAC model. The main components of the model are FRUs, PINs and semantic information units (SIUs), which are all interconnected. The model follows the connectionist logic: units within a pool compete with each other, and when one of these units is activated, the rest are inhibited. The FRUs have the same function as that of the original Bruce and Young model. When we see a familiar face, an FRU for that face is activated, followed by an activation of the PIN for that person. It is important to note that, in this model, PINs can also be activated by other information such as names (name input units, NIUs). If a PIN reaches a threshold level of activation, that input face is categorised as familiar. Unlike the Bruce and Young model, familiarity decisions are dependent on the activation of PINs. Moreover, SIUs contains semantic information such as, interest, occupation, nationality, etc. Instead of a strict serial processing (as proposed in the Bruce and Young model), The IAC model assumes that top-down feedback between subsequent stages facilitates the processing during the whole procedure. For example, naming or person identity can affect the first stage of processing for structural encoding (Herzmann & Sommer, 2010).

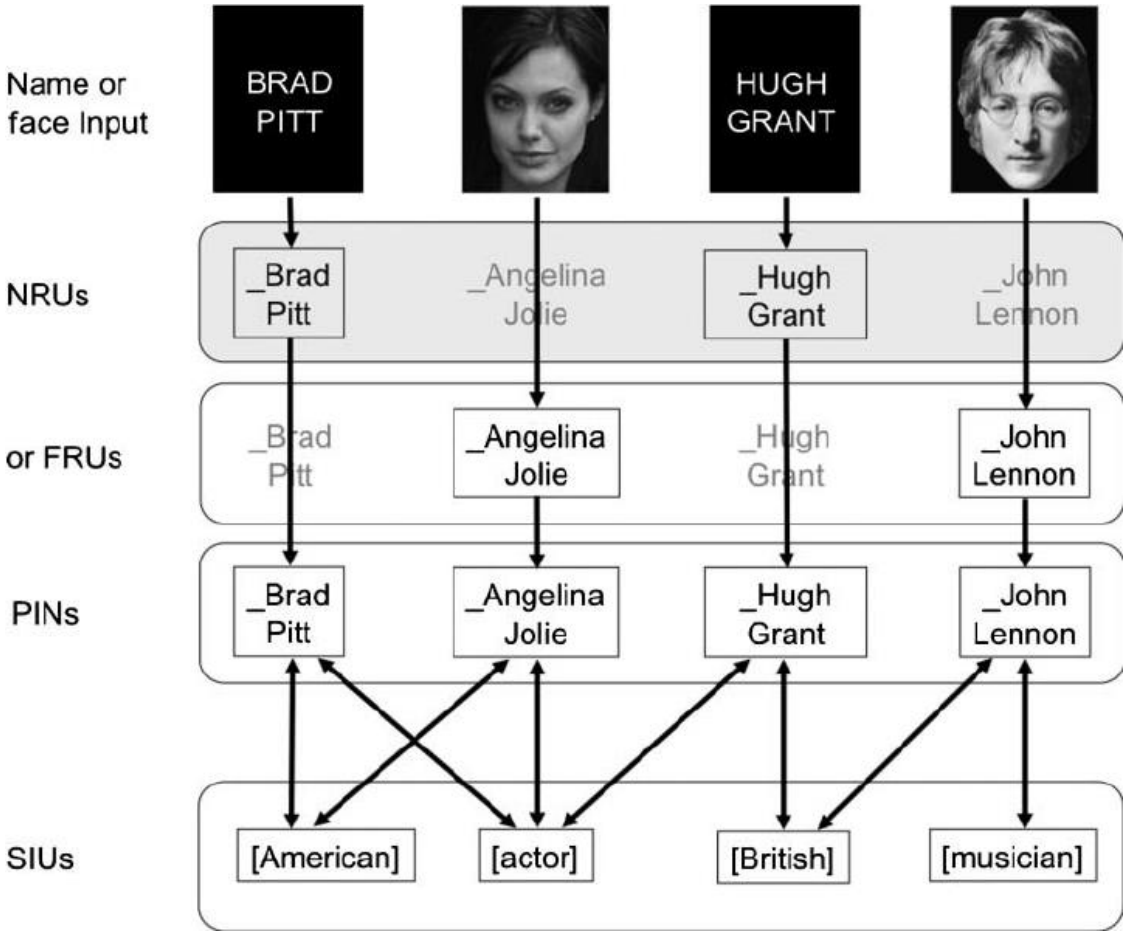


Figure 1.5. Illustration of the IAC model. NRUs = name recognition units; FRUs = face recognition units; PINs = person identity nodes; SIUs = semantic information units. Adapted from (Burton et al., 1990).

1.3.3 Valentine's Face Space Model.

Valentine's (1991) multidimensional face-space framework (MDFS) is by far the most influential model for the investigation of face recognition (Byatt & Rhodes, 2004; Lee, Byatt, & Rhodes, 2000; Lewis, 2004; Papesh & Goldinger, 2010; for a review, see Valentine, 2001). It accounts for many effects, including the own-race bias (Chapter 3) and the distinctiveness effect (unfamiliar faces rated as being distinctive are identified more accurately than typical faces) (see Chapter 4). According to this framework (Valentine & Endo, 1992; Valentine, 1991), which assumes a norm-based model, faces are encoded as unique points in a multidimensional space in which the norm or prototype face is located at

the centre of the face space (see *Figure 1.6*). Each face can be represented as a specific point in this face space, depending on its position along each dimension. Highly similar faces which share common characteristics will be densely clustered together. The density of exemplars in the surrounding area of the space will decide the ease with which a face is recognised. Typical faces are stored closest to the centre of the face space due to their average values on facial dimensions, whereas distinctive or less typical faces are stored along the outer edges of the face space. Since facial features, and therefore faces, are assumed to be normally distributed, there should be a dense cluster of typical faces at the centre of the face space. In contrast, distinctive faces should be stored in more sparsely populated regions of the face space, along the perimeter. With less similarity and density among the distinctive exemplars and more similarity and density among the typical exemplars, distinctive faces are therefore retrieved relatively easily, while typical faces are less easily remembered. Although the number of dimensions is not clearly specified, it could include variations such as eye colour, nose length, and spacing between eyes. According to Valentine (1991, 2001) and Valentine and Endo (1992), any useful feature that helps discriminate between faces can be considered as a "dimension". Although empirical data have suggested dimensions such as gender and race (Johnston, Kanazawa, Kato, & Oda, 1997), Valentine remains unsure concerning the actual dimensions that may support individuation in the face space.

Under the norm-based model, the similarity between two faces is defined as a function of the inner-product of their two vectors. During a recognition task, this similarity is computed between the stimulus face (i.e., test face) and the faces encoded in this multidimensional space. The stimulus face is recognised if the closest encoded face is the target face. If one generates a stimulus face that is close to the target face (e.g., the target face under slightly different illumination conditions), and the target face is located in the low-density region of the multidimensional space, the probability of the target being selected as a

match is higher than if the target was in the high-density region. This explanation is consistent with the previous reported findings that distinctive faces are recognised more accurately than typical faces (Newell, Chiroro, & Valentine, 1999; Valentine & Endo, 1992).

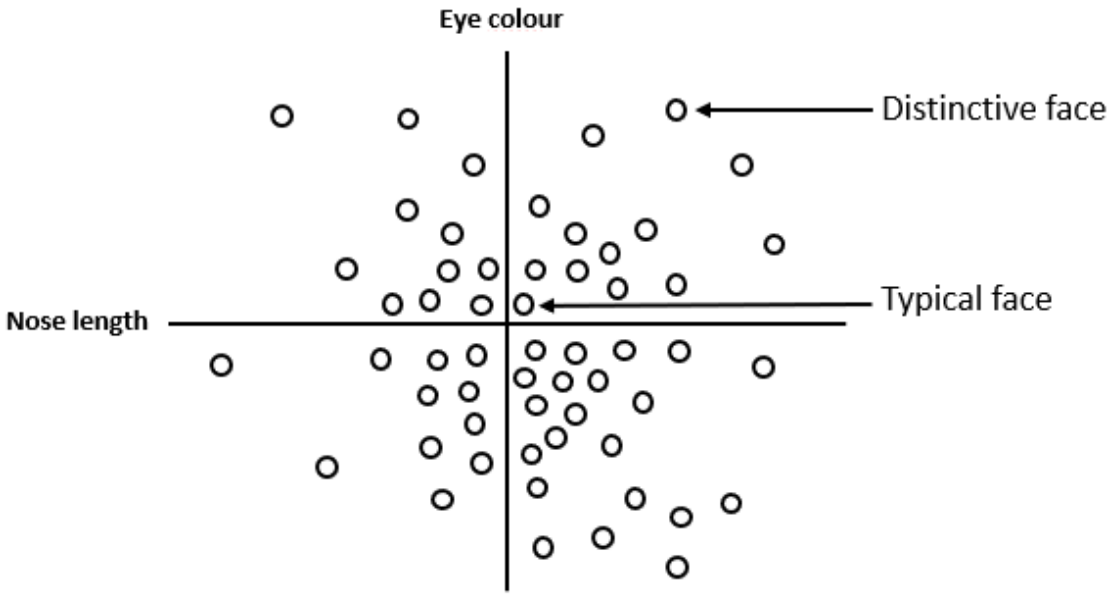


Figure 1.6. A two-dimensional representation of a norm-based model (Valentine, 1991).

Valentine's norm-based model also accounts for the ORB by assuming that other-race face points are more densely clustered than the own-race faces. The dimensions of face space are shaped by experience in a way that they effectively differentiate faces from categories with which adults have abundant experience. Due to an individual's limited experience with other-race groups, own-race faces stored in more sparsely in the central region of face space and other-race faces tightly clustered together in the periphery of the face space (*see Figure 1.7*; Valentine, 1991). Hence, it becomes difficult to tell other-race faces apart because the existing own-race tuned dimensions do not enable individuals to discriminate other-race faces very well.

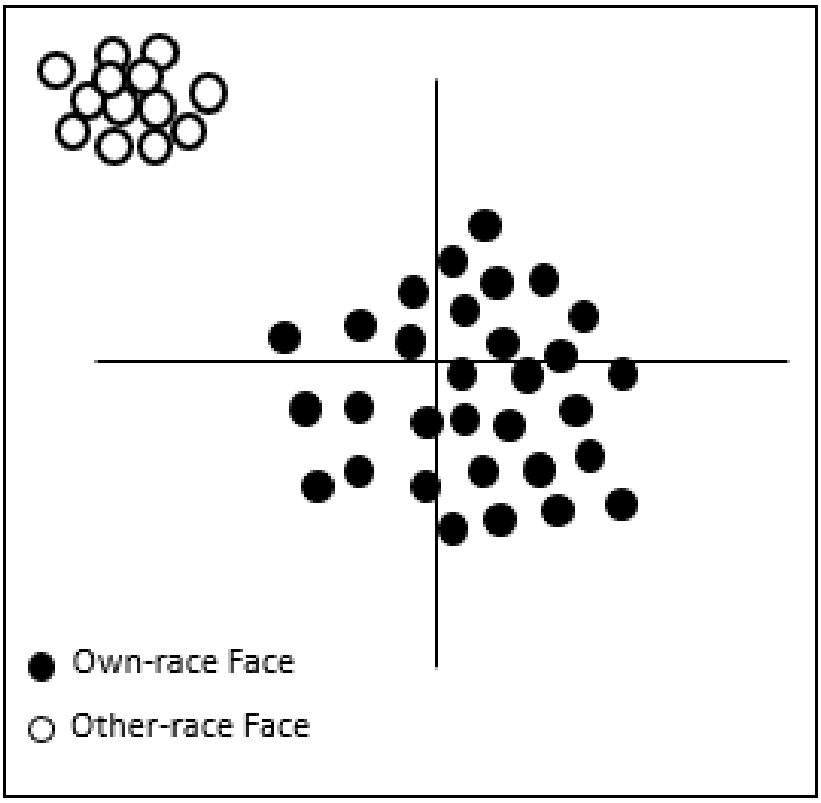


Figure 1.7. An example of the different exemplar density for own- and other-race faces in a hypothetical, two-dimensional face-space. Each dot represents a face and each vector represents a dimension along which face can vary in the face space. Note: The own-race exemplars are clustered about their own average and have a narrower distribution on the face-space dimensions than own-race faces.

Empirical evidence to support this model comes from the fact that the dimensions more appropriate for differentiating own-race faces might not be the same ones for the other-race faces (Shepherd & Deregowski, 1981), e.g., Africans may focus more on the shape and location of the eyes, eyebrows and ears, whereas Caucasians may focus more on hair texture, and hair and eye colour (Ellis et al., 1975; Lindsay, Jack, & Christian, 1991). Using this density difference between own-race and the other-race faces, the own-race face will be recognised more accurately than a face from another race. In another study, Papesh and Goldinger (2010) asked Caucasian participants to rate the similarity of Caucasian and South

African computerised faces. The two sets of faces were identical and differed only in skin tone. Based on a multidimensional scaling method, they reported that the inter-face distance for other-race faces is smaller than that of own-race faces, indicating a more densely clustered representation of other-race faces than own-race faces. Byatt & Rhodes (2004) further replicated this finding using Asian and Caucasian faces, providing stronger support for the multidimensional face space model and its explanatory power for the ORB.

While the multi-dimensional face space model has been successful in describing some critical effects, including the ORB in face perception, it has a clear limitation: the dimensions of face space are vaguely specified. These dimensions might be features and their spacing (e.g., nose length, distance between the eyes) or more abstract dimensions (e.g., eigenfaces; Hancock, Burton, & Bruce, 1996). Most importantly, it does not explain how face representations can be activated by multiple instances of faces.

1.4 Applied Research in Face Recognition

Face recognition studies not only allows researchers to inform theories and models on the psychological and neural representation of faces, but also have practical implications for forensic and security settings, including eyewitness identification. Over the last few decades, there is a wealth of evidence that eyewitnesses make errors when identifying suspects, which can lead to wrongful convictions (Brigham, 2007; Doyle, 2001). In 2010, 249 falsely convicted people were exonerated and released from US prisons by the Innocence Project, using DNA testing (Innocence Project, 2019). The average sentence served by these individuals was 12 years; 17 of these people had been sentenced to death. Unfortunately, these cases are thought to be just the “tip of the iceberg” because most crimes will not leave behind any DNA marker (Naughton & Tan, 2010). An examination of 340 exonerations in the US between 1989 and 2003 discovered that in 64% of cases, at least one eyewitness misidentified the defendant. Despite its unreliability, eyewitness testimony was made as the

primary evidence in 88% of the rape exonerations reviewed by Gross, Jacoby, Matheson, & Montgomery (2005).

In the security setting, White, Kemp, Jenkins, Matheson, & Burton (2014) reported that passport officers did not show performance advantage over a group of student participants on a face matching task. More surprisingly, passport officers' task performance (range 58–95%) did not correlate with their length of experience or training. The lack of any group difference between the passport officers and undergraduate students implies that the occupational training does not necessarily improve face matching accuracy. The null effect of training task in this context is consistent with laboratory studies, where generalisable training-related enhancements have typically been small, transient or absent (e.g., Hills, Cooper, & Pake, 2013; Hills, Ross, & Lewis, 2011; Hills & Lewis, 2006; Rodríguez, Bortfeld, & Gutiérrez-Osuna, 2008). Considering the surprisingly high incidence of misrecognition in forensic and security settings, a deep understanding of unfamiliar face recognition and face matching is important to inform development of training methods (e.g., Degutis, Cohan, & Nakayama, 2014; DeGutis, DeNicola, Zink, McGlinchey, & Milberg, 2011; Limbach, Kaufmann, Wiese, & Witte, 2018; Rose, 2013), to improve the face identification in security and legal settings, as well as to enhance the social functioning of people with impaired face identification ability (e.g., prosopagnosics). Some training studies have promoted holistic mechanisms of face processing (e.g. DeGutis et al., 2011) while others foster compensatory strategies (e.g. verbal strategies and feature-based processing; Hillstrom, Sauer, & Hope, 2013; Megreya, 2018; Towler, White, & Kemp, 2017). Despite several attempts to improve face recognition in patients with prosopagnosia (e.g., Degutis et al., 2014) as well as normal controls (e.g., Bornstein, Laub, Meissner, & Susa, 2013; Towler, White, & Kemp, 2014), success has been limited, questioning the plasticity of face processing mechanisms in adults.

Chapter 2

The Own-Race Bias in Face Recognition

As a prime source of social information, the human face also conveys an important social signal: race. Despite the ease with which facial information can be processed, human accuracy for face recognition can be easily affected by the issues of race and ethnicity (Meissner & Brigham, 2001). The own-race bias (ORB; also known as the other-race effect and cross-race effect) is a robust phenomenon characterised by poor recognition memory for other-race faces compared to own-race faces (e.g. Sporer, 2001; Wright, Boyd, & Tredoux, 2003; Goldinger, He, & Papesh, 2009; Walker & Hewstone, 2006a). By receiving extensive empirical attention, the ORB has consistently been found across different cultures and has been replicated in adults from different racial backgrounds, including individuals with Caucasian, African, and Asian ancestry (see Meissner & Brigham, 2001, for a meta-analytic review). To date, the ORB has been of longstanding interest in various fields of research, including visual perception, cognitive psychology, social psychology, and forensic psychology. This phenomenon has been cleverly applied in the real world. For instance, during the 2018 FIFA World Cup in Austria, one of Sweden scouts was caught spying on the South Korean team's closed training session. To deal with the situation, South Korea's coach deliberately made his players swap shirts (wear different numbered shirts) in friendlies to confuse opponents who he thought could not tell them apart. The South Korean coach told a press conference, "…it is very difficult for Westerners to distinguish between Asians and that's why we did that" ("Players Swap Shirts," 2018). Meissner and Brigham (2001) confirmed the robustness of the ORB in their meta-analysis, involving 39 research studies

and nearly 5000 participants. They reported that the chance of a mistaken identification is 1.56 greater for other-race identities than that for own-race identities (Meissner & Brigham, 2001). The ORB is a common phenomenon among those who live in primarily mono-racial societies and it emerges not only in adults (Caharel et al., 2011; Tanaka & Pierce, 2009) but also in children (Anzures, Kelly, & Pascalis, 2014) and infants (Hayden, Bhatt, Joseph, & Tanaka, 2007; Kelly et al., 2005). An important caveat, however, is that recent developmental studies have demonstrated the absence of ORB in very young children and only emerges during the first year of life (Heron-Delaney et al., 2011; Mckone et al., 2019), unless perceptual training with other-race faces during this critical stage prevents it (Tanaka, Heptonstall, & Hagen, 2013), suggesting a strong influence of early visual experience on one's capacity to deal with faces from our own compared to other races.

2.1 Theoretical Explanations for the ORB

Despite the many years of research on the ORB, its underlying mechanisms are still under debate. Several theoretical explanations for the ORB have been proposed. This section will review the five major theoretical accounts of the ORB: the inherent physical differences hypothesis, contact hypothesis, perceptual expertise hypothesis, experience-based holistic account and the social cognitive account.

2.1.1 Inherent Physical Differences Hypothesis

One early explanation for the ORB was that there may be inherent physical differences in facial features between races that make discrimination easier within some races than others. However, this account has been found to be inadequate because there is no evidence to suggest on the basis of either anthropometric or behavioural data that faces from one race are physically more homogenous than faces from other races (e.g., Goldstein & Chance, 1978; Walker & Tanaka, 2003). In Goldstein & Chance (1978), Caucasian-American

participants were asked to rate the facial similarity of pairs of Japanese and Caucasian faces. Their results showed that they did not rate the Japanese faces as more similar to each other compared to the Caucasian faces. Significant evidence against the inherent physical differences hypothesis also derives from the full cross-over interactions between participant and face race that can be observed in many studies. For example, Walker & Tanaka (2003) found that Caucasians are better at recognising Caucasian faces than East Asian faces, whereas East Asians in the same study exhibited the opposite pattern of performance on the same stimuli. Walker & Hewstone (2006b) also observed a similar pattern of own-race recognition advantage among Caucasian British in a face discrimination task involving Caucasian and South Asian faces. However, their South Asian participants living in the U.K. did not exhibit an ORB. The fact that the participants of each race typically demonstrated the ORB indicates that there are no inherent physical characteristics of a particular race that make processing faces from that race easier or harder than processing faces from other races.

2.1.2 Contact Hypothesis

One of the most popular explanations for the ORB appeals to the quantity of experience people have with own-race faces versus other-race faces, which is known as the contact hypothesis. According to the contact hypothesis, the ORB is due to limited contact with people of the other race. This is supported by the accumulated evidence that the amount of contact that an individual has with another race is positively correlated with the ability to recognise faces of that race (Jackiw, Arbuthnott, Pfeifer, Marcon, & Meissner, 2008). For example, Wright, Boyd, & Tredoux (2003) investigated the ORB and interracial contact in the UK and South Africa. They employed a classic old/new recognition task in which participants (UK-Caucasians and South Africans) were presented with 30 faces (half African and half Caucasian) during the learning phase. Subsequently they were presented with 60 faces (half old and half new) and were asked to indicate whether they had seen each face

during the recognition phase. As expected, the ORB was observed for Caucasian participants (from the UK and South Africa) where they recognised own-race faces better than African faces. Surprisingly, African participants (from South Africa) also recognised Caucasian faces better. The authors then attributed the reversal of ORB observed in African participants to the fact that African participants in the study were university students who had been more highly exposed to Caucasian people than had most of the South African local population. In support of the contact hypothesis, the researchers also discovered that as African participants' interracial contact with Caucasian people increased, their recognition accuracy for Caucasian faces also increased.

It should be noted, however, that while many researchers agree that varying other-race contact levels can explain the ORB to a certain degree, the contact hypothesis offers only a descriptive account of the ORB. That is, it does not further explain *why* people with low amount of interracial experience would show a larger ORB in face recognition tasks (Levin, 2000; Ng & Lindsay, 1994; Slone, Brigham, & Meissner, 2000; Sporer, 2001; Tanaka, Kiefer, & Bukach, 2004). To specify what effects lower contact levels with other-race faces have on face recognition accuracy, the perceptual-expertise perspective of the ORB was proposed (e.g., MacLin, Van Sickler, MacLin, & Li, 2004; Tanaka, Heptonstall, & Hagen, 2013).

2.1.3 Perceptual Expertise Hypothesis

Perceptual expertise refers to learning that is specific to a domain, that transfers to new items within the trained domain. It could lead to automatic processing in the sense that expertise effects can be measured across a variety of tasks (e.g. holistic processing tasks, recognition tasks). It is arguable that specialized face recognition is a kind of perceptual expertise in which we are experts in the recognition of certain classes of faces (e.g. own-race faces) and relative novices in the recognition of other classes of faces (e.g. other-race faces).

Understanding the development of perceptual expertise is crucial because, if perceptual expertise is the product of the trajectory of normal visual learning, then studying perceptual experts can provide fundamental insights into the general rules, limits, and possibilities of human learning and neural plasticity. One widely accepted theoretical explanation for the ORB in face recognition is that of *perceptual expertise*. According to this account, more frequent interaction with members of own-race groups compared to other-race groups results in richer and more differentiated cognitive representations of own-race faces (see reviews by Meissner & Brigham, 2001; Sporer, 2001), leading to specialized expertise at processing and recognising own-race faces. In other words, poorer recognition of other-race faces may be rooted in the observer's perceptual learning and the amount of individuating experience that he or she has had with people of other races. Although contact effects are not always evident in standard face recognition tasks, there is considerable evidence to support the hypothesis that differential experience with own- and other-race faces contributes to the ORB in face recognition tasks (Chiroro & Valentine, 1995; Kelly et al., 2008; Zhao, Hayward, & Bülthoff, 2014).

Some studies found that the size of the ORB decreases as the amount of experience with faces from other races increases. Walker and Hewstone (2006b) examined the ORB in adolescents from two racially segregated communities in United Kingdom – Caucasian and South Asian. They found that the ORB was only present in the Caucasian group which is the majority race (low contact group), but not in the minority South Asian group (high contact group). Similar results were observed in a recent study by Fioravanti-bastos, Filgueiras, & Landeira-Fernandez (2014), which involved Caucasian and Japanese children of 5-7 and 9-11 years old born and living in Brazil. They discovered that Brazilian-Japanese children did not show the ORB, whereas Brazilian-Caucasian children in both age groups demonstrated the ORB. In line with Walker & Hewstone (2006b), these results support the prediction that

individuals with more other-race individuating experience (i.e. quality of interracial contact) might have a higher level of expertise for distinguishing other-race faces and consequently disrupting the ORB.

Developmental studies have also revealed that the ORB emerges in Caucasian and Chinese infants as young as six months old. Even three-month-olds can demonstrate a preference for (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly et al., 2005), and discriminate between (Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005) own-race faces more than other-race faces. However, by employing a standard face recognition task, De Heering, De Liedekerke, Deboni, & Rossion (2010) found that East Asian children between 6 and 14 years of age who were adopted by European families between 2 and 26 months of age did not show a significant recognition advantage for East Asian over Caucasian faces. In a similar study, Sangrigoli et al. (2005) tested adults of Korean origin who had been adopted by European-Caucasian families when they were between the ages of 3 to 9. The adoptees performed a delayed match-to-sample task in which a photograph of a target face (either Caucasian or Asian) is briefly displayed, followed by two photographs (one distractor and one target face). They had to select the one matching the target. The results demonstrated that, regardless of the age of adoption, the Korean adoptees exhibited a reversed ORB, with a better recognition for Caucasian (other-race) faces than for Korean (own-race) faces. These results support the idea that the ORB derives from experience with other racial groups and it can be reversed by sufficient experience during early childhood stage where the face processing system is maturing.

2.1.4 Experience-Based Holistic Account

Holistic processing has been proposed as one important mechanism underlying the ORB. According to this account, compared to own-race faces, people are inefficient at integrating facial components from other races into a whole representation (Tanaka et al.,

2004). Despite extensive evidence for a holistic mode of processing for faces, there have been several inconsistent reports as to whether own- and other-race faces are processed holistically to the same degree (for a recent review, see Hayward, Crookes, & Rhodes, 2013). Researchers have used a range of experimental paradigms to manipulate holistic processing directly, attempting to determine if observers are equally affected by these manipulations on own-race and other-race faces. If own-race faces are processed more holistically than other-race faces, then manipulations that disrupt holistic processing should produce a greater impact on participants' recognition performance for own-race faces than for other-race faces. To date, support for this hypothesis has been mainly derived from studies examining the inversion effect, the composite effect, and the whole-part effect where a reduced magnitude of holistic processing for other-race faces has been reported. For a comprehensive literature review, see Chapter 6.

2.1.5 Socio-Cognitive Account

While the perceptual hypothesis offers an elegant explanation of the ORB, social cognitive models of the ORB have recently gained popularity (Hourihan, Fraundorf, & Benjamin, 2013; Hugenberg, Young, Bernstein, & Sacco, 2010; Levin, 1996; Lewis, 2015; Sporer, 2001). Socio-cognitive theories of ORB argue that other-race faces are typically categorised as outgroup, decreasing motivation to individuate them. A lack of motivation to process other-race faces may eventually lead to increased error when recognising other-race faces. Supporting socio-cognitive accounts, a few recent studies have reported improved recognition for other-race faces when they were categorised as belonging to the participants' in-group (Hourihan, Benjamin, & Liu, 2012; Lewis, 2015). These claim that two mechanisms are responsible for ingroup biases: an advanced processing style for ingroup faces and greater motivation for processing ingroup faces (Young, Hugenberg, Bernstein, & Sacco, 2012).

According to the in-group/out-group model, the ORB is due to differences in social cognitions elicited when processing in-group versus out-group members (Sporer, 2001). Sporer (2001) claims that own-race faces are processed in greater depth because a shared in-group membership signals that own-race faces are important to individuate, whereas individuating information from other-race faces is often disregarded. To individuate own-race members, one must attend to facial characteristics that are identity-diagnostic (e.g., configural information) rather than category-diagnostic (e.g., skin colour), leading to a more accurate identification and discrimination of own- than other-race faces. Moreover, the processing style applied to in-group versus out-group faces may be motivationally determined because interactions with in-group members are deemed more significant, likely and productive than those with out-group members (Hugenberg, Miller, & Claypool, 2007; Hugenberg et al., 2010).

Levin (2000) proposed a feature-selection model which posits a tendency to perceive out-group members categorically, but to individuate in-group members. This leads to an asymmetrical search for features in own-race versus other-race faces. These asymmetries are believed to translate into differential recognition accuracies, thus causing the ORB. Levin (1996; 2000) found that other-race faces are classified by race faster than own-race faces, at the expense of encoding identity-diagnostic features. Although people appear to categorise faces into in- and out-group clusters based on race, some studies have shown that group classifications can be made based on additional markers (Bernstein, Young, & Hugenberg, 2007; Hourihan et al., 2013; Yan et al., 2017). For example, Bernstein et al. (2007) produced an "own-group" bias by attaching social labels to otherwise identical stimuli. In their study, facial photographs were randomly labelled with the name of the participants' university or with that of a rival school. The participants in this study displayed an in-group bias, exhibiting greater recognition accuracy for those faces identified as students of their alma

mater; controls, who were not exposed to university labels, showed no bias when observing the same set of faces. In addition, the authors were able to elicit a similar in-group bias among participants who completed a mock personality test, which randomly divided them into "red" and "green" personality types. The participants in this study displayed a significant in-group recognition bias for facial photographs that labelled the subject as having the same personality type (red or green) as the participant.

A review of the literature also indicates individuals may not categorise all faces of a particular race identically; instead they may subdivide members of a race group into in-group and out-group classifications. For example, in a study conducted by Chiroro et al. (2008), Black and White South African participants were exposed to photographs depicting individuals from four ethno-geographic groups: Black Americans, White Americans, Black South Africans, and White South Africans. The participants in this study showed significant own-race recognition bias, but only for the Black and White South African photographs; there was no ORB for the American photographs. In addition, the participants were significantly less accurate when considering the American faces, regardless of race. The individuals in this study appeared to group all of the American photographs, Black and White, into a single out-group category. These findings suggest that individuals do not always determine in-group and out-group classifications along broad ethnic boundaries, but may take additional information, including familiarity, into consideration.

Recently, Hugenberg et al. (2013, 2010) have proposed a new model, the *categorisation-individuation model*, attempting to link the three main factors identified in the ORB phenomenon: experience, categorisation and motivation to individuate. The authors acknowledge the important role of perceptual expertise in the ORB; however, they give added credence to the notion that interracial contact will be beneficial only when it allows people to learn to individuate outgroup members. Hence, not all types of exposure could lead

to better face recognition abilities. Instead, a meaningful and motivated experience with a group of faces is needed to acquire the ability to remember them. According to this model, the initial stage involves an automatic and unavoidable process – categorisation (Hugenberg et al., 2010). In addition to the race, any type of socially relevant identity can also trigger categorisation to form in-group and out-group clusters. This claim is supported by the observation of own-age (Anastasi & Rhodes, 2005; Hills & Lewis, 2011; Proietti, Laurence, Matthews, Zhou, & Mondloch, 2018) and own-gender biases (Herlitz & Lovén, 2013; Scherf & Scott, 2012; Wright & Sladden, 2003). In this perspective, the ORB is part of a more general phenomenon of ingroup-outgroup differentiation (Sporer, 2001), such that people tend to selectively attend to identity-diagnostic characteristics among own-race faces but to attend to the category diagnostic features of other-race faces (Hugenberg et al., 2010). However, this bias may be redirected towards another dominant social identity or group membership depending on the situational cues (Hehman, Mania, & Gaertner, 2010).

For instance, Hehman et al. (2010) demonstrated that people showed different types of memory biases, depending on the type of group categorisation. They tested recognition performance of Caucasian and African participants with sets of faces that were either categorised by race (Caucasian or African) or by university affiliation (own versus other). As a result, the typical ORB was observed when faces were grouped by race; however, when faces were grouped by university affiliation, the ORB disappeared and faces of their own university were recognised better than those of an outgroup university (Hehman et al., 2010). Other studies have also shown that the encoding of and memory for a particular target face depend greatly on the affiliation of this face to the in-group or outgroup (Hourihan et al., 2013; Hugenberg et al., 2010; Kloth, Shields, & Rhodes, 2014; Yan et al., 2017). Taken together, social categorisation can be initiated through category activation and situational

cues; this process determines the depth of facial identity information stored during encoding and contributes to the emergence of the ORB.

While the categorisation-individuation model has been used to explain the ORB, it has been criticised on the grounds that increased motivation do not always affect the ORB. For instance, Tullis, Benjamin, & Liu (2014) asked Caucasian participants (half of them received the instructions to individuate) to perform an Asian and Caucasian face memory task. Surprisingly, the individuation instructions did not reduce the ORB. Wan, Crookes, Reynolds, Irons, & McKone (2015) also reported that individuation instructions did not reduce the ORB in their samples of Caucasian and Asian participants. These findings did not support the categorisation-individuation model; instead they imply that, regardless of motivation, individuals do not have full control over their ability to encode faces.

Other researchers have also investigated whether and how the ORB affects, and affected by, racial stereotypes and attitudes (Ferguson, Rhodes, Lee, & Sriram, 2001; Lebrecht, Pierce, Tarr, & Tanaka, 2009; Levin, 2000; Walker & Hewstone, 2007). In a study conducted by Ferguson, Rhodes, Lee, & Sriram (2001) prejudice was not found to influence cross-race face recognition. The study used the bona fide pipeline measure of implicit bias (see Fazio, Jackson, Dunton, & Williams, 1995) with Caucasian and Chinese faces and good or bad words and Walker's (1994) *Attitudes towards Asian* scale as a measure of self-reported prejudice against Asians. No impact of prejudice was found for either measure of recognition accuracy. Participants were shown Asian or Caucasian faces and were later assessed for recall of those faces as a measure of recognition bias. There was no interaction effect between prejudice levels and race of the face on measures of recognition accuracy. Yet, there was an interaction between participant race and self-reported prejudice such that Caucasian participants with high levels of own-race preference showed increased own-race recognition (Ferguson et al., 2001).

In contrast, another study showed that individuation training ameliorates the perceptual ORB and reduces socio-cognitive implicit racial bias in Caucasian participants (Lebrecht et al., 2009). Lebrecht et al. (2009) measured implicit race bias using the affective lexical priming score (ALPS) which combines a facial recognition task with a lexical decision task with positive and negative words. In the ALPS, bias is measured by the amount of time to respond to a letter string after a face when those words are negative or positive. Fast responses to other-race faces and positive words imply low bias and vice versa. The ALPS was administered before and after a training program where stimulus faces had to be remembered by letter or by their racial category. Results showed that Caucasian participants in the individuation training, but not in the categorisation training, experienced significant reduction in their ORB, suggesting a causal link between the ORB and implicit racial bias.

2.1.6 Why might the ORB exist?

While different cognitive and social models of the ORB have been proposed to explain *how* the ORB might be formed, there is still no real consensus as to exactly *why* the ORB exists. An advantage in recognising own-race faces who share similar characteristics may serve evolutionary purposes. From an evolutionary perspective, responding cautiously toward individual whose physical attributes are unfamiliar and, accordingly, classifying that individual as an outgroup member is an essential ability. This is because the likelihood of reproduction in an organism that is unable to detect potential threat will be reduced dramatically. This interpretation is supported by results from classification tasks with adults (e.g., Caldara, Roisson, Bovet, & Hauert, 2004; Levin, 1996; Thornton et al., 2018), which have consistently found that other-race faces are detected more readily and classified more rapidly than own-race faces. Collectively, the findings from both infants and adults suggest that humans begin to display sensitivity to race at a very early age and continue to show differences related to classification throughout the lifespan (Kelly et al., 2009). The ORB is

also likely to have assisted in negotiating our survival, mediating among other things, approach-avoidance behaviour (Engell, Haxby, & Todorov, 2007; Todorov, 2008), mate selection (Little, Jones, & DeBruine, 2011; Rhodes, 2006; Rhodes, Simmons, & Peters, 2005), and the recognition of kin (DeBruine et al., 2009; Maloney & Dal Martello, 2006).

The accurate recognition of others is a fundamental aspect of social cognition, allowing us to detect the intention, attention and identity of an individual (among other attributes) (Bruce & Young, 1986). Malpass (1990) provided a utilitarian perspective of the ORB, based on the central idea that humans use their cognitive resources to maximize the rewards, and minimize the losses, of their social interactions. Being able to recognise faces enables humans to predict whether a particular social interaction will be beneficial or harmful, and to what degree. Within an individual's in-group, the value of social interactions is likely to vary quite widely, and there may be no obvious visual cues to denote which members will be valuable to interact with. Recognising in-group faces (e.g. own-race faces) more accurately than out-group faces (e.g. other-race faces) is therefore important for maximising the value of social interactions. In addition, Allport (1954) suggested that people, as cognitive misers, tend to categorise other-race people as oversimplified groups instead of individuating them, and this is significant for handling the huge amount of facial information that we encounter in daily life. Since race is a reliable cue of in-group members, the existence of ORB could prepare us to rapidly make inferences about individuals' trustworthiness on the basis of their facial features and perceived group membership. This view is supported by empirical studies in which people are better at remembering who is trustworthy and who is not within their own race than across race (e.g. Strachan et al., 2017).

2.2 The ORB in Multiracial Societies

Investigating multiracial populations with potential changes in ability to process other-race faces would be beneficial as it may provide us with a unique opportunity to

investigate how the face representation adjusts itself to better accommodate other-race faces with different morphologies. To the best of my knowledge, studies investigating the ORB in multi-racial social settings (i.e. high proportion of more than two main races) are scarce (Fioravanti-bastos et al., 2014; Goodman et al., 2007; Su, Tham, Bremner, & Hay, 2017) and have produced inconsistent results. Goodman et al. (2007) demonstrated that South Africans who grew up and lived in a highly multi-ethnic (African-Caucasian) society did not evince a smaller ORB than Norwegians from a predominantly Caucasian population. However, a few studies on individuals from multiracial societies have garnered some empirical support for the perceptual experience hypothesis, showing that ORB is reduced in multiracial populations, where other-race faces are frequently seen and individuated (e.g., Fioravanti-bastos et al., 2014; Tan, Stephen, Whitehead, & Sheppard, 2012; Tham, Woo, & Bremner, 2018; Wright et al., 2003).

Research on individuals from multiracial backgrounds also provides support for the perceptual experience hypothesis. ORB tends to be reduced in multiracial populations, where other-race faces are frequently seen and individuated (e.g., Bar-Haim et al., 2006; Chiroro & Valentine, 1995; Wright et al., 2003). As mentioned earlier, Wright, Boyd, & Tredoux (2003) found that Black South Africans, a minority population in England, exhibit a lesser level of ORB compared to Caucasians (the majority population) and their self-reported interracial contact was positively correlated with cross-race recognition accuracy. In contrast, Goodman et al., (2007) demonstrated that the ORB in children from 8 years old and young adults growing up in completely mixed or biracial context (Caucasian-African Americans) can be equally strong as those growing up in less racially diverse environments (Caucasians living in the United States, Norway, or South Africa), suggesting that exposure *per se* was not enough to avoid the ORB.

To date, the issue regarding the role of experience in shaping the ORB remains unresolved and deserves further investigation. It is also worth noting that the differential-experience hypothesis has not yet been fully explored for multiracial populations. A meta-analysis, by Meissner & Brigham (2001), reports that the majority (about 88%) of research on ORB employed White or Black populations, with only a few studies employing other races. In the past two decades, a growing body of research has also addressed the ORB in East Asian populations (e.g., Goldinger, He, & Papesh, 2009; Kelly et al., 2005; Wu, Laeng, & Magnussen, 2012). However, these findings may not necessarily apply to other racial groups because the social environment for individuals from a multi-racial country can be more complex and vary drastically in comparison to that of individuals from a mono-racial background. Therefore, more specific research on the ORB with Southeast Asians (e.g. Malaysians) living in a racially diverse environment would be beneficial for understanding the effect of lifelong exposure to multiple races on the plasticity of face representation as well as the face processing specialisation for own-race and other-race faces that have been experienced in daily life.

2.3 Eye-Tracking Methodology

Recording eye movements is an effective means to study information intake, as eye movements to facial features provide an index to the allocation of visual attention (Findlay & Gilchrist, 2003; Yarbus, 1967). Henderson, Williams, & Falk (2005) suggested that eye movements may affect face learning in a way that fixations on (or near) specific features help encode those features and their configurations. Given the robust ORB in recognition memory, it is important to establish whether patterns of information selection differ between own-race and other-race faces and whether information processing differs between observers of different race groups. In this thesis, I measured the frequency and durations of fixations to various areas of interest (AOIs) in faces, and I primarily focused on two measures: average

total number of fixations and average total fixation duration (averaged across participants). Because the AOIs were of slightly different sizes across stimuli, area-normalised scores were calculated by dividing the proportion of fixations (or durations) by the proportion of the screen the AOI occupied (see Bindemann et al., 2009). To ease the data comparison with the results in the previous eye-tracking studies conducted in Malaysian-Chinese young adults (Tan, Sheppard, & Stephen, 2015; Tan et al., 2012), an analysis on the raw non-area-normalised data was also conducted and is presented in the Appendix B-F. This analysis produced an identical pattern of results to that of area-normalised data.

2.4 Neuroimaging Studies on the ORB

While numerous behavioural studies have reported deficits in the encoding, storage and/or retrieval of other-race face representations from memory (e.g., old/new face recognition task; for a review, see Meissner & Brigham, 2001), electrophysiological studies investigating the ORB at the neural level suggests that the ORB occurs at an early perceptual stage of face processing and is associated with different structural encoding and configural processing of own- versus other-race faces. In fact, several EEG studies have shown greater amplitudes of N170 and P200 for own-race than other-race faces (Hahn, Jantzen, & Symons, 2012; Ito & Urland, 2015). Ito & Urland (2005) measured the N170 response when presenting Caucasian participants images of Caucasian and African faces. Results showed a greater N170 response was elicited for Caucasian faces than for African faces. Given that the N170 is also most strongly triggered for images that one has expertise with (Rossion, Gauthier, Goffaux, Tarr, & Crommelinck, 2002), this supports the assumption that people are experts at recognising faces of their own race. N170 and P200 components have been indicated as a marker of face processing; more specifically, they are thought to reflect structural encoding and holistic processing of faces. Because these two components peak over temporo-occipital brain regions about 170ms and 200ms after face stimulus onset, are

larger for faces than most other stimulus categories, it implies that the ORB could be partly due to impairments in the early formation of sensory representations of other-race faces (structural encoding) and in the integration of facial features into a whole when encoding other- than own-race faces (holistic processing).

In addition, fMRI studies conducted to explore the time-course as well as the localisation of activity associated with the processing of own- versus other-race faces have shown greater activation of fusiform gyrus (FFA) and occipital face area (OFA) for own- than other-race faces (Feng et al., 2014; Golby et al., 2001; Kim et al., 2006). While the OFA has been found to be sensitive to face parts and configuration, FFA shows a stronger activation for own race faces as compared to other race-faces. In Golby et al. (2001), European-American and African-American participants were presented with their own-race and other-race faces; meanwhile, their brain activity was examined using fMRI. Results showed that the FFA was less responsive to other-race faces than to own-race faces, indicating that the ORB is associated with impaired sensitivity to the structure of facial features in other-race faces, likely a directly result of limited perceptual experience with these faces (Feng et al., 2014; Natu & O'Toole, 2013).

2.5 Cultural Differences in Face Processing

It is widely but not universally believed that humans may have evolved specialised perceptual and neural mechanisms devoted to face processing (Kanwisher, 2010; Kanwisher & Yovel, 2006). Face recognition requires rapid scanning of facial features in order to encode a new identity or to recognise whether an individual has been encountered previously or not. To address these, investigating the underlying strategies people deploy in order to distinguish faces is of specific interest for human social behaviour. Like many basic visual processes, it was initially assumed that human face-processing mechanisms are common and universal. This view has been challenged by a number of studies using eye tracking methodology. Eye

tracking provides a direct judgment of where and for how long a person fixates when viewing a stimulus such as a face. This non-invasive method has facilitated a deeper insight into the underlying cognitive processes involved in face perception. Knowing where people look when viewing faces provides an objective measure of the part of information entering the visual system as well as into the cognitive strategies involved in facial perception. By applying eye-tracking techniques, many studies investigating face processing have set out to dispute the concept of universality (Blais, Jack, Scheepers, Fiset, & Caldara, 2008; Kelly, Liu, et al., 2011; Miellet, He, Zhou, Lao, & Caldara, 2012), forcing reconsideration of longstanding notions regarding how humans perceive faces. While the underlying factors for such diversity are not yet fully understood, the research literature has highlighted three main plausible explanations in terms of culture (Blais et al., 2008; Kelly, Jack, et al., 2011; Kelly, Miellet, & Caldara, 2010; McKone et al., 2010; Rodger, Kelly, Blais, & Caldara, 2010; Senju, Vernetti, Kikuchi, Akechi, & Hasegawa, 2013; Tan et al., 2012), facial appearance/ontogeny (Fu, Hu, Wang, Quinn, & Lee, 2012; McKone, Crookes, Jeffery, & Dilks, 2012), or genetic heritage (Knox & Wolohan, 2014; Park, Newman, & Polk, 2009).

Recent cross-cultural studies employing eye-tracking techniques have found systematic differences in the way observers perceive and recognition faces. Blais, Jack, Scheepers, Fiset, & Caldara (2008) discovered that Western and East Asian adults who have been raised in different cultural backgrounds, exhibit dissimilar looking patterns during face processing tasks. More specifically, they found that East Asian adults tended to fixate on the central region of the face, in the nose region, which suggests a holistic processing style. On the other hand, Western Caucasian adults showed triangular fixation patterns (shifting between the mouth and eyes region) when perceiving faces, indicating a featural processing of individual features. As the preference for holistic or featural styles of processing between East Asians and Westerners has also been observed in a variety of cognitive and perceptual

tasks (Ji, Peng, & Nisbett, 2000; Nisbett, Peng, Choi, & Norenzayan, 2001), the researchers argued that culture plays a major role in shaping how people look at faces. Indeed, evidence accumulating from cross-cultural studies has highlighted that human thought and visual processes can be heavily affected by the social environment and cultural practices. The Eastern collectivist culture, with its focus on the relationships between individuals within groups, may have led Easterners to assimilate focal objects with background context. In other words, Easterners appear to think more "holistically" by paying greater attention to context and relationship. On the other hand, Western individualist culture emphasises on the value of individuals as independent entities. This may lead Westerners to be more "analytic" in their thinking by focusing on the salient objects more than contextual information. The contrasting holistic-analytic styles associated with Eastern and Western cultures may possibly extend to the eye movement strategies that East Asian and Western Caucasian observers employ in face perception task, such as face recognition (Blais et al., 2008; Miellet, Vizioli, He, Zhou, & Caldara, 2013).

Consistent with the results presented by Blais et al. (2008), cultural differences in face processing between East Asian and Western Caucasian participants were also found by Kelly et al. (2011a) who tested children aged between 7 and 12 years from the UK and China with an old/new face recognition paradigm, lending support to the significance of cultural forces in face processing. Taken together, the findings from both studies are actually consistent with the enculturation hypothesis proposed by Caldara, Zhou, & Miellet (2010), which suggest that one develops a culture-specific pattern of face scanning through cultural learning. To further assess the relative contribution of genetic and cultural factors, Kelly et al. (2011b) investigated eye movement strategies in a population of British-born Chinese adults. As a result, most British-born Chinese observers employed either Eastern or Western eye movement strategies, with fixation landing predominantly around either the eyes or nose area.

However, a reanalysis of the data by Tan et al. (2012) suggests that the majority of participants actually employed an intermediate looking strategy. More remarkably, British-born Chinese participants performed equally well at recognising East Asian and Western Caucasian faces. This finding indicates that although British-born Chinese participants are genetically Asian, increased exposure to and familiarity with other-race faces enhances recognition abilities via an intermediate eye movement strategy that is advantageous for recognising both own- and familiar other-race faces. Research studies have increasingly provided evidence pointing towards culture as the crucial factor that shapes human eye movements for face processing; however, making such conclusions would be somewhat premature. It remains unclear whether, as is often claimed, the key factor that explains the diversity in eye movement strategies is the culture to which participants have been primarily exposed. Instead, levels of exposure to the faces of different races during development might also be a critical factor in driving such cultural perceptual differences.

Differential processing of the characteristic features of own-race versus other-race faces may contribute to prejudice and stereotyping (e.g., Hugenberg et al., 2010). There have been several recent studies that have used the eye-tracking methodology to examine how individuals visually scan own- and other-race faces (Chalovich & Eisenberg, 2005; Ellis, Xiao, Lee, & Oakes, 2017; Gaither, Pauker, & Johnson, 2012; Goldinger et al., 2009; Wu et al., 2012; Xiao, Quinn, Pascalis, & Lee, 2014). Although some researchers have found that participants use the same eye movement strategies when scanning own- and other-race faces (Blais et al., 2008; Kelly et al., 2010; but see Miellet et al., 2012), several previous studies suggested that adults encode different kinds of information from own-race faces compared to other-race faces (Anzures et al., 2014; Fu et al., 2012; Hu, Wang, Fu, Quinn, & Lee, 2014; Klama & Milton, 2009).

Prior studies that attempted to link the ORB in face recognition directly to the underlying face-coding mechanism have found mixed results, leaving the question of how other-race experience affects face processing mechanisms open. Michel, Caldara, & Rossion (2006) found that other-race experience was linked to more holistic coding of other-race faces (measured using the whole-part task), but only for Caucasian, and not East Asian participants. Another study examining the relationship between contact level, holistic coding, and recognition performance has found that self-reported contact with other-race faces was negatively correlated with the ORB in recognition performance and holistic coding for both Chinese and Caucasian participants (Hancock & Rhodes, 2008). In addition, participants who did not show a strong other-race effect in recognition performance tended to employ a similar holistic coding for both own- and other-race faces. Although higher *quality of contact* was found to be associated with decreased ORB, the authors have proposed that *quantity of contact* is not always negatively correlated with the other-race effect as studies have found that living in a racially diverse environment does not reduce the ORB (Gaither, Pauker, & Johnson, 2012; Goodman et al., 2007; Walker & Hewstone, 2006a). It appears that quality interaction, which requires one's ability to discriminate other-race faces, provides an opportunity for observers to learn the diagnostic features that differentiate faces of other-races.

2.6 Malaysia as a Multiracial Country

Malaysia is a multiracial and multicultural country. Although the term "multiracial" has been used by psychological researchers interchangeably with the terms "multicultural' or "multi-ethnic", without offering clear definitions. Culture is the patterns of living learned consciously and unconsciously by a group of people. These patterns can be seen in language, governing practices, arts, customs, festivals, food, religion, dating rituals, and clothing. Here I chose to use "race" or "multiracial" because it allows me to make a reference to the genetic

contribution to variation in facial morphology between the three major race groups in Malaysia (Ngeow & Aljunid, 2009; Wai, Thwin, & Yesmin, 2015) more directly. In addition, "multiracial" is preferred over "multicultural" in this thesis because it conceptually address the issue of whether, and if so, how everyday exposure to *race-related variations* of facial features shapes looking strategies. Another reason why I chose not to use the term "multicultural" is because there is a large overlap of culture in the country. It has been reported that the cultural values in Malaysians of different ethnicities are more converging rather than diverging (Fontaine and Richardson, 2005). By using Schwartz Value Survey (SVS) as the instrument to explore the cultural values of 324 employees working in various industries across peninsular Malaysia, the researchers noticed a high degree of shared cultural values (91% at individual level; 82% at the cultural level) between the three main ethnic groups (i.e. Chinese, Malays, and Indians). This indicates that a unified Malaysian culture is emerging in the country (Kawangit et al., 2012).

Malaysia is a Southeast Asian country, but its racial composition is highly diverse, serving as a prime example of a multi-racial society. Its population comprises ethnic groups of Malay (50.4%), Chinese (23.7%), Indian (7.1%), indigenous Bumiputra groups (11%), and others (7.8%; including Africans and Western Caucasians) (Department of Statistics Malaysia, 2008). This multiracial context makes Malaysia far more racially diverse than the famously homogeneous societies of Japan and South Korea, or even those of Taiwan (with its split between indigenous Taiwanese and mainlanders) or Singapore (which has the same major race groups as Malaysia but is more than 75% Chinese). The high degree of ethnic diversity in Malaysia is also indicated by the Ethnic Fractionalization Index (EFI), an index that measures the racial (phenotypical), linguistic and religious cleavages in society (see Table 2.1) (Yeoh, 2001). This index is based on the probability that a randomly selected pair of individuals in a society will belong to different groups (Rae and Taylor 1970; as cited in

Nagaraj, Nai-peng, Chiu-wan, Kiong-hock, & Pala, 2015). The inflow of Chinese and Indian immigrant workers into Malaysia during the British colonization era led to the emergence of a multiracial characteristic of the population, with diverse religions, culture, language, and customs. Besides, the population is also highly influenced by Western culture, having been under British rule until 1957 (Kawangit et al., 2012). Considering its unique multiracial characteristics, Malaysia provides an interesting ground for face recognition research and a rich field area for studying the ORB in the context of high interracial contact among the different race groups.

Table 2.1

Ethnic fractionalization index (EFI) of selected countries

Country	EFI
India	0.876
Canada	0.714
Malaysia	0.694
Singapore	0.479
United States of America	0.395
United Kingdom	0.325
Taiwan, Republic of China	0.274
Australia	0.096
Japan	0.079
Republic of Korea	0.002

Note. Data for ethnic fractionalization of different countries from Yeoh (2001)

In a multiracial society like Malaysia, the population is likely to have been exposed to a greater variety of ethnic groups within their social environment. Due to added exposure to

several different race exemplars, they should be able to possess the discrimination abilities for multiple racial categories, especially for the faces from their own nation. In other words, it could have been the case that Malaysian participants might not display the traditional ORB due to the racial diversity of Malaysia and daily heterogeneous exposure to other races. Two recent studies have highlighted the unique cultural and ethnic diversity in Malaysia, and how this can have direct influences on face processing ability for own- and other-race faces in infants (Su et al., 2017) and young adults (Tan et al., 2012). For instance, Tan et al. (2012) reported that Malaysian Chinese participants performed equally well at recognising East Asian and Caucasian faces, but less well at recognising African faces. Based on their eye tracking results, Malaysian Chinese adopt intermediate looking strategies rather than employing the Eastern or Western eye movement strategies while performing a face recognition task on East Asian, Western Caucasian, and African faces. However, it is important to note that the face stimuli used in Tan et al.'s study (2012) were presented with the distinctive external cues (e.g. hair, ears). Numerous studies have shown that the hair and hairline may provide high diagnostic value for unfamiliar face recognition (Ellis et al., 1979; Endo, Kanako, & Kinya, 1984). It is possible that the participants in Tan et al.'s study based their judgment on these external diagnostic cues to achieve a generally high recognition performance across face races. I address this question through experiments that examine the relative contributions of internal and external features to own- and other-race face recognition in Chapter 3 and 5.

As a Southeast Asian country, Malaysia is considerably multicultural in terms of the high proportion of the three main races and also influenced by Western culture. Thus, Tan et al. (2012) proposed that increased familiarity with Western culture and greater exposure to the Western people through media may have shaped the way how Malaysian Chinese extract information from faces, enabling them to accurately recognise the faces they encounter most

frequently. However, only Malaysian Chinese samples were involved, without including Western Caucasians as a comparison group. Moreover, the fixation patterns of other major races living in Malaysia remain unexplored. The current research seeks to address this gap directly by including Malaysian-Malays and Malaysian-Indian participants who live in the same multi-racial environment. Furthermore, Caucasian participants who had resided in Malaysia for a short length of time (approximately 4 months on average) were also recruited to facilitate the testing of the enculturation hypothesis by exploring how the face scanning patterns produced by Caucasians differ from those by the three Malaysian groups.

2.7 Definition of 'Race' and 'Ethnicity'

The confusion of the concepts of race and ethnic groups is mainly caused by the overlapping of certain racial and ethnic characteristics between sub-societal groups. As this thesis revolves around the topic of own-race bias in face recognition, it is important to discuss the precise definition of the concept of race and ethnic groups. The contemporary view on the race concept is that it is a system for biologically categorising people based on physical attributes (e.g., skin colour, facial physiognomy). On the other hand, the concept of ethnicity is somewhat multidimensional, as it is more flexibly defined by a much wider range of cultural, linguistic, and religious characteristics: for example, a person who was born in Japan to Japanese parents, but as an infant, she was adopted by a German family in Germany. Arguably, she could be considered ethnically as German because she practices German cultures, customs and religious beliefs. Even though she knows nothing about Japanese history and culture, she would still be treated racially as Asian in a foreign country. Hence, the term 'ethnicity' may refer to anything from a cultural group that clearly shares a common descent and cultural background (Yinger, 1986) and to persons who share a same citizenship but diverse culturally (Yeoh, 2001). Although Malay, Chinese, and Indian may also be referred to as different ethnic groups rather than racial groups, the term 'race' has been used

pervasively in Malaysia, even in academic writings. Hence, the term "race" was used throughout this thesis to indicate that the three major ethnic groups in Malaysia are separate groups which can be differentiated based on physical (physiognomic) as well as cultural characteristics.

2.8 The Difference between "Multiracial" and "Multicultural"

Malaysia is a multiracial and multicultural country. The term "multiracial" has been used by psychological researchers interchangeably with the terms "multicultural' or "multi-ethnic", without offering clear definitions. Culture is the patterns of living learned consciously and unconsciously by a group of people. These patterns can be seen in language, governing practices, arts, customs, festivals, food, religion, dating rituals, and clothing. Here I choose to use "race" or "multiracial" because it allows me to make a reference to the *genetic* contribution to variation in facial morphology between the three major race groups in Malaysia (Ngeow & Aljunid, 2009; Wai, Thwin, & Yesmin, 2015) more directly. In addition, "multiracial" is preferred over "multicultural" in this thesis because it conceptually address the issue of whether, and if so, how everyday exposure to *race-related* variations of facial features shapes looking strategies. Another reason why I chose not to use the term "multicultural" is because there is a large overlap of culture in the country. It has been reported that the cultural values in Malaysians of different races are more converging rather than diverging (Fontaine and Richardson, 2005). By using Schwartz Value Survey (SVS) as the instrument to explore the cultural values of 324 employees working in various industries across peninsular Malaysia, the researchers noticed a high degree of shared cultural values (91% at individual level; 82% at the cultural level) between the three major race groups (i.e. Chinese, Malays, and Indians). This indicates that a unified Malaysian culture is emerging in the country (Kawangit et al., 2012).

2.9 General Aim of the Thesis

Despite a wealth of research investigating the ORB, relatively little is known about the role of multi-racial experience (i.e. exposure to more than two racial group) in shaping the ORB as well as the nature of the representations of own-race versus other-race faces. Recently, it has been suggested that even in adulthood the face processing system can be modulated by prolonged visual experience with a specific face category (de Heering et al., 2010). If our face recognition system remains plastic throughout development even into adulthood, it should be able to handle different race of faces efficiently, and consequently show a wider tuning to face morphology when exposed to several races of face than when exposed to a single race. Based on the perceptual experience hypothesis, the ORB would be smaller in participants raised in highly multiracial societies than in populations living in less racially diverse societies. Yet, a few studies have shown that the magnitude of the ORB is not modulated by differential experience (e.g., Goodman et al., 2007; Malpass & Kravitz, 1969; Ng & Lindsay, 1994). Instead, meaningful contact or selective attention is likely a more important factor; physical proximity between different racial groups does not necessarily lead to a quality of contact that increases cross-racial recognition accuracy. If this is so, it would not be surprising if the ORB remains evident in a multiracial population. In this thesis, by employing a series of face memory and face perceptual tasks, I aim to test this hypothesis with Malaysian individuals (Chinese, Malay, Indian) raised in a multiracial society and compare their recognition performance with individuals from less racially diverse countries (Western-Caucasians and Africans).

Previous eye-tracking research revealed that observers from different cultures employ different fixation patterns when perceiving faces (Blais et al., 2008; Kelly et al., 2011; Kelly et al., 2010; Miellet et al., 2012). However, the underlying mechanism in face processing remains unidentified. Caldara, Zhou, & Miellet (2010) identified the facial information

extracted by East Asian and Western Caucasian observers by using the '*Spotlight technique'* to restrict the facial information available to observers in varying degrees. Results revealed that observers from both cultures use identical facial information (i.e. the eyes and mouth) to recognise faces when facial information outside of the central vision was restricted within 2 and 5 degrees. However, when visual information from the eyes and mouth is readily available in the 8 degrees condition, East Asian observers employed a different fixation pattern by focusing on the centre of the face, in the nose area. This finding suggests that the same facial information is utilized to recognise faces although East Asian and Western Caucasian observers employ different fixation patterns to achieve recognition.

Given that eye tracking methodologies may reveal the underlying cognitive processing related to face learning and recognition, I investigate the similarities and differences of eye movement patterns between Malaysian and Western-Caucasian young adults when perceiving own- and other-race faces. This study is the first study to directly explore whether the different face processing styles between Malaysian-Malay, Malaysian-Chinese, and Malaysian-Indian individuals who live in the same East-Asian country with Western influences truly exist.

This thesis includes nine chapters. Following the two introductory chapters on face recognition (Chapter 1) and the ORB (Chapter 2) respectively, Chapter 3 describes an investigation of whether Malaysian individuals (i.e. Malay, Chinese, and Indian) with more interracial experience in a multicultural society would exhibit a reduced ORB in comparison to Western-Caucasian individuals with less interracial experience. In this eye-tracking study, the fixation patterns produced by the four racial groups when performing a classic old/new face recognition task involving own- and other-race faces were also compared. Chapter 4 addresses the issues of (1) whether the consistently better performance for Indian faces than for other-race faces across race groups in Experiment 1 could be due in part to a larger

amount of variability in distinctiveness within Indian faces than within the sets of other-race face and (2) how facial distinctiveness affects the recognition of own- and other-race faces.

Chapter 5 describes an experiment that examined whether and, if so, to what extent the presence of external features reduces the ORB in face memory. In particular, I replicated Experiment 1 using the identical procedure but different stimulus type. Rather than egg-shaped faces, face images including the external features were presented. Chapter 6 assesses whether the ORB in face memory can be attributed to reduced holistic processing of unfamiliar other-race faces, by having Malaysian-Chinese, African, European-Caucasian and Australian-Caucasian participants perform four different tasks: (1) yes-no face recognition, (2) composite, (3) whole-part and (4) global-local tasks. Chapter 7 reports two experiments which were designed to test the hypothesis that directing immediate attention to diagnostic features would reduce the ORB in Malaysians, Australian-Caucasians and South Africans. Chapter 8 describes a face matching experiment run with gaze-contingent technique to examine whether restricting facial information outside/inside central vision affects face recognition accuracy for own- and other-race faces in Malaysian-Chinese, Malaysian-Malay, Malaysian-Indian and Western-Caucasian observers.

Lastly, Chapter 9 is the General Discussion for the thesis. It summarises all the findings of the experimental chapters and interprets them based on the different theoretical accounts of the ORB. It draws together evidence from the face memory task (Chapter 3 and Chapter 6) to support the view that interracial contact during adulthood is ineffective at reducing the ORB. It discusses evidence that the ORB in adulthood is less malleable than commonly assumed and indirectly suggests that a lack of childhood contact is one factor of the ORB in a multiracial setting. A primary finding in Chapter 4 is the significant correlations between memory performance for target faces and facial distinctiveness for own-race faces but not for other-race faces. This finding is discussed based on Valentine's (1991) face-space

model that dimensions of face space are optimised for own-race faces, and the ORB is likely to be attributable to the inefficiency in the use of norm-based coding for other-race faces.

Results from Chapter 5 showed that the magnitude of the ORB was modulated by the presence/absence of external features, such that other-race faces with limited external facial information were recognised poorly. The social contact questionnaire administered to the different race groups showed that their recognition performance did not positively correlate with self-reports of the quality and quantity of contact they had with own- versus other-race individuals (Chapter 3 and 5). Additionally, the magnitude of the ORB appeared to be modulated by the presence/absence of external features, such that other-race faces with limited external facial information were recognised poorly. This sheds further light on the underlying representation of own- and other-race face recognition. The overall findings derived from the holistic tasks (Chapter 6), fixation-cross cueing task (Chapter 7), and gaze-contingent paradigm (Chapter 8) lead to the conclusion that neither the inability to perceive other-race faces holistically nor the difficulty in directing attention to diagnostic features can fully account for the ORB. Chapter 9 also describes the theoretical as well as practical implications from these results and discusses what questions remain unsolved following the current work and what issues would be important to follow up in the future research.

Chapter 3

Comparing the ORB between Different Racial Groups

3.1 Introduction

The majority of early ORB research employed Caucasian or African populations, with only a few studies employing other races (Meissner & Brigham, 2001). In the past two decades, a growing body of research has addressed the ORB in East Asian populations (e.g., Kelly et al., 2005; Goldinger, He, & Papesh, 2009; Wu, Laeng, & Magnussen, 2012). However, empirical findings from monoracial populations may not necessarily apply to individuals from a multi-racial country because their social environment can be more complex and vary drastically in comparison to that of individuals from a mono-racial society. Investigating populations with potential differences in abilities and strategies to process other-race faces due to immersion in natural multiracial environments would be beneficial as it may provide a unique opportunity to investigate how the face representation adjusts itself to better accommodate other-race faces. In this chapter, I focus on a key question: Does daily exposure to faces of multiple races over a long period of time, that is not possible in a laboratory setting, augment face recognition ability and facilitate other-race face processing?

To the best of my knowledge, studies investigating the ORB in multi-racial social settings are scarce (Fioravanti-bastos et al., 2014; Goodman et al., 2007; Su et al., 2017) and have produced inconsistent results. Goodman et al. (2007) demonstrated that South Africans who grew up and lived in a highly multiracial (African-Caucasian) society did not evince a smaller ORB than did Norwegians from a predominantly Caucasian population. However, Fioravanti-bastos et al. (2014) found that Japanese-descendant children born and living in Brazil did not manifest the ORB when recognising Caucasian and Japanese faces, whereas

Caucasian children demonstrated the ORB in favour of own-race faces, suggesting that experience with faces from social interaction during early stages of development can modify the ORB.

Su et al. (2017) recently reported that British-Caucasian children between 5 to 6 years and 13 to 14 years of age showed an ORB to three other-race faces (Chinese, Malay, and Black African) that was stable across age while Malaysian-Chinese children showed a recognition deficit for less frequently encountered faces (African Black) but showed a recognition advantage for faces of which they have direct (Chinese, Malay faces) or indirect experience (Caucasian faces). Overall, recent research on individuals from multiracial societies have garnered some empirical support for the *perceptual experience hypothesis*, suggesting that the ORB could be reduced in multiracial populations, where other-race faces are frequently seen and individuated (Coetzee, Greeff, & Barrett, 2009; Su et al., 2017; Tan, Stephen, Whitehead, & Sheppard, 2012; Wright, Boyd, & Tredoux, 2003). For example, Tan and colleagues (2012) found that Malaysian-Chinese adults showed a recognition advantage for own-race Chinese faces and other-race Caucasian faces but showed a recognition deficit for less experienced African faces. The authors suggested that a reduced ORB in Caucasian faces may be explained by the high exposure to Caucasian people, indirectly through media (e.g., Western movies) and directly through daily social interaction within a branch campus of a British university.

Although Malaysia is a multicultural society, it is significantly influenced by Western culture. 86% of films shown in Malaysian cinemas are Western (from the US and EU) while only 14% are local; in comparison, 57% of films shown in East Asian countries such as China and Japan are local (Epstein, 2011). With increased digital media content, a diverse array of movies and television shows will provide ample opportunities for indirect face contact experiences. Thus, Malaysians may learn about Caucasian individuals via media. A

long-term visual exposure to Western movies and television series could reasonably be thought to facilitate Caucasian face perception and shape face norms permanently (Wang & Zhou, 2016). However, a recently published paper claimed that it is not a lack of perceptual experience per se that results in an ORB, but specifically a lack of childhood perceptual experience (Mckone et al., 2019).

Despite the robustness of an own-race face recognition advantage, laboratory studies have demonstrated that the ability to recognise other-race faces can also be enhanced via exposure training in infant (Anzures et al., 2012; Heron-Delaney et al., 2011), child (Qian, Quinn, Heyman, Pascalis, & Lee, 2017), and adult face recognition (Tanaka & Pierce, 2009), lending further support to the perceptual experience hypothesis. In addition, experience effects have been demonstrated in the interracial adoption studies. For example, De Heering, De Liedekerke, Deboni, & Rossion (2010) studied 6- to 14-year-old Mainland Chinese and Vietnamese children who were adopted by Caucasian families living in Western Europe between 2 and 26 months of age. Age-matched (East Asian) controls showed a clear recognition advantage for own-race faces, whereas the adopted participants performed equally well with both Caucasian and Asian faces. In another adoption study, a complete reversal of the ORB was observed in Korean adults who had been adopted by European Caucasian families for approximately 23 years (Sangrigoli et al., 2005). Taken together, both training and inter-racial adoption studies provide direct indications of the flexibility of the ORB and the plasticity of one's face recognition system during childhood, the effect from training studies is often transitory (e.g., Hills & Lewis, 2011) and evidence from adoption studies is retrospective. These studies do not assess the effects of immersion from birth in a multiracial environment.

3.2 Experiment 1

In this study, the country selected for the multiracial population was Malaysia, involving participants from the three major races: Chinese, Malay and Indian. Given its racial diversity, this country provides an environment that could potentially reduce or even eliminate the ORB because of the frequent direct and indirect exposure to various races in daily life. The primary aim of this study was to test for the presence of ORB amongst the three main Malaysian race groups, who grew up in a highly multiracial society, plus a Western-Caucasian comparison group. Participants' performance in a face recognition task involving own- and other-race faces was measured, in terms of accuracy and sensitivity, using a classical old/new paradigm and a large set of carefully controlled stimuli presented in full colour but without external feature. In the free viewing task, participants were asked to learn a series of unfamiliar faces in preparation for a later face recognition test.

To examine whether increased other-race contact reduces cross-race differences in recognition performance, a social contact questionnaire was also used in this study to measure participants' *quantity* and *quality* of contact with other-race people. Due to high levels of exposure to several different racial groups within their social environment, Malaysians are likely to possess discrimination abilities for multiple racial categories, especially for the faces from their own nation (e.g., Malay, Chinese, and Indian faces). I reasoned that Malaysian participants (Chinese, Malay, Indian) with sufficient multiracial experience would develop a broadly tuned face representation, such that they may show comparable recognition for all races of faces. On the other hand, Caucasian participants from a less racially diverse population are likely to show the ORB – with superior performance on own-race Caucasian faces and poorer performance on less experience races (Chinese, Malay, and Indian).

Another objective of this study was to investigate using eye tracker whether the fixation patterns produced by young Caucasian adults differ from those by young Malaysian adults when perceiving own- versus other-race faces. It is also particularly interesting to see whether the similar looking patterns between Malaysian Malay, Chinese, and Indian individuals who live in the same Southeast-Asian country with Western influences truly exist. Based on the *enculturation hypothesis,* I conjectured that Caucasian participants would make a triangular fixation pattern (i.e. moving between the eyes and mouth) as reported in Blais et al.'s (2008) study, whereas Malaysian participants (Chinese, Malay, and Indian) would direct more fixations to the eyes and nose than the mouth as reported in Tan et al. (2012).

3.3 Methods

3.3.1 Participants

94 young adults were recruited from the University of Nottingham Malaysia Campus. Participants consisted of 26 Malaysian Chinese (10 male, 16 female; *M* = 20.23 years, *SD* = 2.14; range = 18-26 years), 23 Malaysian Malays (10 male, 13 female; *M* = 19.70 years, *SD* =3.29; range = 18-22 years), 22 Malaysian Indians (11 male, 11 female; *M* = 22.50 years, *SD* = 4.35; range = 18-35 years) and 23 Western Caucasians (13 male, 10 female; *M* = 22.26 years, *SD*= 3.93; range = 19-34 years). All Malaysian participants were students attending the University of Nottingham Malaysia Campus, and had not lived outside of Malaysia for more than three years. All Caucasian participants were British exchange students who had not resided in Malaysia for more than one and a half years (*M*= 3.95 months, *SD* = 3.42, range = 1-14 months). All participants had normal or corrected-to-normal vision and none of them reported neurological or psychiatric disorders. Participants either received course credit or were paid RM5 each for their participation in the study. The protocol was approved by the Faculty of Science Ethics Committee at the University of Nottingham Malaysia Campus and signed consent forms were obtained from every participant prior to their participation.

3.3.2 Apparatus

Participants' eye movements were recorded using the Tobii T60 eye tracker (0.5˚ precision, sampling rate of 60 Hz). The eye tracking sensors and illuminators were integrated into a 17-inch TFT monitor with a screen resolution of 1280 × 1024 pixels. The eye tracker performs binocular tracking and utilizes both "bright pupil tracking" and "dark pupil tracking" based on automatic optimization to determine eye position. It uses infrared technology to measure the corneal reflection in the observers without the use of a head-mounted device. Tobii Studio software (version 3.1.6) was used for stimulus presentation and analysis of eye movement data.

3.3.3 Materials

3.3.3.1 Image collection.

In the face recognition task, face stimuli were used to compare the recognition performance and eye movement strategies adopted by the different race groups. The Malaysian face images were extracted from the face videos obtained from 54 university students (18 Chinese, 18 Malay, and 18 Indian) using Panasonic HDC-TM300 digital video camera at the University of Nottingham Malaysia Campus so that only full head with frontal view will be presented. These face images were taken from videoclips at different keyframes so that the facial expressions (neutral or happy) vary between study and recognition phase to avoid trivial matching strategies for memorizing faces (Bruce et al., 1999). These faces were validated for race and emotional expressions by a sample of undergraduate participants. Based on facial attractiveness ratings from a pilot study, faces with extreme attractiveness rating scores were not used in order to reduce potential confounding effects of facial attractiveness on participants' recognition performance. The Australian Caucasian facial images were collected from 22 university students at Macquarie University, Australia. Similar to the Malaysian facial images, this set of facial photos is taken using Canon EOS 70D under

highly-standardized settings (i.e. photographed in a lighting booth painted with grey paint and illuminated with fluorescent tubes). For all face races, frontal views of each "model" displaying neutral and moderately happy facial expressions were photographed with all glasses, makeup, and facial jewellery removed.

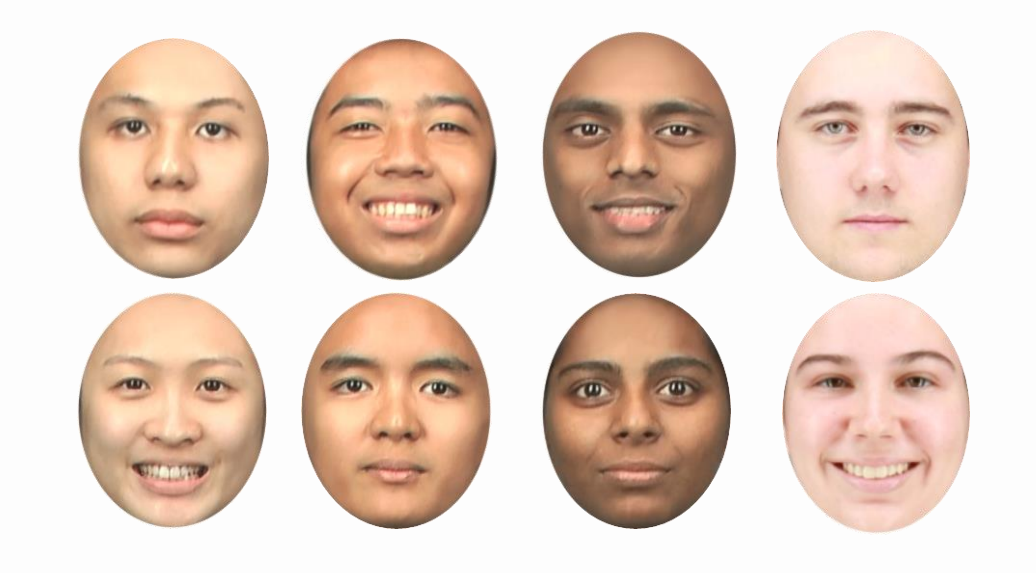


Figure 3.1. Examples of face stimuli with happy and neutral expressions: Each row shows a male and a female face for each ethnic group (Malaysian Chinese, Malaysian Malay, Malaysian Indian, and Western Caucasian)

3.3.3.2 Image processing.

To prepare the images for the eye-tracking study, all stimuli were edited using Adobe Photoshop CS6. All original photographs of the faces were resized to 370 × 470 pixels (16-bit depth), corresponding to an approximate visual angle of 8.75˚ horizontally and 11.22˚ vertically at a viewing distance of 60cm.To eliminate any confounding variations between different types of stimuli, Gaussian (radius = 3 pixels) and Pixelate Filters (cell size = 2 square) in Photoshop™ were applied to the Caucasian facial images as an attempt to normalise the image resolution/quality. All images were also aligned on the eyes' position and cropped around the face in a standard oval to exclude salient cues such as ears and hairstyle. The colour faces were presented with hair cues and face outline removed to avoid ceiling

effects in the participants' recognition performance due to potential reliance on external facial features (e.g. hair, ears, full head outline). Results obtained using these stimuli would be indicative of genuine face recognition rather than potential hair or external contour recognition. *Figure 3.1* shows some examples of face stimuli used in the study.

3.3.3.3 Social contact questionnaire.

The questionnaire used in this study contained 15 statements, which sought to access quality (the first 10 items) and quantity (the last 5 items) of contact with individuals from the three main racial groups in Malaysia (i.e. Malay, Chinese, and Indian) and with Caucasian people. The social contact questionnaire used in this study was identical to the one used by Toseeb, Keeble, & Bryant (2012), which was also a modified version of the one employed by Walker & Hewstone (2007). The questionnaire had the same 15 items for own- and other-race people. Participants rated each statement using a 5-point scale, with 1 meaning 'very strongly disagree' and 5 meaning 'very strongly agree'. The scores from each participant were used to assess quantity and quality of contact (i.e. individuating experience) with own- and other-race people.

3.3.4 Procedure

The experiment was conducted in a quiet and windowless room illuminated by fluorescent lamps under normal indoor lightning conditions, thus keeping the luminance level of the room constant and ensuring that pupillary fluctuations were not caused by changes in the ambient illumination. The participants took part in the study individually. Upon arrival, participants were briefed about the study and were introduced to the eye-tracking setup and experimental procedure. To foster incidental encoding, it was not revealed initially that the specific purpose of the study was to investigate the ORB in memory for faces and to compare the scanning patterns that individuals of different ethnic group adopt while perceiving own- and other-race faces; instead, participants were told that the study was merely to test people's

ability to recognise faces. They were then required to fill out the demographic form containing information about gender, ethnicity, age and course of study. Before performing the face recognition task, the eye-tracking setup and seat were adjusted to a comfortable position for each of the participants. Viewing distance was kept approximately at 60 cm from the eye tracker monitor.

A 9-point calibration was conducted before the recording of eye movements. The calibration program asked participants to follow a bouncing red dot with their eyes as it moved around the screen. Calibration accuracy was checked and repeated if necessary. All subsequent gaze data at individual level were calculated from these calibration values. Once the calibration was successful, the experimental instructions were presented. For post-experiment calibration check, a red fixation cross would be presented pseudo-randomly in one of the four quadrants of the computer screen after every eight trials. Participants' fixation points were compared subjectively with the location of the red fixation crosses to ensure the calibration accuracy by checking if the participants' fixations were more than 2.5 cm away from the centre of the red crosses.

To familiarise participants with the experimental task, they first took part in a practice phase. Four photos (1 Malaysian Malay, 1 Malaysian Chinese, 1 Malaysian Indian and 1 Western Caucasian) were presented to the participant to be remembered. Then, they were mixed four new faces (one for each race). The participant judged whether they were old or new faces. The facial images shown in the practice phase were never used again in the subsequent experimental trials. Then, in the learning phase, participants viewed 32 target faces (8 Malaysian Malay, 8 Malaysian Chinese, 8 Malaysian Indian, and 8 Western Caucasian, 4 males and 4 females for each race) one at a time. Each trial began with a fixation cross at the centre of the screen for 1 second, followed by a face presented for 5 seconds randomly in one of the four quadrants of the screen against a white background.

Participants were asked to remember as many of the faces as possible. Upon completion of the learning phase, participants were given a distracter task in which they were required to complete a social contact questionnaire (lasted for 3-4 minutes). At the beginning of the recognition phase, the above calibration procedure was performed again, and the results were used to calculate the fixation points of the participants in the test block. 32 faces (including 16 targets and 16 distractors) were presented one at a time for 5 seconds. For learned faces, the facial expression changed between the study and test phases (i.e. randomised into learning and test phases) to avoid trivial image matching strategy. Three different orders of presentation were created for both learning and recognition blocks of trials so that the target and foil faces in each block were counterbalanced between participants. The location of the fixation cross and the order of each photograph within each block were also pseudo-randomised.

Participants then performed a yes/no face recognition memory task by indicating whether it was an old or new face. After viewing each face, participants were required to choose one answer from the three following options: (*1) Yes*, (*2) No*, or (*3) Yes, I definitely know this person in real life*. Participants selected '*Yes*' if they thought the face was learned (i.e. old) and '*No*' if they thought the face had not been presented in the learning phase (i.e. new). Furthermore, they had the option to choose an additional answer '*Yes, I definitely know this person in real life*' if they were familiar with any of the faces outside the experimental setting: for example, the individual in the stimulus was a friend of theirs or they were coursemates. A mouse connected to the computer running the Tobii Studio program was used to respond. There was no time limit for the participants to make their response and they were told to take as long as necessary, but to go with their initial reaction as much as possible. No response accuracy feedback was given. Participants' eye movements and responses were recorded. At the end of the recognition phase, participants were fully debriefed about the real

purposes of the study and given the compensation for their participation. Any questions regarding the study were answered by the experimenter.

3.3.5 Data Analyses

3.3.5.1 Recognition sensitivity and response bias.

Data from the recognition phase were sorted into four conditions for Malaysian Chinese, Malaysian Malay, Malaysian Indian, and Caucasian faces: hits (correctly identified learned faces), misses (learned faces wrongly classified as new), correct rejections (new faces correctly identified as new), and false alarms (new faces wrongly classified as learned). Signal detection measure of sensitivity (*d'*) was used as the index of recognition performance (i.e. discrimination ability). To overcome infinite values of *d'* in the case where hit rate or false alarm rate equals to 1.0, the Snodgrass & Corwin (1988) correction factor was applied by using the following formulas:

$$Hit\ rate = \frac{number\ of\ hits + 0.5}{total\ number\ of\ trials\ with\ signal\ present + 1}$$

$$False\ alarm\ rate = \frac{number\ of\ false\ alarms + 0.5}{total\ number\ of\ trials\ with\ signal\ absent + 1}$$

Participants' corrected hit and false alarm rates from the face recognition task were combined into *d'* scores, where *d'* is equal to z-score for hit rates (Z_H) minus z-score for false-alarm rates (Z_{FA}) (Macmillan & Creelman, 1991). A higher *d*' score represents more sensitivity to a signal, whereas a score that approaches 0 represents less sensitivity. A measure of each participant's response bias criterion (*c*; Macmillan & Creelman, 1991) was also used to assess participants' tendency to favour one response over the other. Response bias was calculated as the sum of the z-transformed hit rate and the z-transformed false alarm rate multiplied by −0.5 (Wickens, 2001). This basic bias measure is defined as $c = -0.5\ (Z_H + Z_{FA})$.

For the ideal observer $c = 0$; when the observer adopts a more liberal strategy c is negative, and when the observer adopts a more conservative strategy c is positive.

3.3.5.2 Areas-of-interest (AOI) analysis.

A general area-of-interest template was created for each of the faces, outlining a region for the eyes, nose, mouth, and other face areas not including the key features (i.e., chin, forehead, and jaw) (see *Figure 3.*2). These predefined AOIs were similar to those in most cross-cultural face processing studies (e.g., Blais et al., 2008; Kelly et al., 2007; Tan et al., 2012). Various measures were derived from the eye movement data, including the total number of first fixation, the mean number of fixations, and the mean duration of fixations directed to each AOI. These eye tracking metrics were extracted from the Tobii Studio software for statistical analyses.

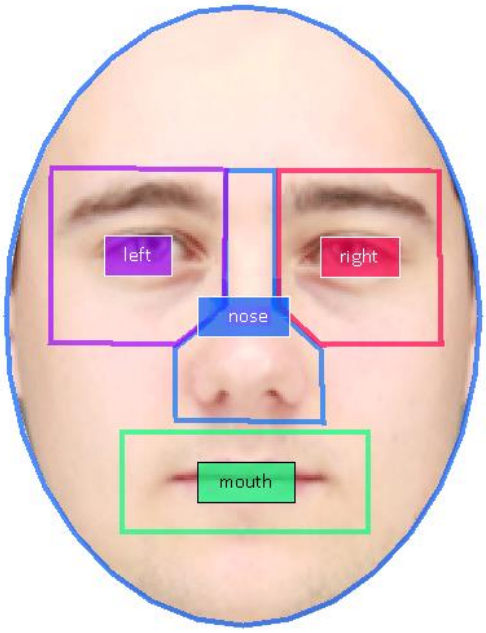


Figure 3.2. An example of the predefined area of interest (AOI): left eye, right eye, nose, mouth, and whole face. The size and the location of the AOI were similar across different stimuli.

3.4 Results

3.4.1 Behavioural Data

Preliminary analyses demonstrated that assumptions of normality and homogeneity of variance were both met in all of the three behavioural measures (i.e., percent correct, *d*', and response bias). Preliminary analyses also revealed no reliable main effects or interactions as a function of expression of face stimulus and participant gender, so analyses were collapsed across expression and gender in subsequent analyses on the behavioural data. In addition to accuracy scores, signal detection calculations were also used to analyse the results in the recognition phase to verify that the ORB effect occurred. Two signal detection measures, sensitivity (*d'*) and response bias (*c*) were obtained for each participant separately for responses to faces of four different ethnic groups.

3.4.1.1 Accuracy

A two-way mixed-factorial ANOVA on percent correct including Race of Face as within-subject factor and Race of Observer as between-subject factor found no significant main effect of Race of Observer, F (1,90) = 1.15, p =.33. An interaction between Race of Face and Race of Observer appeared to be highly significant, F (9, 270) = 5.61, p<.001, η_p^2 =.16, indicating that the ORB was present in the sample. Simple main effect analysis showed that Chinese participants recognised own-race faces significantly better than Malay (p=.005) and Caucasian (p=.011) faces. Malay participants performed significantly better for own-race faces than Chinese (p=.004) and Caucasian faces (p=0.002). Indian participants were significantly better at recognising own-race faces than Chinese faces (p = 0.05). Caucasian participants recognised own-race faces more accurately than Chinese (p =.02) and Malay faces (p =.04) (see *Figure 3.3*).

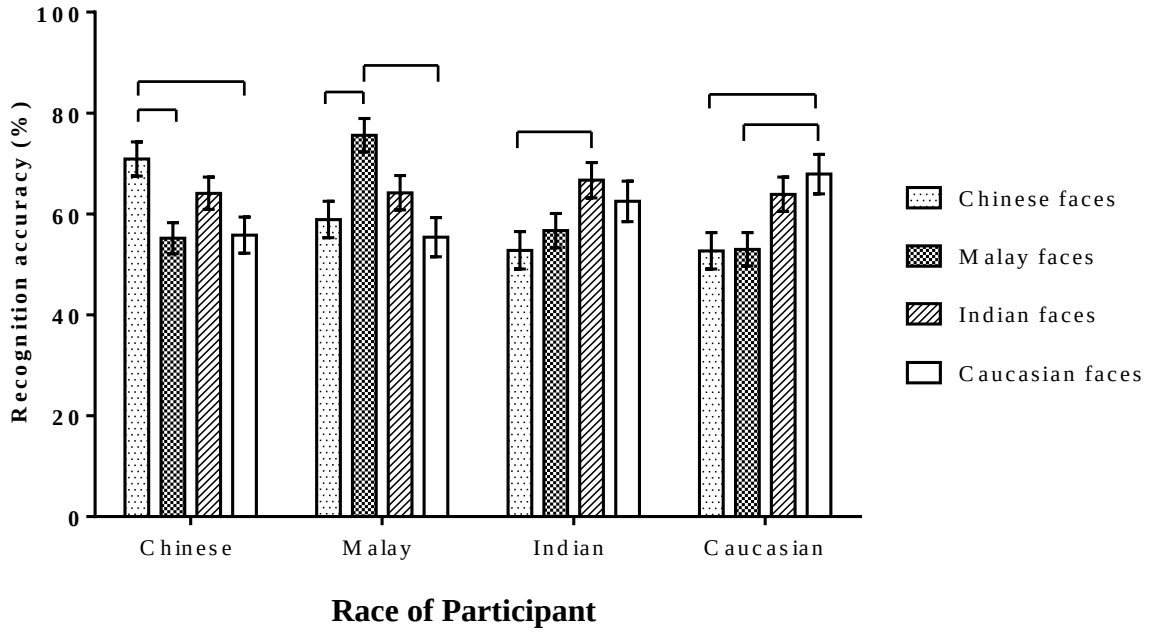


Figure 3.3. Recognition accuracy of Chinese, Malay, Indian, and Caucasian participants for own- and other-race faces in the face recognition task. Error bars represent standard errors of the mean.

3.4.1.2 Sensitivity *d'*

To obtain an unbiased (e.g., strategy free) measure of people's face recognition performance, recognition sensitivity *d'* was examined. A 4 (Race Group: Malaysian Chinese, Malaysian Malay, Malaysian Indian, and Western Caucasian) × 4 (Race of Face: Malaysian Chinese, Malaysian Malay, Malaysian Indian, and Western Caucasian) mixed factorial ANOVA on *d'* scores showed no significant main effect of Race Group, F (3, 90) = 1.18, p = 0.32, η_p^2 =.04, and a marginally significant main effect of Race of Face, F (3, 270) = 2.16, p = 0.09, η_p^2 =.02. Most importantly, there was a highly significant interaction between Race Group and Race of Face, F (9, 270) = 5.45, p<.001, η_p^2 = .15 (see *Figure 3.4*).

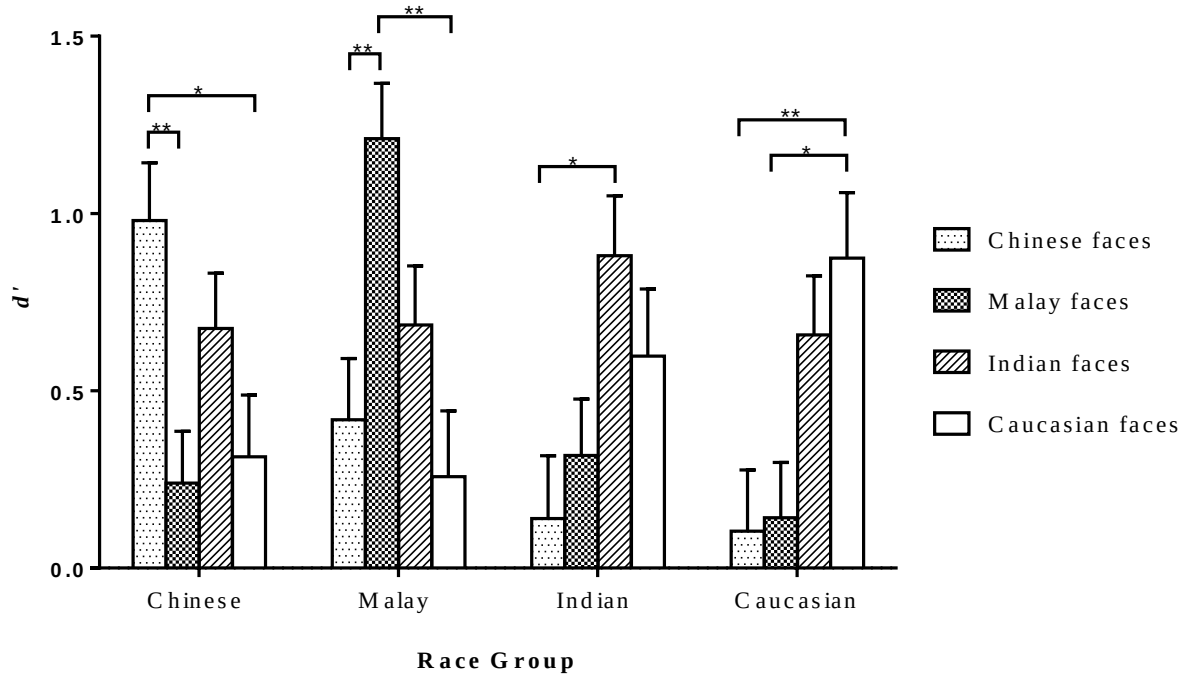


Figure 3.4. d' scores for the old/new face recognition task of own- and other-race faces in Chinese, Malay, Indian, and Caucasian participants. Error bars represent standard errors of the mean. (**p<.01, *p<.05)

Consistent with analysis of recognition accuracy, simple main effect analysis for the significant interaction demonstrated better recognition performance to own-race faces (as shown by higher *d'* scores) than to other-race faces (except for Indian faces) in Chinese, Malay and Caucasian participants, whereas the ORB was not prominent in Indian participants. In Chinese participants, there was a sensitivity advantage for recognising own-race faces over Malay (p=.005) and Caucasian (p=.03) faces. Malay participants showed a significant ORB for Malay faces versus both Chinese and Caucasian faces (p =.005 and p =.002, respectively), but there was no difference between Malay and Indian faces (p =.14). Indian participants tended to be more sensitive to own-race faces only when compared to Chinese faces (p =.06). Caucasian participants were more sensitive to own-race faces than to Chinese (p=.01) and Malay faces (p=.03). Notably, this pattern of significant results was identical to that of recognition accuracy.

3.4.1.3 Response bias *c*

Participants' response bias for both target and distractor faces was measured. A positive *c* value suggests a tendency to answer 'No' (i.e., conservative strategy), whereas a negative *c* value indicates a tendency to answer 'Yes' to faces (i.e., liberal strategy). Results from 4 × 4 mixed factorial ANOVA on the response bias measure with Race Group as between-subject variable and Race of Face as within-subject variable revealed both significant main effects of Race of Observer, F (3, 90)=3.54, p = 0.02, η_p^2 = .11, and Race of Face, F (3, 270) = 5.91, p = 0.001, η_p^2 =.06. Post-hoc Bonferroni test for the main effect of Race of Observer showed a significant difference of *c* values between Chinese and Malay participants (p = 0.02), with higher *c* values observed for Chinese participants than for Malay participants. That is, compared with Malay participants, Chinese participants manifested a higher tendency to indicate a face as not seen before (i.e. adopting a more conservative strategy, irrespective of actually having seen the face before. For the main effect of Race of Face, when deciding whether they had seen a face before, participants across race groups maintained a stricter response criterion for Chinese faces (M=.07, SD =.25) and a more liberal criterion for Malay (M = -.11, SD=.23), Indian (M = -.15, SD=.23) and Caucasian faces (M = -.16, SD=.22) (p=.05, p=.005 and p=.002, respectively). No significant interaction between Race of Observer and Race of Face was found, F (9, 270) = 1.02, p = 0.43, η_p^2 =.03 (see *Figure 3.5*).

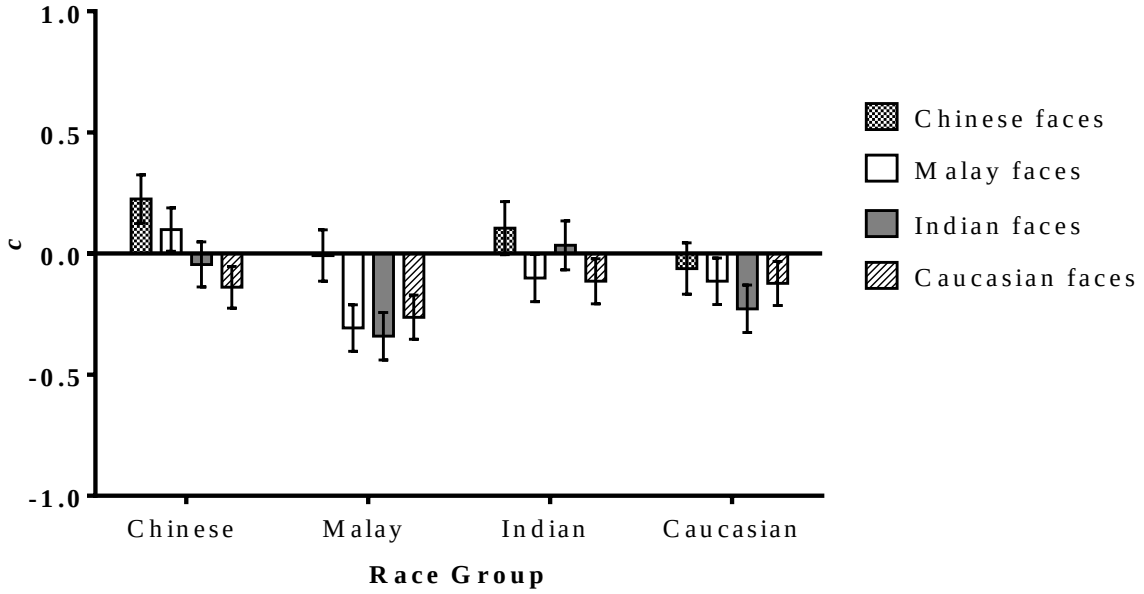


Figure 3.5. Response bias criterion *c* as function of face race and race of participant. Error bars represent standard error of the mean.

In terms of facial expression, a paired-sample t test found a higher response criterion for happy faces over neutral faces, t (93) = 2.76, p = 0.007, indicating that happy faces did cause biases to be more conservative than neutral faces. However, no significant main effect of facial expression on the accuracy and sensitivity was found in a preliminary analysis.

3.4.2 Social Contact Questionnaire Responses

Amount and quality of contact was assessed using a modified version of a social contact questionnaire used by Toseeb et al. (2012). Mean scores were calculated by taking the average for each participant on both measures of quantity and quality of contact with own- and other-race groups (see Table 3.1). Internal consistency (Cronbach's alpha) was examined separately for each measure, showing a high internal reliability (α = 0.85, quantity of contact; α = 0.96, quality of contact). Preliminary mixed factorial ANOVA revealed a strong three-way interaction between Contact (quality and quantity), Race of Participant, and Race of Face, F (9, 270) = 22.03, p < 0.001, η_p^2 =.42. Splitting the analyses by Race of Participant, multiple pairwise comparisons (Bonferroni-corrected) showed that Malay, Chinese, and

Caucasian participants had significantly greater quantity and quality of contact with own-race than other-race people (all $p < 0.01$). For Indian participants, quality of own-race contact was significantly higher than contact with other races (i.e. Malay, Chinese, and Caucasian) (all $p < 0.001$) whereas their quantity of contact with Malay and Chinese people was not significantly lower than that of own-race people ($p = 0.34$ and $p = 0.69$, respectively), implying that Indians (minority group) generally had more opportunity for other-race contact with Malay and Chinese people (majority groups). Similar to Chinese and Malay participants, they had significantly lower quantity of contact with Caucasians than own-race individuals ($p < 0.001$).

To reduce the possible issues of subjectivity and response bias in the self-reported data, I computed the relative scores for both quantity and quality of contact with other-race people for each race group using the following calculation:

Relative quality of contact with other race people =
quality of contact with other-race people – quality of contact with own-race people

Relative quantity of contact with other race people =
quantity of contact with other-race people – quantity of contact with own-race people

In addition, I calculated the size of ORB in recognition memory for each participant by subtracting *d'* scores for other-race faces from *d'* scores for own-race faces to control for possible individual differences in face recognition ability. Pearson correlations were calculated between own-race recognition advantage and relative scores (see Table 3.2). For easier interpretation, the bar graph below (*Figure 3.6*) shows the pattern of correlations between relative scores for quality/quantity of contact and own-race recognition advantage. Based on the contact hypotheses, I anticipated that individuals who reported higher levels of interracial contact would show a smaller ORB in comparison to those who reported less

interracial contact. Negative correlations between these two measures were expected. After applying Bonferroni correction for multiple comparisons in light of the increased chance of Type I error, Pearson correlation analyses revealed that all correlations were not significant, and a few were even in the opposite-to-predicted direction. This suggests that both self-reported quantity and quality of contact with other-race individuals did not consistently predict how well other-race faces would be recognised.

Although failed to surpass the Bonferroni-corrected α of .002 (.05/24), two-tailed, three correlations were found to be significant at the α of .05. For Chinese and Indian participants, the relative quantity of contact score was significantly related to their own-race recognition advantage over Malay faces (Chinese: $r = 0.45$, $p = 0.02$; Indian: $r = 0.57$, $p = 0.006$). For Malay participants, there was a significant relationship between relative quality of contact with Indian people and recognition sensitivity of recognising Indian faces relative to own-race faces ($r = -0.47$, $p = 0.02$). Specifically, Malay participants with relatively higher quality of interracial contact with Indian people showed lesser ORB for Indian faces.

Table 3.1

Means and standard errors (in parentheses) of the level of social contact (1 = no or low degree of interaction; 5= high degree of interaction) with own- and other-race individuals reported by Chinese, Malay, Indian, and Caucasian participants.

	Chinese participants		**Malay participants**		**Indian participants**		**Caucasian participants**	
	Quality of contact	Quantity of contact	Quality of contact	Quantity of contact	Quality of contact	Quantity of contact	Quality of contact	Quantity of contact
Chinese people	4.55 (0.09)	4.62 (0.07)	3.24 (0.17)	3.10 (0.14)	3.28 (0.21)	3.34 (0.15)	2.27 (0.24)	2.34 (0.16)
Malay people	2.48 (0.20)	2.50 (0.16)	4.43 (0.15)	4.60 (0.08)	2.96 (0.26)	2.84 (0.20)	1.94 (0.20)	2.03 (0.15)
Indian people	2.50 (0.20)	2.34 (0.15)	2.70 (0.23)	2.42 (0.15)	4.02 (0.13)	3.98 (0.12)	2.26 (0.21)	2.43 (0.19)
Caucasian people	1.82 (0.16)	1.86 (0.11)	1.75 (0.17)	2.16 (0.10)	1.94 (0.25)	1.96 (0.16)	4.17 (0.17)	4.35 (0.17)

Table 3.2

Correlations between relative contact scores and own-race recognition advantage (d' scores for own-race faces – d' scores for other-race faces) for Chinese, Malay, Indian, and Caucasian participants

Race of Participants	Relative Quantity of Contact with Chinese	Relative Quality of Contact with Chinese	Relative Quantity of Contact with Malays	Relative Quality of Contact with Malays	Relative Quantity of Contact with Indians	Relative Quality of Contact with Indians	Relative Quantity of Contact with Caucasians	Relative Quality of Contact with Caucasians
Chinese	-	-	r = 0.45, p = 0.02	r = 0.04 p = 0.84	r = 0.16, p = 0.45	r = -0.06, p = 0.78	r = -0.07, p = 0.72	r = -0.13, p = 0.54
Malay	r = -0.18, p = 0.41	r = 0.09, p = 0.69	-	-	r = -0.24, p = 0.26	r = -0.47, p = 0.02	r = -0.17, p = 0.45	r = -0.21, p = 0.34
Indian	r = 0.30, p = 0.18	r = 0.40, p = 0.07	r = 0.57, p = 0.006	r = -0.07, p = 0.75	-	-	r = -0.20, p = 0.37	r = -0.08, p = 0.72
Caucasian	r = -0.18, p = 0.41	r = -0.03, p = 0.90	r = -0.28, p = 0.20	r = -0.24, p =0.26	r = 0.10, p = 0.64	r = 0.06, p = 0.80	-	-

Note: Shaded cells indicate significant correlation r values (at α =.05) before Bonferroni corrections.

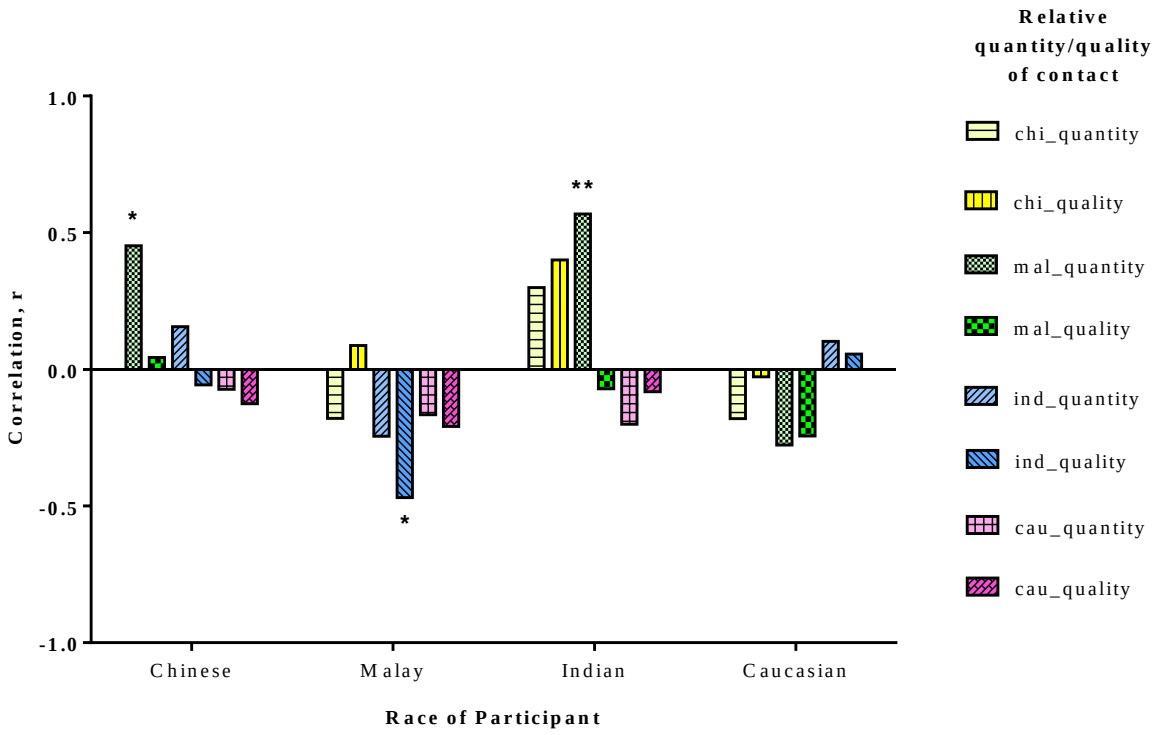


Figure 3.6 A bar graph displaying the pattern of correlations between relative quantity/quality of contact with other-race people and the magnitude of ORB for Chinese, Malay, Indian, and Caucasian participants. **Correlations significant at the .01 level (two-tailed). * Correlations significant at the .05 level (two-tailed).

3.4.3 Eye movement Data

For the eye tracking data, five participants (one Chinese, one Malay, one Indian, and two Caucasians) were dropped from the eye tracking analysis because of excessive eye tracker data loss (gaze samples below 50%), leaving a total of 89 participants (25 Chinese, 22 Malay, 21 Indian, and 21 Caucasian). Preliminary analyses revealed a significant three-way interaction between task type (learning versus recognition), face race and areas-of-interest (AOI). To explicate the interactions related to the type of task performed by participants, eye movement scanning behaviour was analysed separately for learning and recognition session.

Indices of first fixation, fixation count, and fixation duration over the predefined AOI within each face were collected during each trial. For every face presentation, durations and number of fixations on each AOI were summed, and then averaged across faces to provide average total fixation duration and fixation count on each AOI.

3.4.3.1 Average total fixation duration.

A mixed factorial ANOVA with Phase (learning vs. recognition), AOI (eyes, nose, mouth, and other facial areas) and Race of Face as within-subject factors, and Race of Observer as a between-subjects factor, was conducted on the average total number of fixations deployed on each AOI. No main effect of Race of Observer was found, F (3,85) = 1.36, p=.26, indicating that the average time spent fixating on the face stimuli did not differ between race groups. There was a significant main effect of Phase, F (1, 85) = 14.10, p<.001, η_p^2 =.14, such that participants fixated longer on the face in the recognition phase than in the learning phase (p<.001). A significant main effect of Face Race was found, F (3, 255) = 47.01, p<.001, η_p^2 =.36, which showed that fixations of shorter average duration for Caucasian faces than for Chinese, Malay and Indian faces (all p<.001). A main effect of AOI was also highly significant, F (1.62, 138) = 187.28, p<.001, η_p^2 =.69, with Bonferroni-corrected pairwise comparisons revealing that participants made longer fixations on the nose, followed by the eyes (p=.001) and mouth (p<.001), and a significant difference between the eyes and the mouth was found (p<.001). There was a significant two-way interaction between Race of Observer and AOI (see *Figure 3.7*), F (9, 255) = 2.66, p=.006, η_p^2 =.09. Simple main effect analysis revealed that Caucasian participants fixated significantly longer at the eyes region than did Indian participants (p=.01). In addition, Indian participants made longer fixations on the mouth region than did Chinese (p=.001) and Malay participants (p=.05). For the nose and other regions, however, no significant difference was found between race groups (all p>.05).

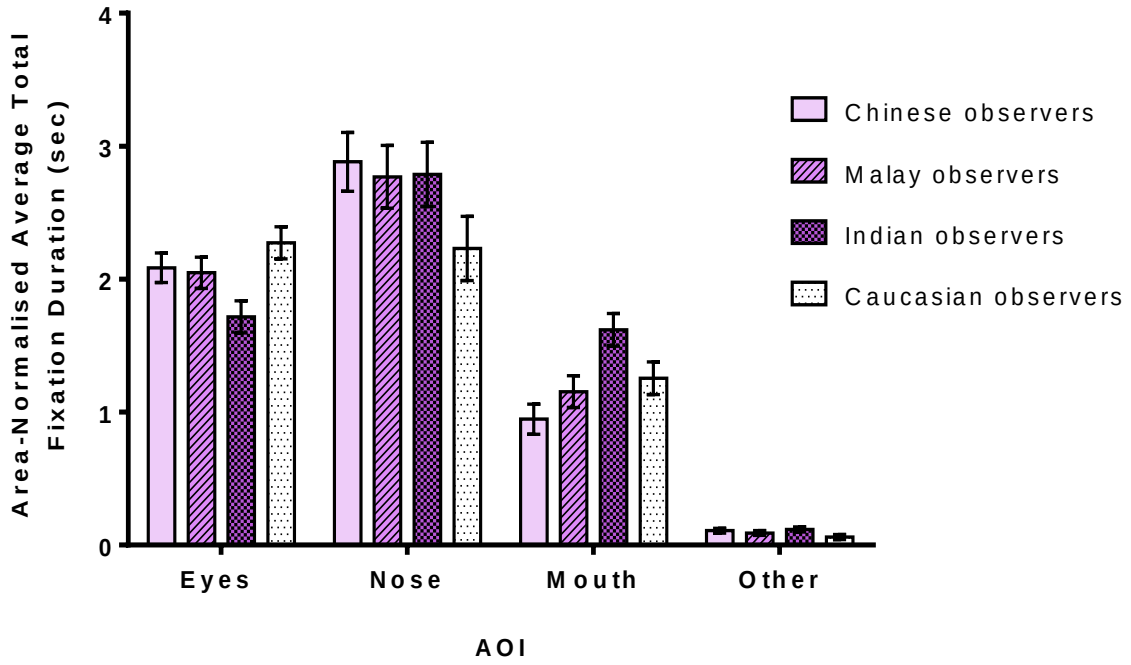


Figure 3.7. Average total fixation duration (area-normalised) on the predefined AOIs for different *races of observers*. Error bars represent standard error of mean.

A three-way interaction between Phase, Face Race and AOI was significant, F (4.66, 395.96) = 4.84, p<.001, η_p^2 =.05. To explore this interaction, two repeated-measures ANOVAs were conducted with the Face Race and AOI separately for each phase (see *Figure 3.8*). In the learning phase, fixation durations on Caucasian eyes were significantly higher than those on Malay, Chinese, and Indian eyes (all p <.001); however, the average total fixation durations on Caucasian nose and mouth were significantly shorter than those on Chinese, Malay, and Indian faces (all p<.001). In the recognition phase, Caucasian eyes were fixated significantly longer than those on the other three face races (p≤.002). The average total fixation durations on Chinese and Malay noses were significantly shorter than those on Caucasian (p=.002 and p<.001, respectively) and Indian faces (p=.03 and p<.001), but no difference was found between Caucasian and Indian nose (p=1). In both phases, no significant difference of average total fixation duration on the other regions was observed between different face races (all p=1).

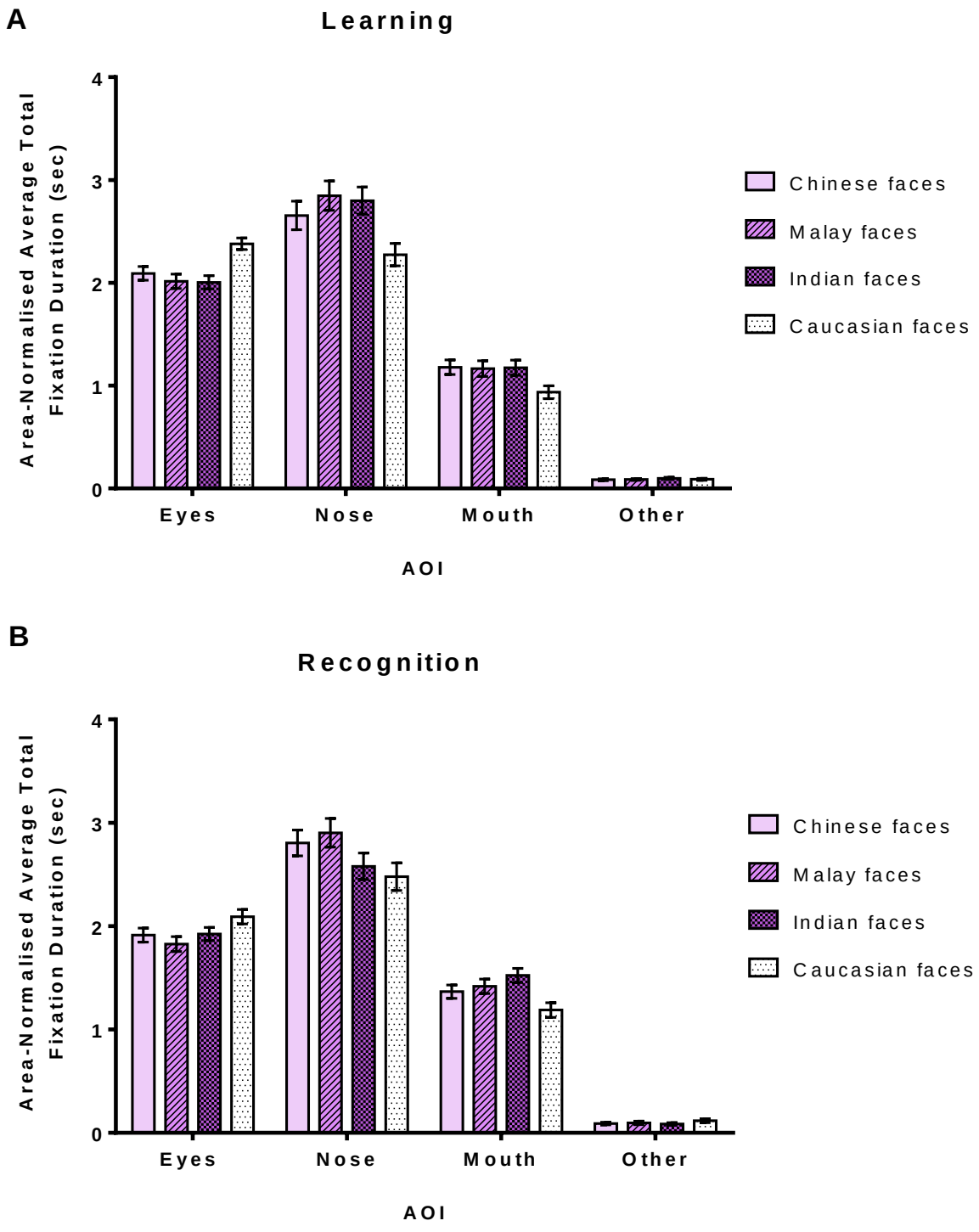


Figure 3.8. Average total number of fixation duration (area-normalised) on the predefined AOIs for different *face races* during the (a) learning and (b) recognition tasks. Error bars represent standard error of mean.

3.4.3.2 Average total fixation count

A similar mixed ANOVA was conducted on the average total number of fixations deployed on each AOI. No main effect of Race of Observer was found, F (3,85) = 1.31, p=.28, indicating that the average total number of fixations on the face stimuli did not differ between race groups. There was a significant main effect of Phase, F (1, 85) = 6.76, p=.01, η_p^2 =.07, such that participants fixated more frequently on the face in the recognition phase than in the learning phase (p<.001). A significant main effect of Face Race was found, F (3,255) = 40.67, p<.001, η_p^2 =.33, which showed that fewer fixations were made on Caucasian faces than on Chinese, Malay and Indian faces (all p<0.001). A main effect of AOI was also highly significant, F (1.67, 142.06) = 279.81, p<.001, η_p^2 =.77, with Bonferroni-corrected pairwise comparisons revealing that participants fixated most on the nose, followed by the eyes, the mouth and then the other regions (all p<.001). There was also a significant interaction between Race of Observer and AOI (see *Figure 3.9*), F (9, 255) = 2.87, p = 0.003, η_p^2 =.09. Consistent with the fixation duration results, simple main effect analysis revealed that Caucasian participants fixated more frequently at the eyes region than did Indian participants (p=.01). In addition, Indian participants made more fixations on the mouth region than did Chinese (p<.001) and Malay participants (p=.02). For the nose and other regions, no significant difference was found between participant race groups (all p>.05).

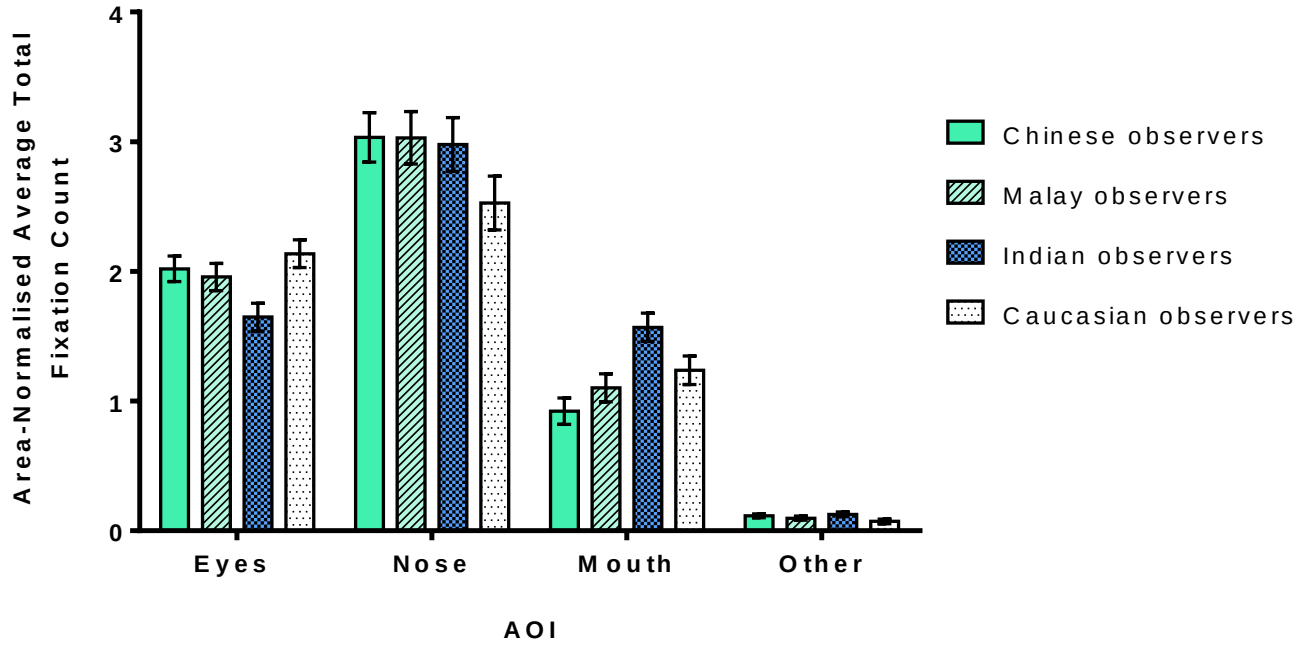


Figure 3.9. Average total fixation count (area-normalised) on the predefined AOIs for different *races of observers*. Error bars represent standard error of mean.

A three-way interaction between Phase, Face Race and AOI was significant, F (4.44, 377.65) = 5.12, p<.001, η_p^2 =.06. To explore this interaction, two repeated-measures ANOVAs were conducted with the Face Race and AOI separately for each phase (see

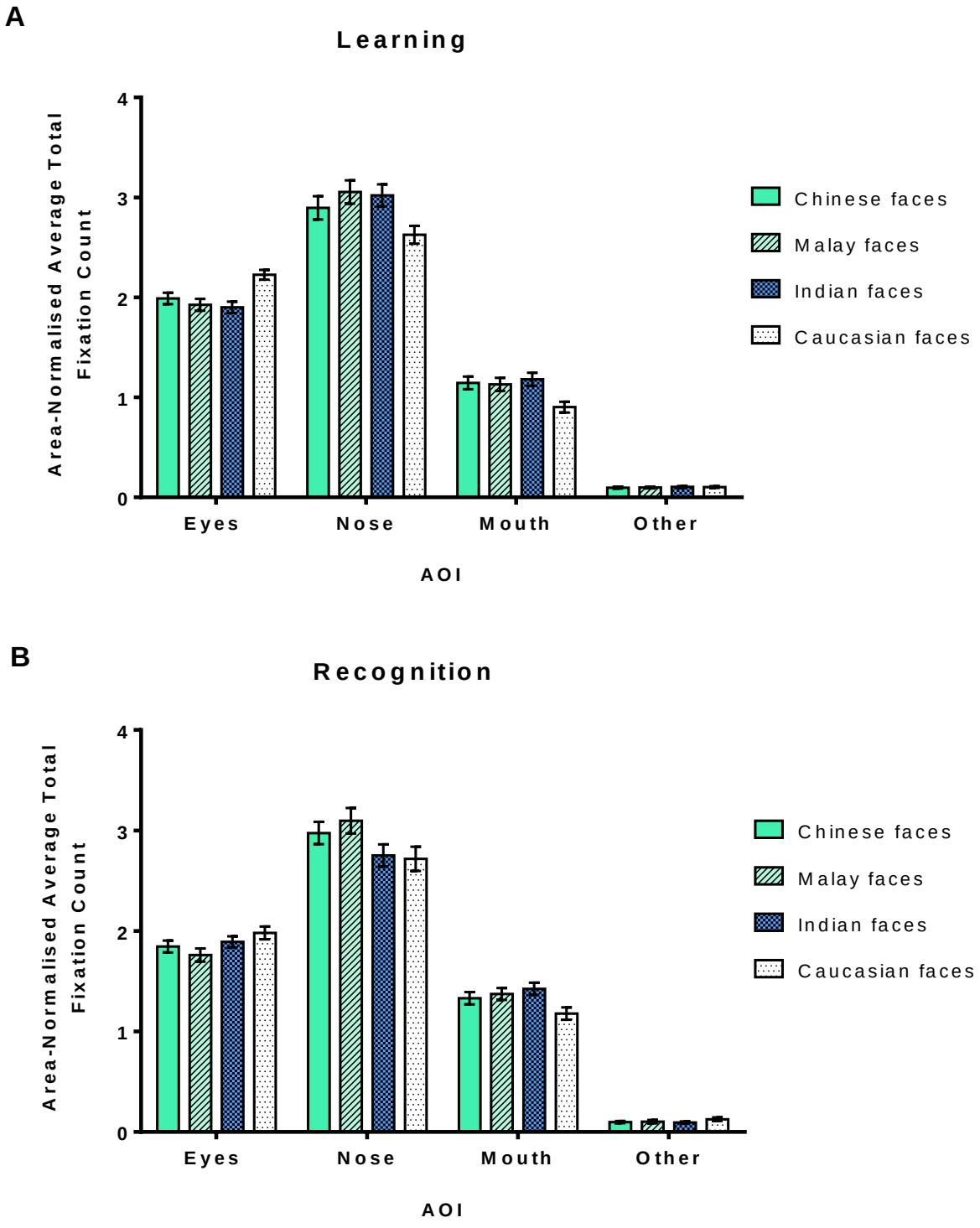


Figure 3.10). In the learning phase, participants fixated more on Caucasian eyes than Malay, Chinese, and Indian eyes (all p <.001); however, they made fewer fixations on the nose ($p \leq .001$) and mouth on Caucasian faces (all p=1) than those on Chinese, Malay, and Indian faces. No difference of fixation count on the other region was found between face races (all

p=1). In the recognition phase, Caucasian eyes were fixated significantly more frequently than Chinese (p=.002) and Malay eyes (p=<.001). In contrast, Chinese and Malay noses received more fixations than those on Caucasian (p=.01 and p<.001) and Indian faces (p=.008 and p<.001), but no difference was found between Caucasian and Indian nose (p=1). Furthermore, Caucasian mouth received significantly fewer fixations than the other three face races (p≤.007).

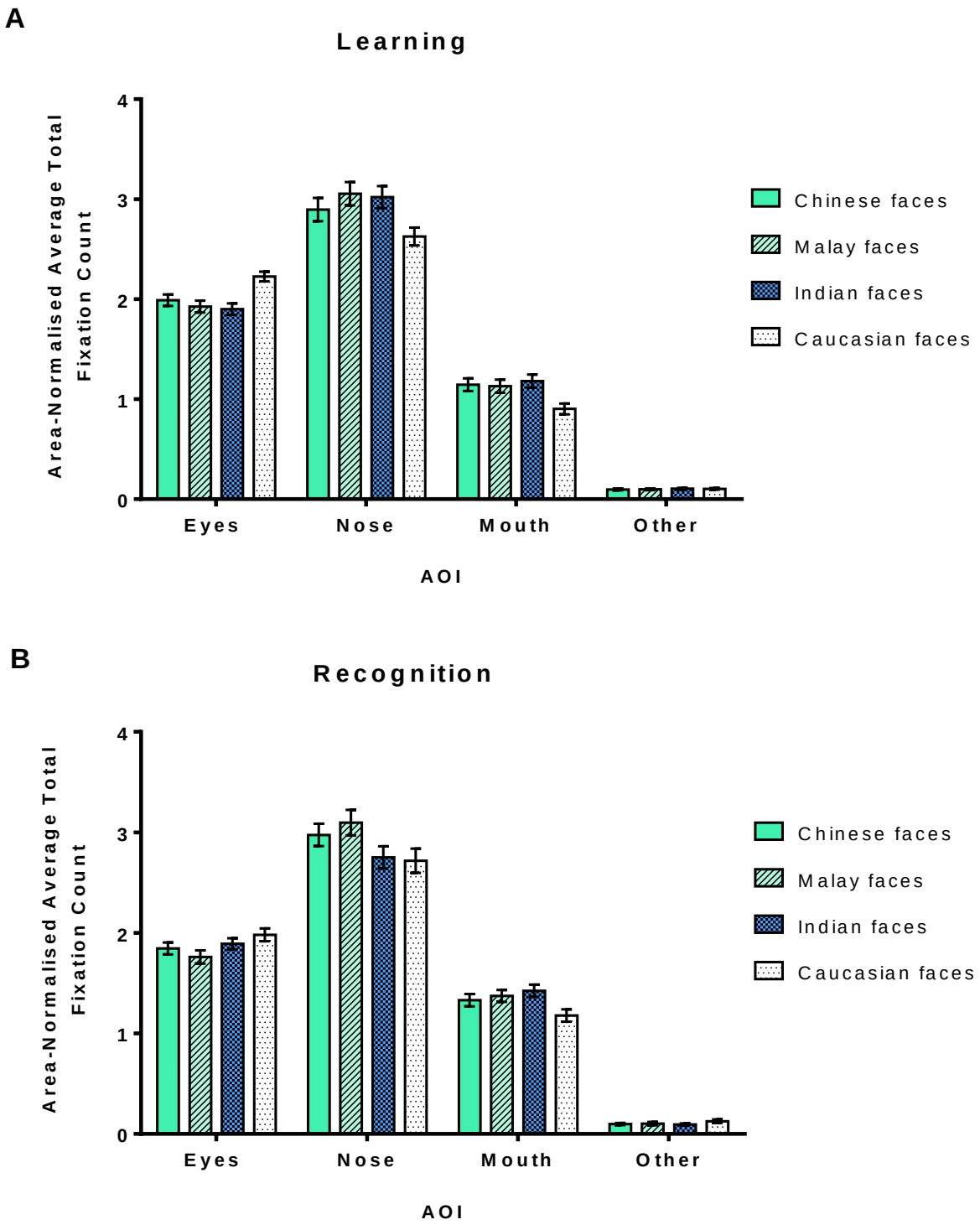


Figure 3.10. Average total number of fixations (area-normalised) on the predefined AOIs for different *face races* during the (a) learning and (b) recognition tasks. Error bars represent standard error of mean.

3.5 Discussion

3.5.1 Behavioural Performance

The current study is the first to investigate the ORB amongst four different race groups: Malaysian-Chinese, Malaysian-Malay, Malaysian-Indian, and British-Caucasian, who had differential exposure to other races in a racially diverse country. One explanation offered for own-race bias suggests that processing of facial information can be improved through contact with others. It was reasoned that if the contact hypothesis was true, Malaysian groups from a multiracial population would be able to develop a facial representation that is broadly tuned to optimally encode individuating facial information from different races, such that they may exhibit a reduced ORB relative to the British Caucasian participants. However, my results do not support this hypothesis. The ORB was found in all four race groups. When presented with face images containing only internal features, Malaysian participants (Chinese Malay, Indian) showed a recognition deficit for other-race faces.

It was found that Malaysian-Chinese participants recognised Malay and Caucasian faces significantly more poorly than own-race faces. Broadly similar to Chinese participants, Malay participants exhibited an ORB in favour of own-race faces, showing higher ability to recognise own-race faces compared to Caucasian and Chinese faces. Caucasian participants were found to be better at recognising own-race faces than Chinese and Malay faces. The ORB was less pronounced in Indian participants compared to other groups, with significant recognition deficit only for Chinese faces, and non-significant differences in the predicted directions for other race faces. These findings are inconsistent with two previous studies testing Malaysian-Chinese children (Su et al., 2017) and young adults (Tan et al., 2012). Su et al. (2017) found that Malaysian-Chinese children tested with four races of faces (Chinese, Malay, African and Caucasian) showed reduced recognition of African faces, but similar

recognition accuracy for Chinese, Malay and Caucasian faces. However, this study differed from the current study in several ways: first, it used children rather than adults; second, the number of faces to remember, and the number of distractor faces was smaller; third, the stimuli included parts of the external facial features (the outline of the face and hairline). The relative easiness of the task renders these findings not directly comparable with my current results.

In another study, Tan et al. (2012) found that Malaysian Chinese participants performed equally well at recognising East Asian and Western Caucasian faces. In contrast, Malaysian Chinese participants in the present study recognised own-race faces significantly better than Caucasian faces. Such a discrepancy may be due to two major methodological differences between the current study and Tan et al.'s (2012). First, the facial stimuli used in Tan et al.'s study were presented with the external features (e.g. hair, hairline, and ears). External features have been shown to be relied on more during other-race face recognition (Megreya, Memon, & Havard, 2012; Sporer & Horry, 2011). In addition, MacLin & Malpass (2001) demonstrated that race-stereotypic hairstyles affect both race categorisation and memory for ambiguous race faces. Based on this empirical evidence, it is possible that the participants in Tan et al.'s (2012) study based their judgment on these external diagnostic cues to achieve a generally high recognition performance across face race. However, Tan et al.'s (2012) area-of-interest analysis did not include the fixations on the external features. Hence, it is difficult to be sure that the equal performance for both Caucasian faces and Asian faces observed in their Malaysian Chinese participants was not simply due to greater distinctiveness of the Caucasian hairstyles in their study. In Chapter 5, a follow-up study was designed to address this issue regarding the impact of external features on the ORB.

It is important to note that regardless of race group, participants recognised Indian faces fairly well, possibly due to greater distinctiveness of the Indian face set. To test this

possibility, I conducted a follow-up study (see Chapter 4) where the facial distinctiveness of the stimulus sets was measured based on the mean subjective ratings obtained not only from same-race raters, but also from other-race raters. The results revealed that the Indian faces selected in the present study were more distinctive from one another than the other three races of faces. This may have increased the recognition performance for Indian faces than for own-race faces in Chinese, Malay and Caucasian participants. Thus, any result derived from the Indian faces should be interpreted with caution.

Many studies have shown that sufficient contact with other-race people can ameliorate the ORB (Fioravanti-bastos et al., 2014; Walker & Hewstone, 2006b; Wright et al., 2003). However, other studies have shown that substantial interracial contact does not necessarily ensure that other-race face recognition will improve (Cross, Cross, & Daly, 1971; Jackiw et al., 2008; Ng & Lindsay, 1994; Rhodes, Locke, Ewing, & Evangelista, 2009; Walker & Hewstone, 2006a). For instance, Caucasian participants with extensive contact with Chinese individuals do not show an improved ability to recognise Chinese faces (Ng & Lindsay, 1994). Developmental studies similarly have shown that African-American children reared in a multicultural environment show a level of recognition of Caucasian faces that is the same as that of children reared in a monocultural African-American environment (Cross et al., 1971). Meta-analysis of the ORB studies revealed that self-report measures of other-race contact accounted for less than 3% of the total variance found in the ORB (Meissner & Brigham, 2001). The equivocal findings from these social contact studies indicate that other factors beyond pure exposure to other-race faces modulate the magnitude of the ORB.

My finding also raises an open question of why ORB seems to be reduced in face training studies (Anzures, Quinn, Pascalis, Slater, & Lee, 2013; Heron-Delaney et al., 2011; Hills & Lewis, 2006) but not in a multiracial environment. One explanation is that more "natural" face experience may not function in the same way as these laboratory

manipulations. Most laboratory training methods only increases other-race face experience quantitatively via photographic exposure in extensive, intentional face learning tasks, which differ from casual individuating experience with faces from other races in the real world. Although training studies provide an indication regarding the flexibility of the ORB and the plasticity of one's face recognition system, the enhancement effect from training studies is often transient (e.g., Hills & Lewis, 2011).

The current study offers evidence to suggest that even Malaysian young adults had difficulty generalising their perceptual expertise for own-race faces to other-race faces they frequently encountered in a multiracial environment. The relationship between other-race contact and the ORB was further assessed in Malaysian and Caucasian samples by examining the pattern of correlations between self-rated interracial contact and other-race recognition performance. According to the contact hypothesis, the amount of contact that an individual has with another race should be positively correlated with the accuracy of recognising individuals from that race. Although demographics imply that Malaysian participants generally had a considerable amount of exposure to other-race people (see Table 3.1), the multiple correlation analyses revealed that both relative quantity and quality of interracial contact did not seem to accurately predict the magnitude of the ORB. This finding is entirely compatible with Meissner & Brigham's (2001) meta-analysis that self-report measures of other-race contact actually accounted for less than 3% of the total variance found in the ORB. The very modest contact effects typically found imply that interracial contact may not be one of the critical factors that mitigates ORB. Rather, it may just play a small, mediating role in the ORB.

Another possibility for the lack of exposure effect on ORB might be due to the measurement I used. The social contact questionnaire did not separate past experience from current experience participants had with other-race people. It remains possible that the

malleability of ORB is determined by the age at which experience with another racial group begins. This argument is supported by evidence from developmental studies showing that infancy (Chien, Wang, & Huang, 2016; Liu et al., 2015; Singarajah et al., 2017) and childhood (De Heering et al., 2010; Sangrigoli et al., 2005; Su et al., 2017) are sensitive periods beyond which the effect of racial experience on face recognition is markedly reduced. Future studies using a different contact questionnaire that distinguishes past from current interracial experience may offer a greater potential for revealing the link between perceptual expertise across development and plasticity of other-race face recognition.

3.5.2 Eye Movement Patterns

Another important objective of the current study was to compare the eye movement patterns between Malaysian Chinese, Malaysian Malay, Malaysian Indian, and Western Caucasian observers. Both similarities and differences in the processing of own- and other-race faces were revealed through the eye tracking procedure. In terms of similarities in face scanning, participants showed general bias in directing their first fixations towards the nose region (i.e. the geometrical centre of the faces), rather than landing their first fixations towards other distinctive facial features during both study and test phase (see APPENDIX B), regardless of face race. The centre of the face is the region optimal for both information extraction and retrieval in face recognition tasks (Peterson & Eckstein, 2012). Hills and Lewis (2011) also proposed that an immediate attentional mechanism can attenuate the ORB when immediate attention is paid to diagnostic features. Their results suggest that the first facial feature attended to is important for accurate face encoding, processing and recognition. This is further supported by a recent finding that the two fixations are sufficient for accurate face recognition (Hsiao & Cottrell, 2008).

The current results also confirm van Belle, Ramon, Lefèvre, and Rossion's (2010) finding of centrally located initial fixations, positioned just below the eye level, on the top

part of the nose. They suggested that this position of first fixation is ideal because it allows normal observers to encode all facial features simultaneously, as a single representation. Nevertheless, there was more variability in the landing point of the first eye movement in the Indian group. More specifically, Indian participants tended to first fixate more on the mouth but less on the eyes compared to other racial groups, suggesting that the mouth region may serve as a secondary diagnostic cue for their face recognition.

In addition, my results showed no between-observer-groups difference in the average total number of fixations and average total fixation durations on the nose region regardless of face race. This result is inconsistent with previous observations that Caucasians perceive faces analytically by moving between the eyes and mouth. Blais et al. (2008) reported that East Asian observers fixated more on the nose region whereas Western Caucasian observers systematically fixated on the eyes and partially the mouth region to extract information from faces. In light of the enculturation hypothesis, the authors argued that this divergence is due to the social norm in East Asian cultures that prolonged eye contact may be regarded as rude, and to the differences in cultural context (collectivistic/individualistic) and cognitive style (holistic/featural) for encoding perceptual information, instead of genetic differences (but see Knox & Wolohan, 2014). Surprisingly, the well-known typical triangular shape or T-shape of fixation pattern of Caucasians that has been reported in most previous studies (e.g., Blais et al., 2008; Kelly, Miellet, & Caldara, 2010), was not clearly replicated in the present study. Here, Caucasian participants made fixations of significantly longer duration on the eyes than the nose and mouth; however, the average total fixation duration for the nose and mouth was not significantly different. At present, it is not entirely clear why the results differ across studies. Both studies used similar participant groups, photographs of the same approximate size, and the same intentional face-learning task. There were several differences across studies, however, that might explain the discrepant results. As a minor difference, Blais et al.

(2008) presented faces of different races in separate blocks whereas I randomly intermixed the face stimuli of different races within each block. This procedural difference might have produced the different outcomes across studies. Furthermore, the most likely source of the disparate results was the stimulus photographs. In the Blais et al. study, the faces presented for learning varied in emotional expressions (neutral, happy, angry, or disgusted). In contrast, I changed the facial expression (happy or neutral) between the study and test phases to avoid trivial image matching strategy. Since eye movement pattern during face processing is sensitive towards stimulus type and societal norms regarding eye contact during emotional displays presentation, these procedural differences may explain the discrepant results.

It is important to note that my study replicated Tan et al.'s (2012) finding that Malaysian Chinese adopt a fixation pattern by looking more at the eyes and nose more than mouth region. However, my results did not favour Tan et al.'s (2012) notion that the unique looking strategy that Malaysian Chinese employ when recognising faces is mainly influenced by their familiarity with Western culture. Among the Malaysian student samples used, Indian participants who had also attended a branch campus of British university (i.e., increased exposure to Western people and culture), displayed a dissimilar fixation pattern compared to that of Chinese participants. In particular, the relatively low number of fixations on the eyes rendered Malaysian Indian participants' eye movement patterns different from other race groups.

When perceiving all races of faces, both Chinese and Malay participants showed identical fixation patterns, attending most to the eyes, followed by the nose and then the mouth, for both learning and recognition tasks. On the other hand, regardless of the race of face viewed, Indian and Caucasian participants made more fixation and spent more time attending to the eyes than the nose and mouth; however, no significant difference was found between the fixations on the nose and mouth. Compared with other three race groups, Indian

participants tend to have shorter fixation durations on the eyes but longer on the mouth. Caucasian participants directed more and longer fixations to the eyes and mouth than Chinese participants did. This inconsistency across race groups suggests that the mechanism underlying the ORB may be attributed to an inability to extract the most diagnostic visual features on other-race faces (Michel, Rossion, Bülthoff, & Hayward, 2013).

Exposure to and familiarity with the diagnostic features of other-race faces encountered during early development may affect one's face scanning pattern (Liu et al., 2012; Xiao et al., 2014). The current results provide evidence that eye movement pattern is modulated by the race of the incoming face stimulus. It appeared that Caucasian faces received more fixations to the eyes, but less on the nose and mouth when compared to other races of faces. Participants attended most to the eyes for Caucasian faces possibly because they convey more individuating information (e.g. eye colour) of a face than for Malaysian faces, which tend to have rather uniform eye colour (Rhodes, Ewing, et al., 2009). Additionally, Malaysian faces produced longer fixations on the nose than other face races, implying that the centre region of the face could be more informative or diagnostic for identifying Malaysian faces. Another possibility is that a higher level of holistic processing was being used to process Malaysian faces. Participants might individuate these faces by assessing the relationship between the features to create an overall impression of a face, rather than analytically assessing the individual features of a face. But such argument will remain somewhat speculative until further empirical work is carried out to measure the level of holistic processing of own- and other-race faces (Chapter 6).

3.6 Conclusion

To my knowledge, the present study is the first to investigate the ORB as well as eye movement patterns among the three different major races in Malaysia (i.e. Malay, Chinese, and Indian) and compare them with that of Caucasians using a yes/no face recognition task.

Despite many years of interracial experience, the ORB in Malaysian young adults does not seem to be attenuated or eliminated as compared to Western-Caucasian young adults who lived in communities that are relatively less racially and ethnically heterogenous. This unexpected finding renders previous reports that the ORB is less evident in multiracial populations (Bar-Haim et al., 2006; Chiroro & Valentine, 1995; Wright, Boyd, & Tredoux, 2001), can be reversed following cross-race adoption before the age of 9 years (Sangrigoli et al., 2005), and can be reduced by training (Hills & Lewis, 2006), difficult to interpret. An open question raised by my data is whether, in addition to interracial contact *per se* affecting the magnitude of ORB, the ability to recognise other-race faces might also be affected by the age at which that contact is obtained. Although the current study was not specifically designed to address this question as the period of contact was not clearly measured, my results raise the intriguing possibility that Malaysian individuals living in a racially heterogeneous context might still lack childhood experience in individuating other-race individuals due to prototypical perceptual environmental in the early developmental stages of face recognition ability. Theoretically, the proposal that ORB might be specifically associated with low childhood contact would imply that the effectiveness of multiracial experience on tuning the adult face recognition system would differ depending on individuals' early other-race experience. In fact, developmental studies have demonstrated a critical period for plasticity of ORB (Chien et al., 2016; Fioravanti-bastos et al., 2014; Su et al., 2017) and such recognition bias can be reduced by contact with the faces of another race during childhood, pointing towards the importance of early individuating experience in developing mechanisms of remembering and distinguishing other-race faces. Perhaps such early-formed recognition bias for own-race faces cannot be readily altered by increased exposure to other-race faces in adulthood, even in a highly multiracial context. Future studies should further investigate the relative contributions of early and late interracial experiences to the size of ORB.

Chapter 4

The Effects of Facial Distinctiveness on the ORB

4.1 Introduction

4.1.1 Facial Distinctiveness

Faces differ in their distinctiveness, that is, how much each would stand out in a crowd. Distinctiveness is known to be an important factor in recognition memory for faces (Newell et al., 1999; Valentine & Bruce, 1986). Highly distinctive faces strongly deviate from an average or prototypical face, as they contain unusually sized or shaped facial features (e.g., particularly small eyes), or unusual facial texture or coloration. In contrast, less distinctive or typical faces are perceptually closer to the prototype. It is well-documented that there are differences in the way humans process typical and distinctive faces (Angeli, Davidoff, & Valentine, 2008; Deffenbacher, Johanson, Vetter, & O'Toole, 2000; Newell, Chiroro, & Valentine, 1999; Rhodes & McLean, 1990; Gillian Rhodes, Byatt, Tremewan, & Kennedy, 1996; Valentine & Bruce, 1986; Valentine & Bruce, 1986). In the literature of adult face recognition, it has been demonstrated that faces judged to be physiognomically distinctive are more accurately and/or more quickly recognised than typical faces in face–nonface classification (Valentine & Bruce, 1986) and old–new recognition tasks (Sommer, Heinz, Leuthold, Matt, & Schweinberger, 1995). Hence, this distinctiveness advantage has been interpreted as evidence for the importance of distinctive information in the mental representations of faces.

Valentine (1991) proposed a theoretical framework which accounts for this distinctiveness effect. In the multidimensional face space, each individual face is encoded as a unique point based on various dimensions that represent both configural (e.g., distance

between the eyes) and featural aspects of faces (e.g., fat/thin face, small/large eyes), which developed from an individual's prior experience with faces. The average or "norm" face lies at the centre of face space, and distinctiveness increases as a face lies further from the centre toward the periphery (see *Figure 4.1*). The ease with which a face is recognised depends on the density of exemplars in the face space. Distinctive faces are therefore remembered relatively easily, while typical faces are more difficult to remember. Catz, Kampf, Nachson, & Babkoff (2009) constructed a multi-dimensional face space, in which the locations of 200 face exemplars were plotted. The list of dimensions consisted of 21 features, such as forehead (height), eyes (colour, distance, shape, and size), nose (shape and size), mouth (shape, size, and thickness), cheeks (shape and size), chin (shape and size), and eyebrows (shape and size). Faces with fewer surrounding exemplars (i.e. those located in less dense areas of face space) were rated as more distinctive and were recognised more accurately than those with more surrounding exemplars (those located in more dense areas of face space). Not only does this model explains the fact that distinctive faces are more memorable in general, but it also addresses a number of representational questions in face recognition, including the well-known ORB in face memory (e.g., Chiroro & Valentine, 1995; Hancock & Rhodes, 2008; Levin, 1996).

4.1.2 The ORB and Distinctiveness Effect

Poor discrimination and recognition of other-race faces (i.e. the ORB) has been commonly explained using the concept of a "face space" (Busey, 1998; Valentine & Endo, 1992), which is argued to be a failure of the face system appropriately to encode the variation along dimensions of other-race faces within the multi-dimensional space. Most face-space models (e.g., Byatt & Rhodes, 2004; Valentine & Bruce, 1986; Valentine, 1991) postulate that the difficulty associated with recognising other-race faces is caused by inefficient storage and/or retrieval of face representations from memory. Importantly, the dimensions around

which the face space is constructed are likely to be shaped by the perceptual experience of the perceiver (Furl, Phillips, & O 'toole, 2002; Valentine & Ferrara, 1991). For instance, a perceiver who has had extensive contact with Caucasian faces will structure their face space around dimensions which are useful for discriminating Caucasian faces. While these characteristics are useful for discriminating between Caucasian faces, they are less appropriate for discriminating between faces from other racial groups (e.g., African or Asian faces). This is clearly supported by Ellis, Deregowski, & Shepherd (1975) who found that Caucasians preferentially attended to the hair texture, hair colour and eye colour when describing faces.

Figure 4.1 shows a hypothetical two-dimensional face space for a Caucasian observer, with own- and other-race exemplars plotted. The two dimensions within this space are hair colour and eye colour. These features vary more widely in Caucasian faces than in Black or Asian faces, for example. Therefore, while the Caucasian faces (light circles) are distributed throughout the face space, the other-race faces (dark circles) are clustered within one small region of the space. As a result, there is higher density of exemplars within this region. The other-race exemplars also fall further from the centre of the space than the majority of the own-race exemplars.

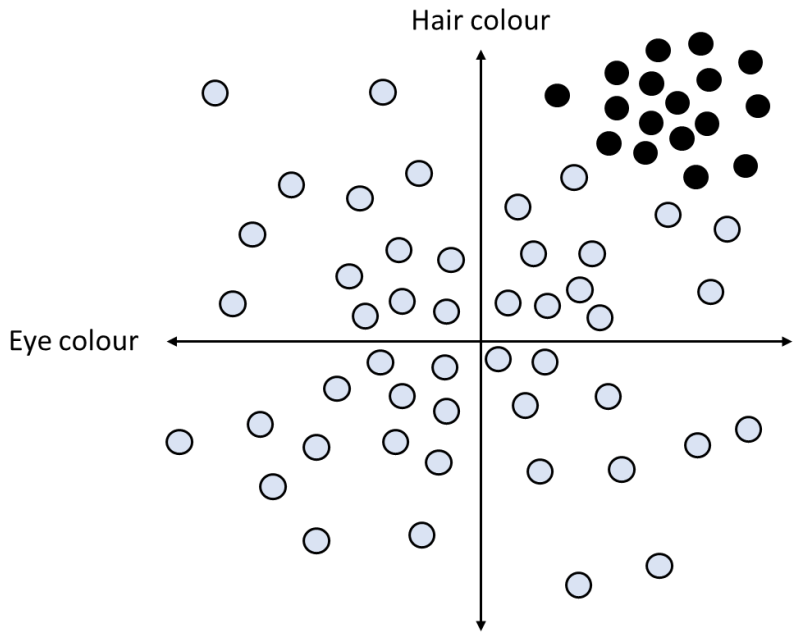


Figure 4.1. Representations of own- and other-race faces in the multidimensional face space (Valentine, 1991). Each dot represents a face and each vector represents a dimension along which face can vary in the face space. Note that the different exemplar density is illustrated for the own- and other-race faces.

To date, researchers generally agree that own-race faces are more evenly distributed throughout the multidimensional "face space" owing to greater perceptual experience (Byatt & Rhodes, 2004; Caldara & Abdi, 2006). They are more distinctively represented and therefore more accurately recognised. On the other hand, other-race faces are more tightly clustered in the periphery of face space. This dense clustering, coupled with the large distance from the centre of the space, could explain the perceptual homogeneity of other-race faces and the deficit in recognising other-race faces. Although a recognition advantage for distinctive faces has been widely reported (e.g. Light et al., 1979), it is unclear whether similar distinctiveness cues are extracted by different racial groups and if this distinctiveness effect can be modulated by perceived race of face. To the best of my knowledge, only two studies directly examined the distinctiveness effect across different race groups using own-

and other-race faces (Levin, 1996; Valentine & Endo, 1992). By employing a race classification task, Levin (1996) found that other-race faces tend to be classified by race faster than own-race faces, possibly based on race-distinctive features. Valentine and Endo (1992) evaluated the distinctiveness effect between British and Japanese participants. Both races were asked to rate the distinctiveness of faces from their own race and from the other race. The correlation between the ratings assigned by British participant, and the ratings assigned by Japanese subjects to British faces was 0.82, while the correlation for Japanese faces was 0.65. According to the authors, these results indicate that the perception of distinctiveness varies depending of the level of familiarity with faces of a particular race. The authors also found that distinctive faces were recognised more accurately then typical faces; however, the distinctiveness effect did not interact with the race of face or the race of participants.

4.1.3 Facial Similarity Rating Task

Faces share a common first-order configuration (two eyes sit above a nose and a mouth), but they are coded in terms of their own distinctive properties. In most facial similarity rating studies, distinctiveness has been defined as the ease of spotting a face in a crowd or the similarity to a typical face. For instance, Valentine & Bruce (1986) asked their participants to rate faces along a unidimensional scale of typicality/distinctiveness by imagine that they are looking for a person at a railway station and to try to judge the difficulty of this task; the easier they think it would be to spot the face, the higher the distinctiveness rating they should give to it. Alternatively, distinctiveness or typicality of a face can be defined with explicit reference to a prototype (i.e. the difference between the average face and the original face). Here I obtained subjective ratings of facial similarity in terms of how similar individual faces are to an average face created from the stimulus set. In particular, for this experiment, I

define typical faces as those that are highly similar to an average face, whereas distinctive faces are highly dissimilar to an average face.

4.2 Experiment 2

The purpose of the present study was two-fold. The first aim was to determine whether the consistently better performance for Indian faces than for other-race faces across race groups in Experiment 1 could be due in part to a larger amount of variability in distinctiveness within Indian faces than within the sets of faces of other races. If this is true, the mean similarity ratings for Indian faces would be lower (i.e. higher distinctiveness) as compared to the other three face races. The second closely related aim was to investigate the contribution of distinctiveness to own- and other-race face recognition. Considering that distinctive faces are associated with greater processing efficiency (Newell et al., 1999; Rhodes et al., 1996; Sommer et al., 1995; Valentine & Bruce, 1986), it might be that facial distinctiveness between different face races affects the magnitude of ORB. In addition, by recording eye movements, I would like to determine the important features used for facial similarity judgement for own- and other-race faces from subsequent eye-tracking analysis.

To investigate these questions, in this eye-tracking study, I collected facial similarity ratings from four race groups: Malaysian-Chinese, Malaysian-Malay, Malaysian-Indian and British-Caucasian participants using Chinese, Malay, Indian, and Caucasian faces. In the facial similarity rating task, they were asked to rate how strongly an original face deviates from an average face generated from faces used in the former old-new face recognition experiment (see Chapter 3). Based on the face-space model, I expect that faces rated as highly distinctive should be more likely than those rated as low distinctiveness to be remembered. If different race groups employ certain diagnostic cues in distinctiveness judgments and those cues are race-specific rather than universal, the own-race faces should be judged as more distinctive than the other-race faces. Furthermore, theories of perceptual

learning (Furl et al., 2002; Valentine, 1991) would predict a processing disadvantage for other-race faces that people have less experience with and this may lead to a failure to encode the distinctiveness of other-race faces.

4.3 Methods

4.3.1 Participants

The ratings of facial distinctiveness were carried out by a total of 95 participants (24 Chinese, 24 Malay, 25 Indian, and 21 Caucasian; 47 males and 48 females). All participants were undergraduate students from the University of Nottingham Malaysia Campus. The age range of participants was 18-35, with a mean age of 21 years (SD = 3.93). They received course credit for their participation. For the eye-tracking data, 15 data (4 Chinese, 4 Malay, 5 Indian, and 2 Caucasian) were removed due to either poor calibration or excessive data loss (samples under 50%), leaving 80 participants in the eye-movement dataset. The study was approved by the Research Ethics Committee at the University of Nottingham Malaysia Campus.

4.3.2 Apparatus and Materials

The original 72 faces (frontal-view view with neutral expression) used in Experiment 1 were assigned into eight groups of faces (nine each) based on gender and race to create average faces. An average face was created by morphing each set of parent faces using Psychomorph software (Tiddeman and Perrett, 2001). Key locations of 179 points (i.e. points of reference) were first manually defined, thereby outlining the shapes and positions of internal (e.g. eyes, nose, mouth) and external features (e.g. jaw line, ears) of each face – a step usually called delineation (i.e., fitting a template face to each of the face images). The software then averages the vectors formed by these points, warps the corresponding image textures and colours to the relevant average shape, and finally, averages the aligned textures

together before superimposing the images to produce a photographic quality outcome (see Tiddeman, Burt, & Perrett, 2001 for further details). These morphed faces represented the average of each sex/race faces. The faces, which were 429 × 573 pixels in size, were presented on a Tobii T60 eye tracker (17-inch TFT monitor with a screen resolution of 1280 × 1024 pixels), at a viewing distance of approximately 57 cm. Both eyes were tracked at a data sampling rate of 60 Hz with high accuracy (0.5˚) and drift compensation (less than 0.3˚). Tobii Studio software was used to present the face stimuli.

4.3.3 Procedure

In the facial similarity rating task, participants viewed 72 pairs (18 Chinese, 18 Malay, 18 Indian, and 18 Caucasian) of faces, each presented for three seconds. Each trial began with a central fixation cross. Two frontal view faces (one original face and one average face) of the same race were then presented on the screen side-by-side for three seconds. This was immediately followed by a question "How similar are these two faces?". Participants were then required to make a similarity judgment and rate each pair of faces on a scale from 1 (extremely different) to 7 (extremely similar) by pressing the corresponding key on the keyboard. The face pairs were presented in a random order, with the constraint that no more than three trials with one race occurred in immediate succession. Half of the original faces of each race were on the left in the test pair, half on the right. The pairs of faces remained visible until participants responded by pressing a key on the keyboard (from 1 to 7).

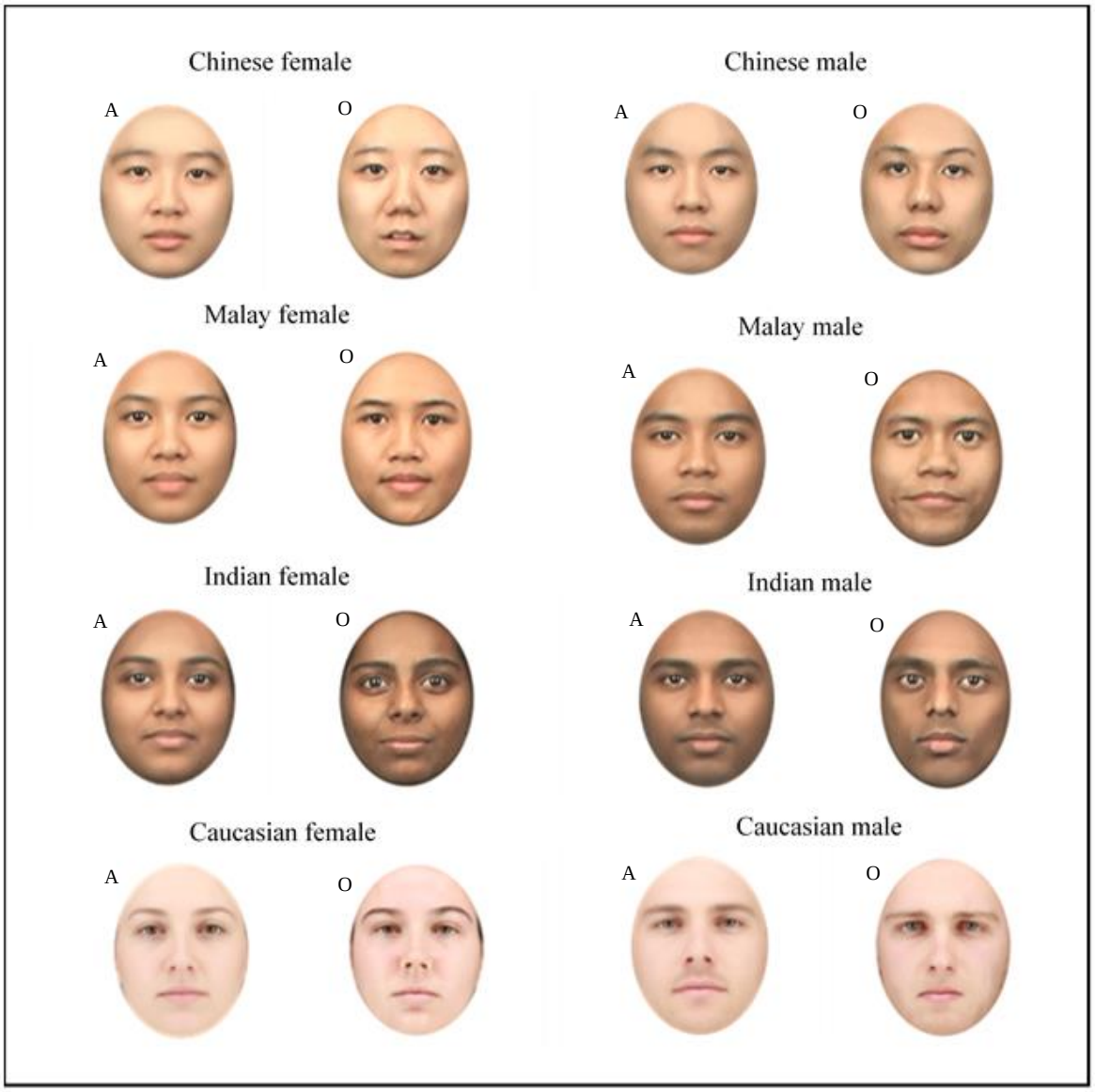


Figure 4.2. Examples of stimuli pairs of different races and genders used in Experiment 2. On each trial, an average face (A) was paired with an original face (O), with the left-right locations counterbalanced.

4.4 Results

4.4.1 Facial Similarity Ratings

A mean similarity rating was calculated for each face. A rating of 1 indicates a face that is very distinctive (or unusual) compared to the average face, while a rating of 7 indicates a face that is typical or very similar to the average face of its race and sex. Across races and sexes, the mean rating for the face pairs was 3.40 (*SD*=0.79), with a range from 2.09 to 5.01, indicating that very few faces were regarded as extremely typical or extremely distinctive. Reliability analysis using coefficient α revealed a high inter-rater reliability for similarity ratings (α = 0.95). A two-way ANOVA was performed on the mean distinctiveness rating scores, with Race of Participant as between-subject factor and Face Race as within-subject factor. No main effect of Race of Participant was found, F (3,87) = 0.64, p = .59, η_p^2 = 0.02, indicating that similarity rating means were consistent across ethnic groups. However, the analysis revealed a significant main effect of Face Race, F (3,261) = 18.56, p < .001, η_p^2 = .18. Pairwise comparisons revealed that the mean similarity ratings for Indian faces (*M*=3.08) differed significantly from Chinese (*M*=3.46), Malay (*M*=3.57), and Caucasian faces (*M*=3.42) (all p <.001). There was also a significant interaction between Face Race and Race Group, F (9,261) = 3.70, p <.001, η_p^2 = .11 (see Table 4. 1). Simple main effects revealed that Chinese participants rated own-race faces as significantly more distinctive than Malay (p=.009) and Caucasian faces (p=.01), but not Indian faces (p=1). Malay participants rated Indian faces more distinctive than own-race faces (p=.01). Indian participants rated own-race faces as more distinctive than Chinese (p=.01) and Malay faces (p<.001) but not Caucasian faces (p=1). Caucasian participants rated own-race faces as more distinctive than Chinese faces, and Indian faces as more distinctive than Caucasian, Chinese, and Malay faces (all p<.05).

Table 4. 1

Mean similarity ratings for Chinese, Malay, Indian, and Caucasian faces by the four ethnic groups

	Chinese (N=24)	Malay (N=24)	Indian (N=25)	Caucasian (N=19)
Chinese faces	3.09 (0.60)	3.48 (0.66)	3.14 (0.66)	3.55 (0.74)
Malay faces	3.30 (0.99)	3.45 (0.86)	3.04 (0.94)	3.36 (0.79)
Indian faces	3.45 (1.17)	3.58 (1.18)	3.05 (1.25)	3.25 (1.15)
Caucasian faces	4.00 (0.74)	3.78 (0.76)	3.08 (0.92)	3.54 (0.95)

Note. Ratings were on a scale from 1 (extremely different) to 7 (extremely similar). Standard deviations are in parentheses. Pairwise comparisons revealed that the mean similarity ratings for Indian faces (*M*=3.08) differed significantly from Chinese (*M*=3.46), Malay (*M*=3.57), and Caucasian faces (*M*=3.42) (all $p < .001$).

4.4.2 Correlations between ratings and recognition rates

Data from the test phases in Experiment 1 were sorted into two conditions: target faces (previously seen) and foil (previously unseen) faces. Pearson correlation coefficients were calculated for each condition to explore the relation between similarity ratings and recognition rates. To examine if the effect of distinctiveness interacts with race of face and race of observer, I split the analysis according to these two variables. For foil faces, no correlation reached significance (all $p > .05$). For target faces, as seen in *Figure 4.3*, some considerably significant correlations were detected for Chinese, Malay, and Caucasian faces, but not for Indian faces. Inspection of the significant correlation values reveals the distinctiveness effects on own-race faces for most ethnic groups, except for Indian group. Overall, participants showed a clear tendency to recognise distinctive own-race faces more

accurately than typical own-race faces. Some of the non-significant trends were also observed in the predicted direction for other-race faces.

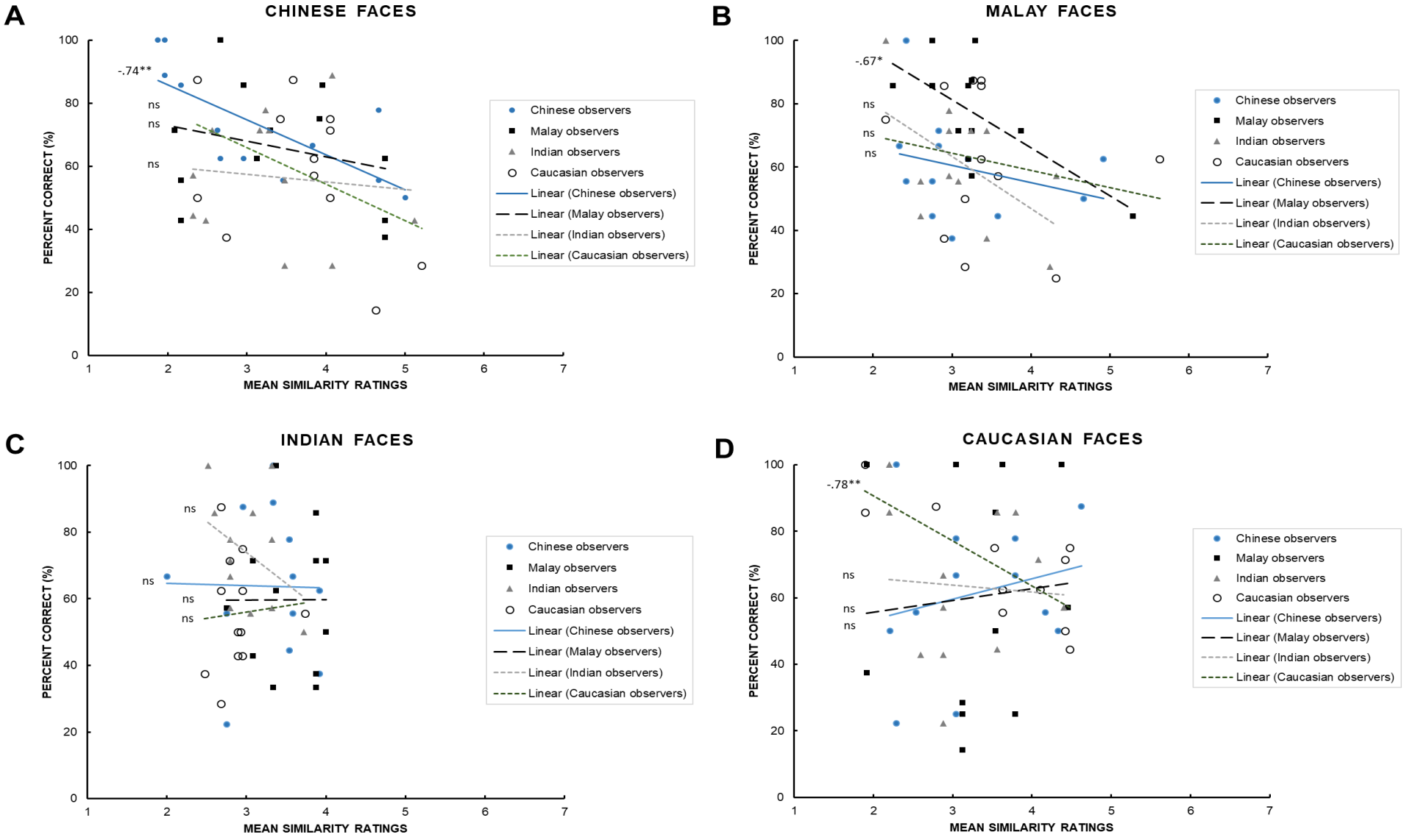


Figure 4.3. Scatterplot of average similarity ratings in relation to the overall recognition rates (Experiment 1) between the four ethnic groups for each target Chinese (A), Malay (B), Indian (C), and Caucasian (D) face. Each point represents a face stimulus. Note that higher rating scores on the 7-point scale indicates lower distinctiveness of faces. **p<.01; *p<.05.

4.4.3 Eye-tracking results

I conducted an analysis on area-normalized AOIs (calculated by dividing the proportion of time spent fixating in the AOI by the proportion of the screen the AOI occupied; see Bindemann, Scheepers, & Burton, 2009; Fletcher-Watson, Findlay, Leekam, & Benson, 2008) in order to deal with the unequal sizes of the AOIs. A mixed factorial ANOVA was performed on the participants' average fixation number and fixation duration, with Race of Observer (Chinese, Malay, Indian, Caucasian) as between-subjects variable and Race of Face (Chinese, Malay, Indian, Caucasian), Stimulus Type (target vs distractor), and Feature (eyes, nose, mouth, and others) as within-subjects variable. The Greenhouse-Geisser correction was utilised in those cases where Mauchly's test indicated a violation of the sphericity assumption.

4.4.3.1 Average total fixation count.

The main effect of Race of Face was significant, F (3,219) = 35.29, p <.001, η_p^2 = .33, showing that Caucasian faces received the lowest number of fixations whereas Indian faces received the highest number of fixations when compared with other three races of faces. There were also significant main effects of Feature, F (3, 132.32) = 251.68, p<.001, η_p^2 = .78, and Race of Observer, F (3, 73) = 4.57, p =.005, η_p^2 =.16, accompanied by an interaction between Feature and Race of Observer, F(9, 219) = 3.86, p<.001, η_p^2 = .14. Simple main effect analysis showed that Chinese, Malay, and Indian participants fixated most on the nose, followed by the eyes and then mouth region (all p <.05); however, Caucasian participants showed no difference of number of fixations between the eyes and mouth (p=1). The interaction between Feature and Face Race, F (4.08, 297.51) = 24.04, p<.001, η_p^2 = .25, was also significant. Participants generally made fewer eye fixations on Indian faces, but more eye fixations on Caucasian faces as compared to other three races of faces (all p <.001). The average number of nose fixations on Caucasian faces was lower than that of Chinese, Malay,

and Indian faces (all $p \leq .001$). In contrast, the average number of mouth fixations was significantly higher on Indian faces than Chinese, Malay, and Caucasian faces (all $p < .001$). Besides, the interaction between Stimulus Type and Feature was also significant, F (1.68, 122.42) = 25.44, $p < .001$, $\eta_p^2 = .26$. Target faces received more fixations on the eyes and nose (both $p = .001$) whereas average faces received more fixations on the mouth ($p < .001$) and other regions ($p = .01$) (see *Figure 4.4*).

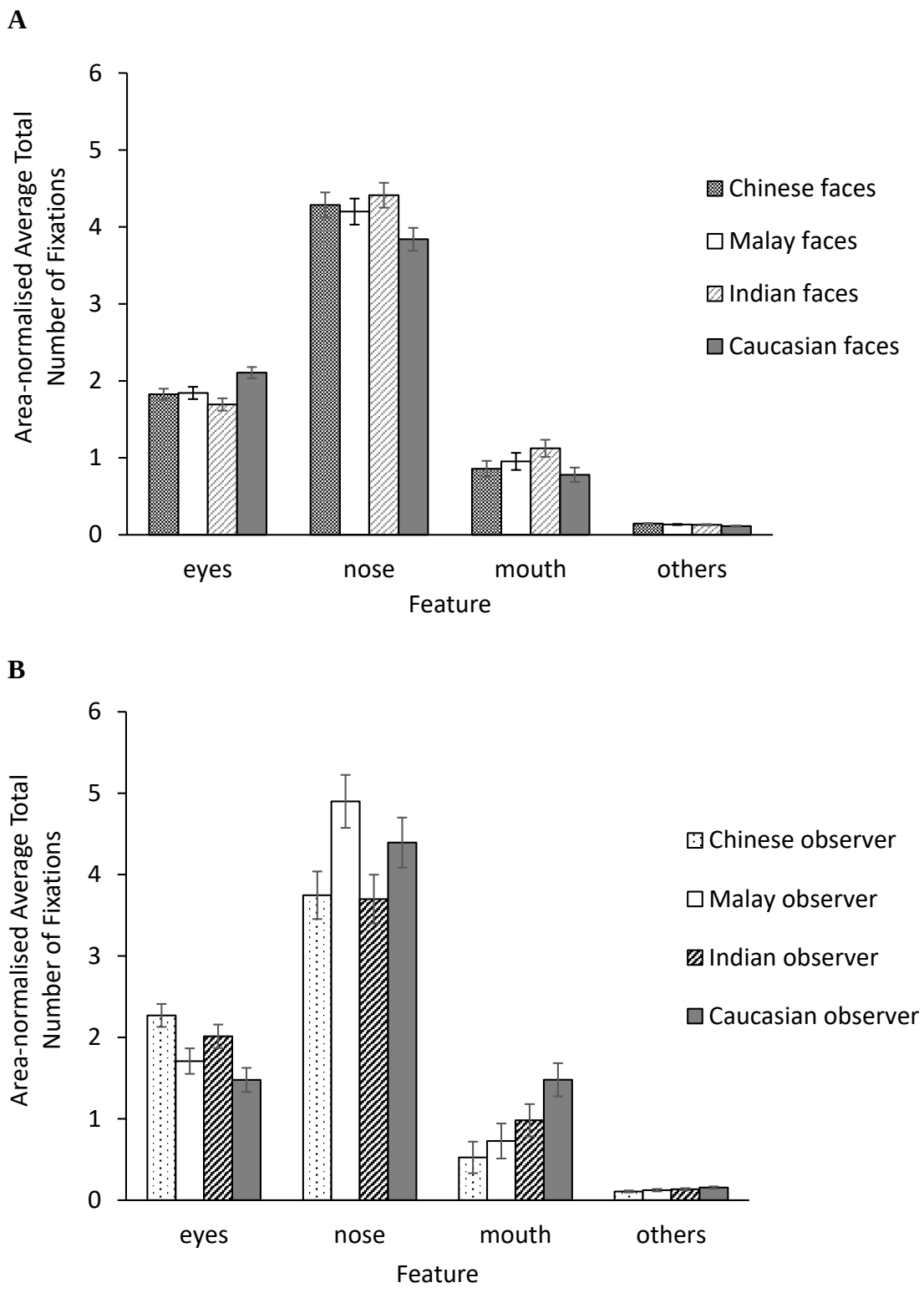


Figure 4.4. Average total number of fixations (area-normalised) on each AOI for the four different (A) face races and (B) races of observers.

4.4.3.2 Average total fixation duration.

The main effects of Face Race, F (2.67, 194.68) = 30.54, p<.001, η_p^2 = .30, and Feature, F (1.74, 127.15) = 212.05, p<.001, η_p^2 = .74, were significant, accompanied by an interaction between Feature and Face Race, F(3.73, 272.13) = 20.48, p<.001, η_p^2 =.22 (see *Figure 4.5*). Participants generally made shorter eye fixations on Indian faces, but longer eye fixations on Caucasian faces as compared to other three races of faces (all p <.001). The average fixation duration on Caucasian nose was significantly shorter than that of Chinese, Malay, and Indian faces (all p≤.001). In contrast, the average fixation duration on Indian nose was longer than that of Chinese, Malay, and Caucasian faces (all p <.01). There was also a significant interaction between Feature and Race of Observer, F (*9*, 219) = 34.28, p< .001, η_p^2 = .14. Simple main effect analysis showed that Chinese, Malay, and Indian participants fixated longest on the nose, followed by the eyes and then mouth region (all p <.05); however, Caucasian participants showed no difference of time spent fixating the eyes and mouth (p=1). A significant interaction between Stimulus Type and Feature, F (1.56, 113.51) = 18.11, p<.001, η_p^2 = .20, was also found. Pairwise comparisons showed that target faces received longer fixations on the eyes and nose (both p < .01) but shorter fixations on the mouth (p<.001) and other regions (p=.01) when compared to average faces.

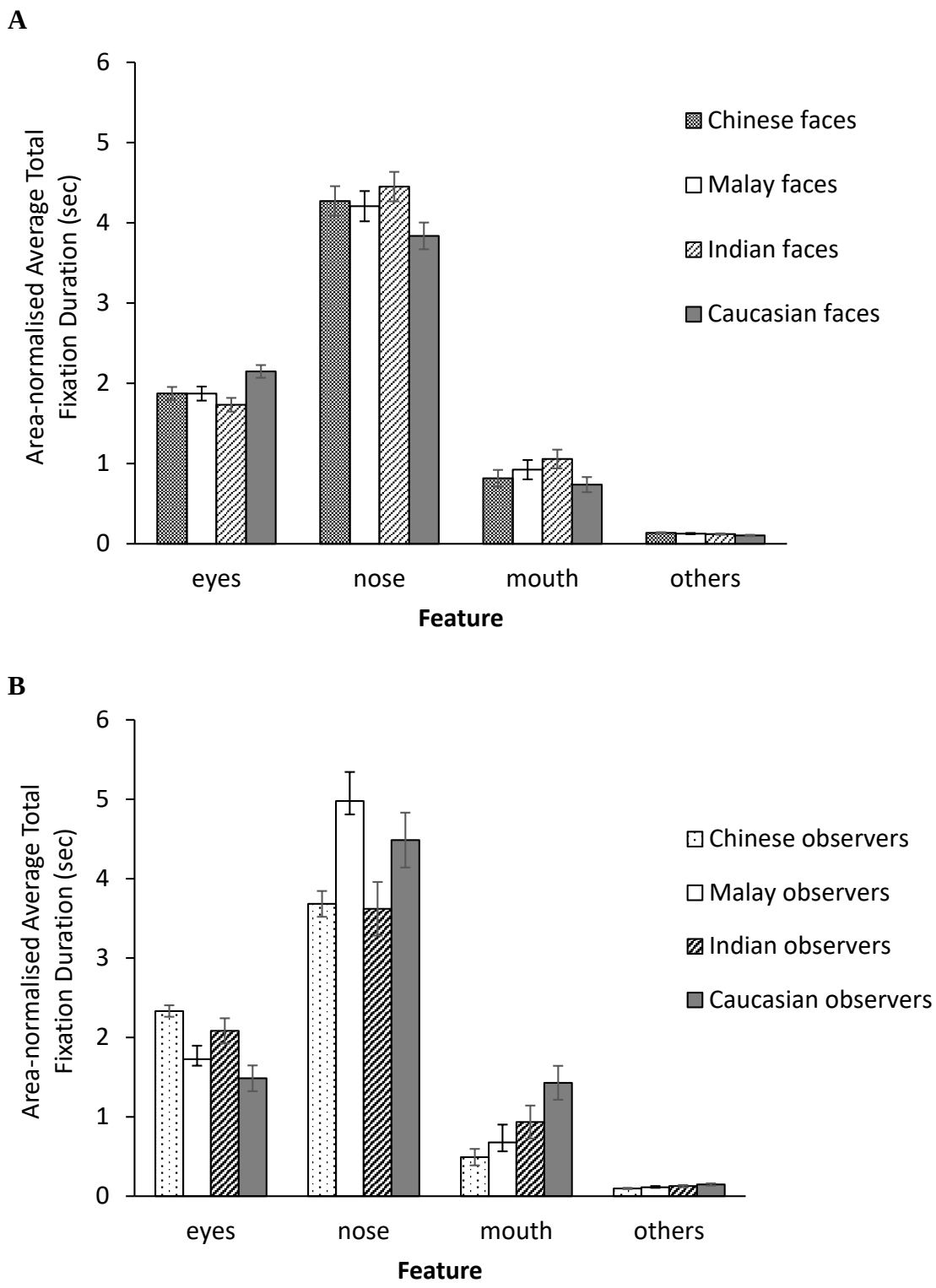


Figure 4.5. Area-normalised average fixation duration on each AOI for the four different (A) face races and (B) races of observers.

4.5 Discussion

The current follow-up study employing a facial similarity rating task yielded three main findings. First, the Indian faces contained in the stimulus set were more distinctive within their own race and therefore happened to be an intrinsically easier set than the other three stimulus races. Second, a cross-over interaction for face race by race of observer was found in similarity ratings, such that own-race faces were judged to be more distinctive than other-race faces. Third, the beneficial effect of distinctiveness for identification performance was absent or smaller for other-race faces as compared to own-race faces. These findings will be discussed in relation to the multidimensional space framework proposed by Valentine (1991).

It is well known that distinctive faces are remembered particularly well (e.g., Chiroro & Valentine, 1995; Valentine & Bruce, 1986), such that more accurate memory for own-race faces in the previous ORB studies may have been partly influenced by differences in distinctiveness in the respective sets of faces. Therefore, distinctiveness is an important factor to consider in ORB research. In Experiment 1, regardless of race group, participants were generally good at recognising Indian faces in a yes-no recognition task. The current rating study confirms that there was a greater variability of facial distinctiveness in the Indian face set as compared to other races of faces. It is likely that certain Indian faces have more informative characteristics for facial identification as indicated by the low similarity rating scores (i.e. high distinctiveness) across participant race groups. Although the Indian community in Malaysia is the smallest of the three main ethnic groups in Malaysia (approximately 7.1% of the population), it is made up of several sub-ethnic groups. Most Indians living in Malaysia are Tamils (approximately 80%) and other sub-ethnic groups include Malayalees, Punjabis, Gujaratis and Sindhis (World Directory of Minorities and Indigenous Peoples, 2015). Although these subgroups are all categorised as ‘Indian’ group,

the facial appearance within the Indian group might vary extensively from one to another. A closer examination of the Indian stimuli set and their demographic information revealed that most of the Indian faces used in my study were collected from Tamils (14 out of 18) and the rest were from the other sub-ethnic groups.

A variety of studies have demonstrated that distinctive or atypical faces have a characteristic advantage in recognition (Chiroro & Valentine, 1995; Newell et al., 1999; Valentine & Bruce, 1986). For example, Valentine and Bruce (1986) found that faces that were considered distinctive were identified more accurately than faces that were considered more typical or average, indicating that distinctiveness may induce a stronger and more readily accessible memory trace of a newly learned face and increase its memorability (Bartle, Hurry, & Thorley, 1984). From a theoretical point of view, distinctive faces are located in a sparser region of the face space; hence it is easier to discriminate faces lying close to a distinctive end-point because they are distinctive themselves.

Moreover, my results demonstrate that own-race faces were perceived as more distinctive than other-race faces. This suggests that participants employed distinctiveness cues when recognising faces, and the sensitivity towards these cues is experience-dependent. Face space model predicts that distinctive information on own-race faces should facilitate recognition relative to other-race faces, owing to greater amount of perceptual learning. The correlational analysis between distinctiveness ratings and recognition performance showed that the level of distinctiveness was positively associated with recognition accuracy, depending on their status as targets or distracters in the old/new recognition experiment. Only distinctive targets seem to have a recognition advantage that results from the encoding and retrieval processes working on the distinctive information of the face; as a result, *distinctive* target faces may gain more familiarity and are less likely to be falsely identified due to prior exposure than *typical* target faces.

It was also found that own-race targets that were rated as very distinctive were recognised better than own-race targets rated as typical. However, other-race face recognition was not facilitated by this distinctiveness effect. The obtained effect of race on perceived distinctiveness provides a possible explanation of the memory advantage for own-race faces compared to other-race faces. Other-race faces which have been less experienced may be processed less efficiently due to a lack of flexibility in face processing (Richler, Gauthier, Wenger, & Palmeri, 2008). Another piece of evidence to support this idea comes from the fact that the dimensions more appropriate to differentiate own-race faces might not be the same ones for the other-race faces (Shepherd & Deregowski, 1981). For example, Africans may focus more on the shape and location of the eyes, eyebrows and ears, whereas Caucasians may focus more on hair texture, and hair and eye colour (Ellis, Shepherd, & Davies, 1979; Lindsay, Jack, & Christian, 1991). Owing to this dimensionality difference between own-race and the other-race faces in the psychological face space, the own-race faces are recognised more accurately than a face from another race.

The current study was not designed to directly investigate racial similarities and differences in face processing. However, the results raise the intriguing possibility that it might be a failure to attend to distinctive featural and/or configural information that leads to deficits in other-race face recognition. During the similarity rating task, observers predominantly fixated the nose regions (i.e. geometric centre of a face), independent of face race, suggesting that the nose may be used as a central reference point for efficient face processing (Kelly, Liu, et al., 2011; Miellet, Vizioli, He, Zhou, & Caldara, 2013). Moreover, I also detected statistically significant, though subtle, differences in fixation pattern between race groups. Chinese, Malay, and Indian participants made most and longest fixations on the nose, followed by the eyes and then mouth region. However, Caucasian participants showed no difference of time spent fixating the eyes and mouth. This reflects different attentional

weight placed on each facial region in different cultures (Blais et al., 2008; Kelly, Liu, et al., 2011) and the use of different attributes to make facial similarity judgement. In future studies it would be interesting to examine whether, and if so to what extent, the inability to process distinctive information on other-race faces during learning hampers memory encoding.

In summary, this study examined how distinctiveness influences memory for own- and other-race faces, with particular aim of determining whether the recognition advantage observed for Indian faces in Experiment 1 could be merely due to distinctiveness effect. As a result, the Indian faces contained in the stimulus set were more distinctive compared to other race face sets. In addition, my results showed that memory for *target faces* improved with distinctiveness; this effect was stronger for own-race faces than other-race faces. This finding offers an explanation of distinctiveness effect in cross-race memory biases: the clustering of distinctive own-race faces in face space explains the high recognition accuracy observed for learned distinctive own-race faces, but not for other-race faces. My eye-tracking results demonstrate the subtle differences in the way different race groups process information, implying that the memory advantage for own-race faces may represent a perceptual processing difference between own- and other-race faces. Taken together, these results provide insight into the contribution of distinctiveness effects on face memory. Future investigation is required to clarify what process underlies the distinctiveness effect (featural and relational components) and how distinctiveness contributes to the representational differences between own- and other-race faces.

Chapter 5

The Significance of External Features for Unfamiliar Face Recognition

5.1 Introduction

As faces contain a wealth of information, previous research has investigated which information may be particularly important for the processing of face identity. Facial features can be categorised into two broad groups: the internal features (e.g. the eyes, eyebrows, nose and mouth) and the external features (e.g. the hair, ears, head, and face outline). Physiologically, fMRI studies have demonstrated that response from the fusiform face area (FFA) is sensitive to manipulations of both external and internal face features (Andrews, Davies-Thompson, Kingstone, & Young, 2010; Axelrod & Yovel, 2010). Behaviourally, it has been shown that these two groups of features might carry different weights in the recognition of target faces, depending upon whether the face to be recognised is familiar or unfamiliar (Clutterbuck & Johnston, 2002; O'Donnell & Bruce, 2001). For example, O'Donnell and Bruce (2001) found that in faces in which the eyes had been altered, this change was detected more accurately for familiarised faces than for the unfamiliar faces, suggesting that as a face becomes more familiar, the eyes play a greater part in the recognition process.

To further examine whether the internal feature advantage gradually increases as a face becomes more familiar, Clutterbuck & Johnston (2002) used three types of faces: highly familiar, moderately familiar and unfamiliar. Participants were presented with a whole face and either the internal or external features of the same person or a different person. They were then asked to judge whether the two people were the same or different. Results showed no familiarity effect for the whole face-external feature pairs; however, for the whole face-

internal feature pairs, highly familiar faces were matched faster than both moderately familiar and unfamiliar faces. This result suggests that, the internal feature advantage may develop over time as a face becomes more familiar.

On the other hand, for unfamiliar faces, empirical evidence on the relative contributions of external and internal face information on recognition performance is relatively inconclusive. Davies, Ellis, & Shepherd (1977) reported that unfamiliar face recognition was most accurate when forehead and hairline information was utilised. A few subsequent studies have also observed an external feature advantage for unfamiliar face discrimination (Bruce et al., 1999; Haig, 1986; Nachson & Shechory, 2002; Veres-Injac & Persike, 2009). Furthermore, learning to recognise an unfamiliar face was found to be associated with an increased looking time on the external features (Henderson et al., 2005). Meanwhile, a number of reports failed to find an external feature advantage for unfamiliar face perception (Clutterbuck & Johnston, 2002; Ellis et al., 1979; Longmore et al., 2015; Toseeb et al., 2012; Young et al., 1985). For instance, Young and colleagues (1985) found no difference in the speed at which observers matched familiar and unfamiliar faces based on their external features. Similarly, Ellis et al. (1979) reported that unfamiliar face recognition accuracy was equivalent when observers were presented with either external or internal feature information. The wide range of experimental methods used with different levels of task demands on memory may partially account for these conflicting results.

Previous studies found that the recognition and matching of unfamiliar faces relies heavily on external features (Ellis, Shepherd, & Davies, 1979; O'Donnell & Bruce, 2001; Young, Hay, McWeeny, Flude, & Ellis, 1985) whereas familiar faces can be easily recognised and discriminated one from another based on internal features, such as the eyes, nose and mouth (Ellis, Shepherd, & Davies, 1979; Henderson, Williams, & Falk, 2005; Sporer & Horry, 2011; but see Toseeb, Keeble, & Bryant, 2012, 2014). Some authors have

argued that perceptual expertise is required to successfully encode internal face features (Megreya & Bindemann, 2009; Megreya et al., 2012; Wang et al., 2015), with developmental studies finding that adult-like processing of internal features is not achieved until between 10 and 15 years of age (Campbell et al., 1999; Want, Pascalis, Coleman, & Blades, 2003; but see Bonner, Burton, Bonner, & Burton, 2004).

ORB studies have focused on the recognition of internal features and used standard face stimuli without hair (Chien, Wang, Chen, Chen, & Chen, 2014; Chien et al., 2016; Horry, Cheong, & Brewer, 2015; McKone et al., 2007), perhaps because the internal features (i.e. eyes, nose and mouth) have been shown to be the most significant features for face recognition, whereas external features (e.g., hairstyle and facial hair) are features that can be easily changed, and therefore are potentially unreliable cues to identity. People who are accurate at matching unfamiliar faces may be able to direct their attention towards the more reliable cues contained in the internal features of the eyes, nose, and mouth and away from the potentially misleading cues contained in the external features of the hairstyle and facial hair. The ability to direct attention towards internal features in preference to external may explain some of the individual differences in unfamiliar face-matching ability.

As a result, relatively little is known about to what extent the presence/absence of external features affect the magnitude of ORB. This is an important consideration because the exclusion of external features may produce findings that are inconsistent with other studies using face images with external features, rendering interpretation of any differences found difficult. In a recent study, Sporer & Horry (2011) tested German and Turkish participants' recognition performance for faces from four ethnic groups: African-American, White-American, White-German, Turkish, with the presence or absence of external features being manipulated. In the classic yes-no recognition task, both groups of participants were least accurate at recognizing African-American faces, the race group to which they would have

had least exposure. The authors also reported that removing external features at encoding reduced recognition accuracy for other-race faces but not for own-race faces. However, further inspection of their data revealed that none of the significant interaction terms involved participant ethnicity. In fact, the advantage for encoding the whole-face over just the internal features occurred only in African-American and Turkish faces. Hence, it remains unknown how this effect may vary depending on participants' perceptual experience with own-race versus other-race faces.

5.2 Experiment 3: The Presence of External Features Eliminates the ORB

In Experiment 1, participants showed an ORB when only information about the internal features was available. The exclusion of external features from the cropped facial stimuli could have somehow increased the difficulty of the recognition task, aggravating the ORB effects. Although there has been extensive research on the contributions of external features to face memory (Ellis et al., 1979; Jarudi & Sinha, 2003; Toseeb et al., 2012), only one study has directly tested its effect on own- and other- race recognition accuracy. Sporer & Horry (2011) tested Turks and Caucasian-Germans with faces from several ethnic groups (African-American, Caucasian-American, Caucasian-German, Turkish) and found that removing external features at encoding was more harmful to outgroup faces than to ingroup faces. This finding highlights the possibility that hair may serve as a racial marker (MacLin & Malpass, 2001) so that when the racial marker is absent it is difficult to determine which race of the face belongs. Once the feature is added, the face is easily perceived as a member of a particular race, facilitating other-race face recognition.

The main objective of the present study was to systematically investigate the relative weighting of internal and external face features for unfamiliar own- and other-race recognition. It is interestingly to see whether and, if so, to what extent the presence of external features reduces the ORB in face memory, including both Malaysian and Caucasian

samples. The procedure was identical to Experiment 1 but with different stimulus type. Rather than egg-shaped faces, face images including the external features were presented. Given that external features are useful for recognising and matching unfamiliar faces (Ellis et al., 1979; O'Donnell & Bruce, 2001; Young et al., 1985; but see Toseeb, Keeble, & Bryant, 2012, 2014), I predicted that adding the external features would improve recognition accuracy. Previous research has shown that participants are less efficient at processing configural relationships between internal facial features of other-race faces than own-race faces (e.g., Wang et al., 2015; Zhao & Bentin, 2011), leading to a reliance on processing of external facial features of other-race faces. If the effect of external features differentially affects participants' face memory for own- versus other-race, then different magnitudes of the ORB between the two experiments (Experiment 1 vs. 3) should be observed. Specifically, I expect that the presence of external features will substantially enhances participants' performance for other-race faces but not for own-race faces.

5.3 Method

5.3.1 Participants

A group of undergraduate students from the University of Nottingham Malaysia Campus participated in this experiment. There were 23 Malaysian Chinese (13 males; M_{age} = 21.52, SD = 3.76), 23 Malaysian Malays (10 males; M_{age} = 19.74, SD=3.76), 25 Malaysian Indians (12 males; M_{age} = 20.92, SD = 5.60), and 20 Caucasians (10 males; M_{age} = 23.05, SD = 4.39). All had normal or corrected-to-normal vision. All participants gave informed consent to participate in the study, which was approved by the ethics committee of the University of Nottingham Malaysia Campus.

5.3.2 Materials

Facial images of the same identity as in Experiment 1 (Chapter 3) was used because it allows direct comparisons between the effects of the external features on long-term memory of face identities. All face stimuli were presented in full colour, and the external features and hair were retained. Other aspects of the stimuli were identical to Experiment 1. Examples of stimuli are shown in *Figure 5.1*.

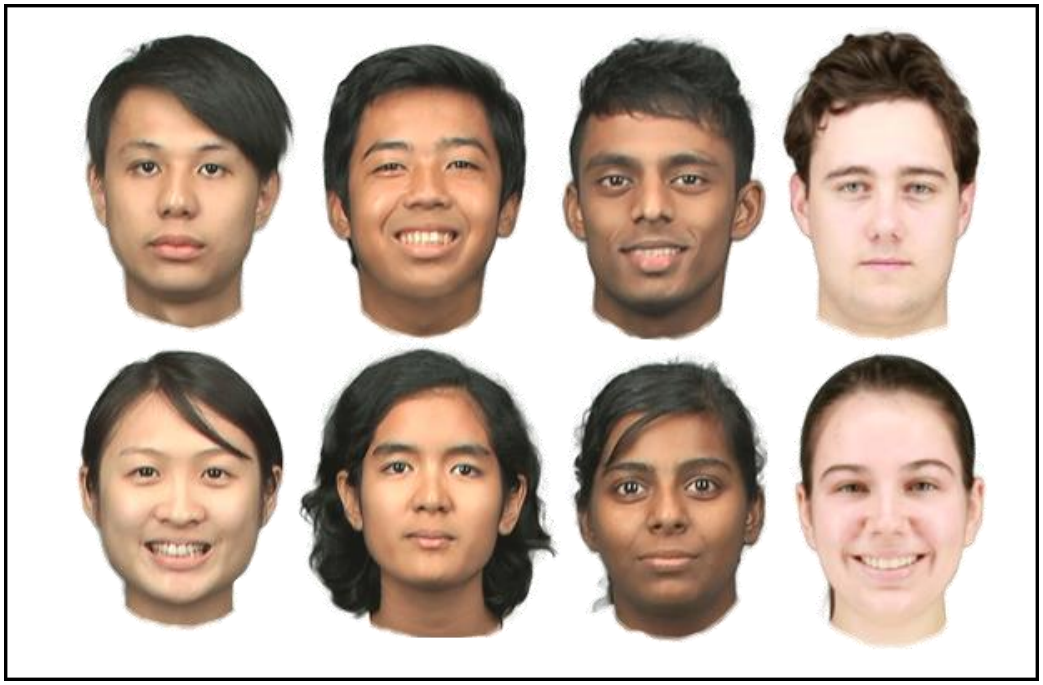


Figure 5.1 Examples of whole-face stimuli with happy and neutral expressions used in Experiment 3: Each column shows a male and a female face for each ethnic group (Malaysian-Chinese, Malaysian-Malay, Malaysian-Indian, and Western-Caucasian, respectively).

5.3.3 Procedure

Experiment 3 followed the same procedure as Experiment 1. In both experiments, participants performed a yes/no recognition task for four face races: Malaysian-Chinese, Malaysian-Malay, Malaysian-Indian, and Western-Caucasian.

5.4 Behavioural Results

5.4.1 Recognition sensitivity.

A 4 (race of face: Malay, Chinese, Indian, or Caucasian) × 4 (race of observer: Malay, Chinese, Indian, or Caucasian) mixed factorial ANOVA revealed that *d'* scores did not differ significantly between races of faces, F (2.55, 222.06) = 0.87, p = 0.46, η_p^2 = .01, Greenhouse-Geisser corrected, as well as between races of observers, F (3, 87) = 1.95, p = .13, η_p^2 = .05. The interaction between race of face and race of observer also did not reach significance, F (9, 261) =1.57, p=0.12, η_p^2 =.06, indicating the absence of ORB among different ethnic groups.

5.4.2 Response bias.

An ANOVA performed showed that neither the main effect of race of observer, F (3, 87) =1.44, p=.24, η_p^2 =.05, nor the interaction between the two factors, F (9, 261) =1.09, p=.37, η_p^2 = .04, reached significance. However, there was a highly significant main effect of face race, F (2.77, 8.32) =16.23, p<.001, η_p^2 =.16, Greenhouse-Geisser corrected. Post hoc tests with Bonferroni correction showed that response bias was significantly more liberal for Caucasian faces (M=0) than Malay (M=0.40) (p<.001) and Indian faces (M=0.22) (p=.001), and there was a marginal difference between Caucasian and Chinese faces (M=0.16) (p=0.09). Further, when deciding whether they had seen a face before, participants maintained a stricter response criterion for Malay faces than Chinese (p<.001) and Indian faces (p=.01).

5.4.3 Does performance improve in the face-with-external-features condition?

In Experiment 3, participants performed equally well at recognising own- and other-race faces (see *Figure 5.2*), suggesting that their recognition performance was influenced by the inclusion of external features. Next, I conducted additional analyses to explore whether the magnitude of ORB (i.e., the recognition performance for own- and other-race faces)

significantly differed between the egg-shaped (Experiment 1) and full-face (Experiment 3) conditions. A 2 (face type: egg-shaped vs. whole) × 4 (race of observer: Chinese, Malay, Indian, and Caucasian) × 4 (face race: Chinese, Malay, Indian, and Caucasian) mixed factorial ANOVA was used to identify any significant main effects and interactions related to face type – where race of observer and face type were between-subject factors, and face race was within-subjects factor. A highly significant main effect of face type, F (1,177) =56.88, p<.001, η_p^2 =.26, was accompanied by a marginally significant interaction between face type and race of observer, F (3, 177) =2.23, p=.08, η_p^2 =.04. Simple main effect analyses revealed that most ethnic groups (Chinese, Indian, and Caucasian) performed significantly better in the whole-face than egg-shaped condition (all p<.001), and there was a marginal difference for Malay participants (p=.07).

A significant three-way interaction involving face type, face race, and race of observer, F (9, 531) =3.21, p=.001, η_p^2 = .05, with Bonferroni-corrected multiple comparisons revealing a difference in recognition sensitivity between whole- and egg-shaped conditions in each ethnic group. Upon close examination, there was a general trend for the presence of external features to affect own-race face recognition to a smaller extent as compared to other-race faces in all ethnic groups (see *Figure 5.2* for means and standard errors). In Chinese participants, the presence of external features substantially improved their recognition of Malay and Caucasian faces (both p<.001) but not for Chinese (p=.38) and Indian faces (p=.45). Malay participants performed better in whole-face trials compared to egg-shaped trials only for Caucasian faces (p=.03) but not Chinese (p=.13), Malay (p=.45), and Indian faces (p=.52). Indian participants recognised Chinese (p=.005) and Malay faces (p=.007) significantly better in whole-face condition than in egg-shaped condition whereas no difference was found for Indian and Caucasian faces (both p>.05). Caucasian participants showed higher accuracy in the whole-face condition for Chinese and Malay faces (both

$p<.001$), and a marginally significant improvement for Indian faces ($p=.07$), but no difference for Caucasian faces ($p=.27$).

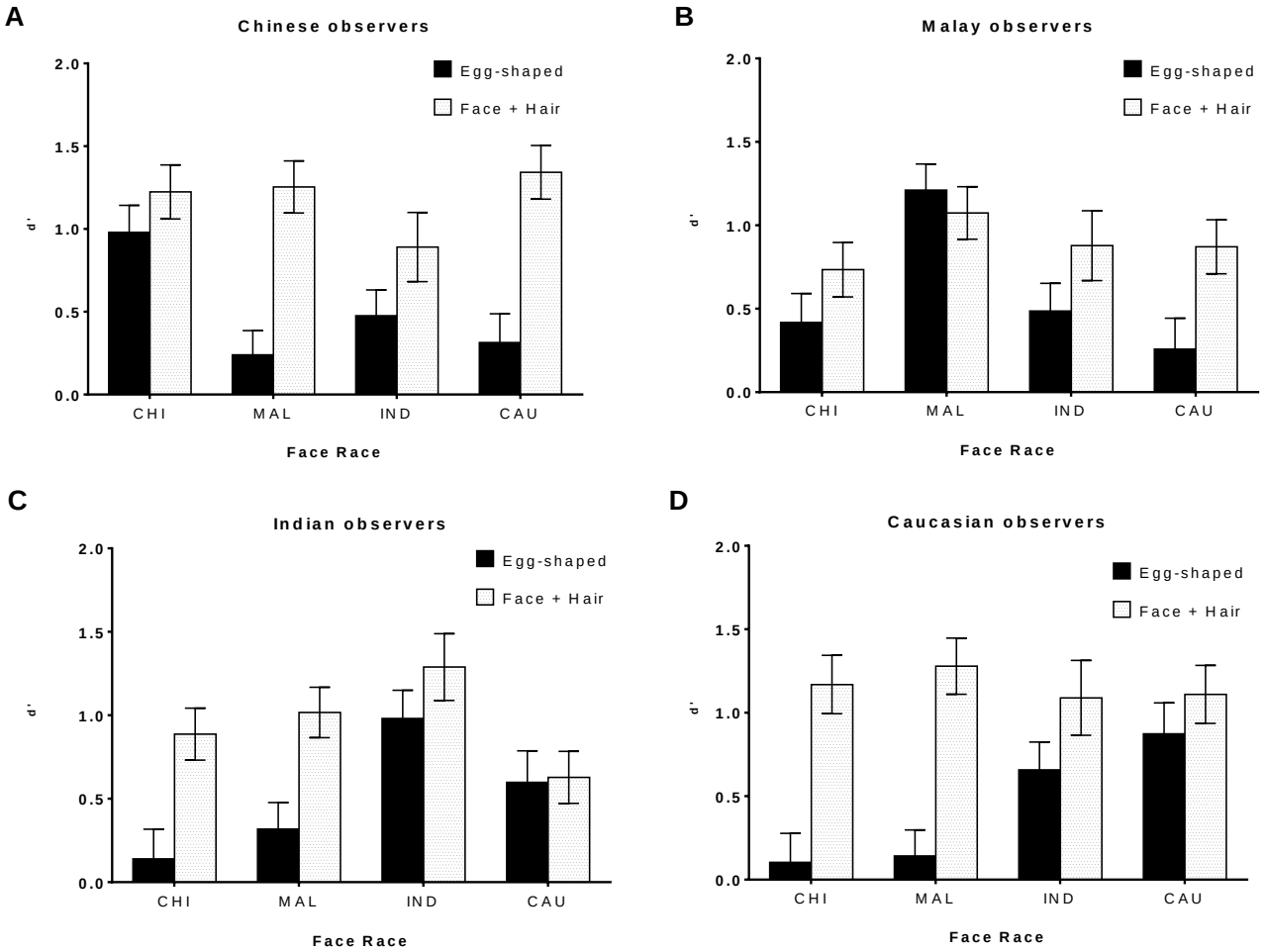


Figure 5.2. d' for Chinese, Malay, Indian, and Caucasian faces in Chinese (A), Malay (B), Indian (C), and Caucasian (D) participants in the recognition task. Error bars represent standard error.

5.5 Eye-tracking results

Data from trials where no fixation was made on the AOIs were excluded from the eye-movement analysis. Two main measures (average total fixation duration and average total fixation count) were checked for outliers (values greater than 2 SD from the group mean) resulting one Indian participant being removed from further analysis, leaving 23 Chinese, 23 Malays, 24 Indians and 20 Caucasians. The same analyses were also performed on the non-area-normalized data, which produced a similar pattern of results (see APPENDIX E).

5.5.1 Average Total Fixation Duration.

A 4 (Race of Observer: Malay, Chinese, Indian, Caucasian) × 4 (Race of Face: Malay, Chinese, Indian, Caucasian) × 4 (AOI: eyes, nose, mouth, and other facial areas) mixed factorial ANOVA was conducted on the average total fixation duration. There was a significant main effect of Feature, F (2.09, 179.81) =413.99, p<.001, η_p^2 =.83, such that participants' average total fixation duration was highest on the nose, followed by the eyes, mouth, other, hair and ears regions (all p<.001). A significant two-way interaction between Feature and Race of Participant was found (see *Figure 5.3*), F(15, 430) = 1.58, p=.05, η_p^2 =.05. Simple main effect analyses revealed that Indian and Caucasian participants fixated longer on the mouth was higher than Chinese participants did (both p=.04). A significant two-way interaction between Face Race and Feature was also found, F(5.38, 463.04)=15.21, p<.001, η_p^2 =.15, showing that participants fixated longer on the Caucasian eyes and hair than those on Chinese, Malay and Indian faces (all $p\leq$.001); however, they made fewer fixations on Caucasian noses and mouths than the other three face races (all $p\leq$.003).

There was also a significant three-way interaction between Phase, Face Race and Feature (see *Figure 5.4*), F (10.03, 862.49) = 3.44, p<.001, η_p^2 =.04. Split analyses by Feature showed that the Phase by Face Race interaction was significant for Chinese faces, F (1.99,

176.68) = 4.85, p=0.009, η_p^2 =.05., Malay faces, F (2.29, 203.92) = 3.25, p=.007, η_p^2 =.04, and Caucasian faces, F (2.60, 231.44) = 10.61, p<.001, η_p^2 =.11, but not for Indian faces, F (1.76, 159.74) = 2.12, p=.13. Simple main effect analysis showed that, when compared to the recognition phase, participants showed higher average total fixation duration on the Chinese eyes but lower average total fixation duration on the Chinese mouth in the learning phase (p=.008 and p=.01, respectively). Malay faces received higher average total fixation duration on the eyes (p=.006) but shorter average total fixation duration on the mouth (p=.02) and other regions (p=.008) in the learning phase than in the recognition phase. Caucasian faces, on the other hand, received greater average total fixation duration on the eyes (p=.004), ears (p<.001), and hair (p=.003), but shorter fixations on the mouth (p<.001) in the learning phase.

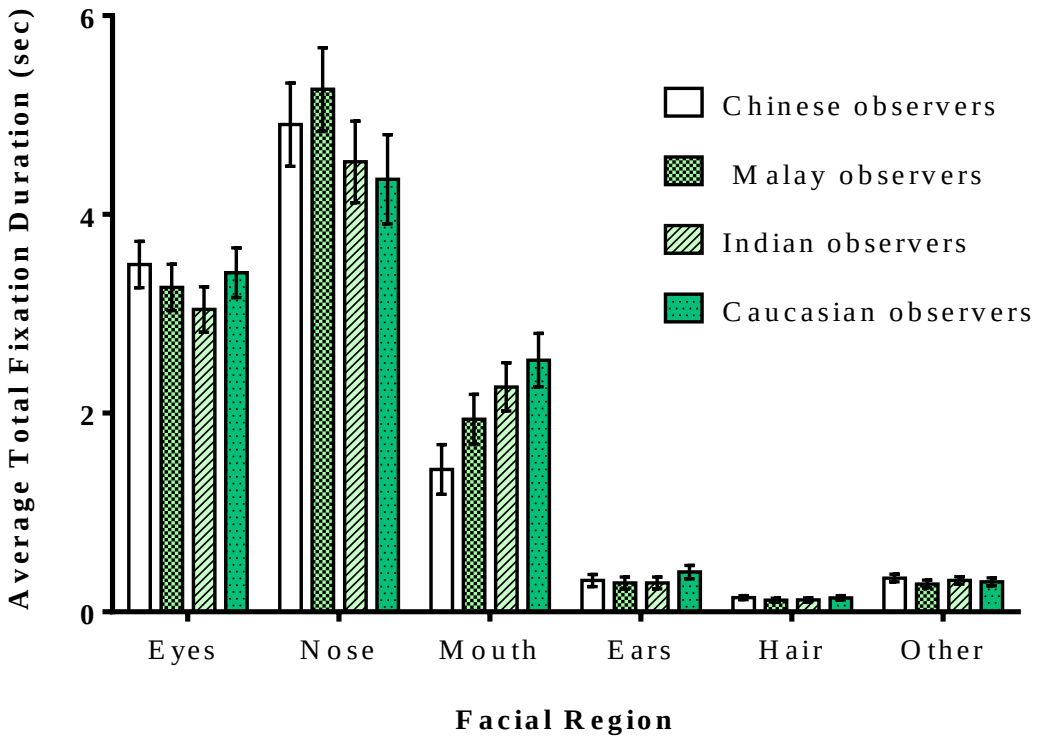
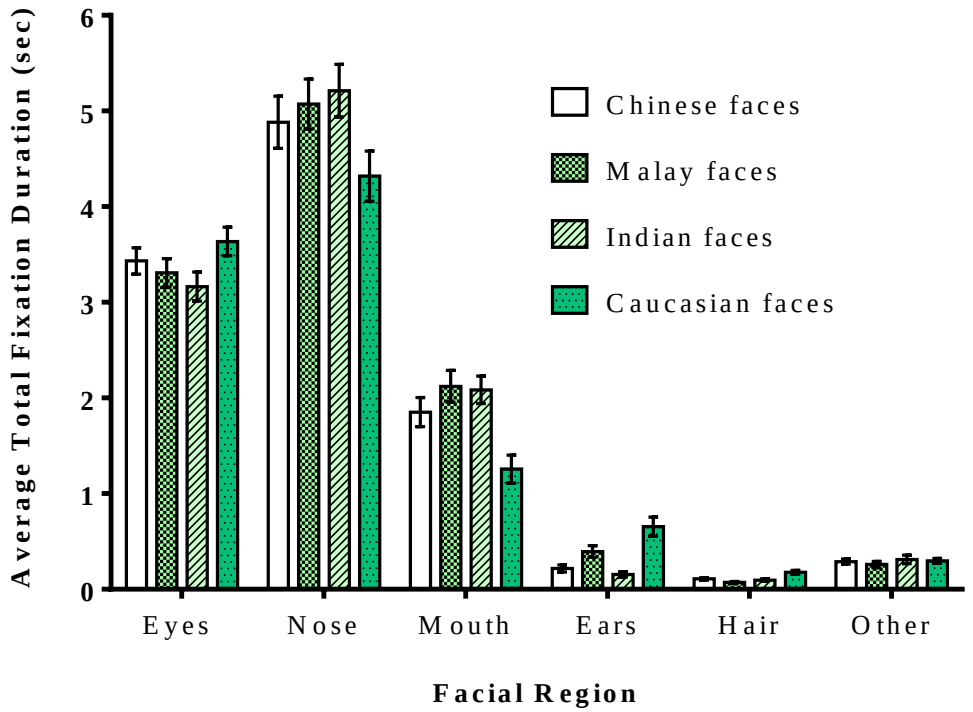


Figure 5.3. Average total fixation duration (area-normalised) on the predefined AOIs across different face races in Chinese, Malay, Indian and Caucasian observers. Error bars represent standard error of mean.



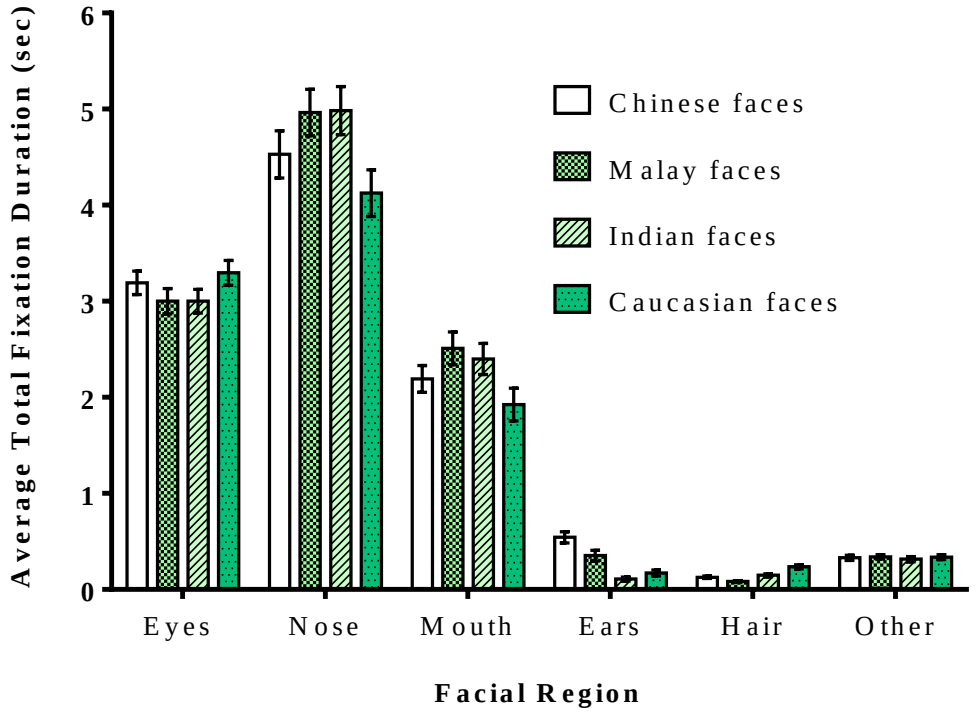


Figure 5.4. Average total fixation duration (area-normalised) on the predefined AOIs for the four *races of faces*. Error bars represent standard error of mean.

5.5.2 Average Total Fixation Count.

A similar four-way ANOVA conducted on the average total fixation count revealed a significant main effect of Feature, F (2.09, 179.81) =413.99, p<.001, η_p^2 =.83. Pairwise comparisons revealed that participants fixated most frequently on the nose, followed by the eyes, mouth, other, hair and ears regions (all p<.001). There was a significant two-way interaction between Feature and Race of Participant (see *Figure 5.5*), F (15, 430) = 2.01, p=.01, η_p^2 =.07. Simple main effect analyses showed that Indian and Caucasian participants fixated more frequently on the mouth than Chinese participants did (p=.04 and p=.01, respectively). A significant two-way interaction between Face Race and Feature was found, F (5.72, 491.83) = 3.15, p=.006, η_p^2 =.04, revealing that participants fixated more on the Caucasian eyes and hair than those on Chinese, Malay and Indian faces (all p<.001); however, they made fewer fixations on Caucasian noses and mouths than the other three face races (all $p\leq$.02). While Chinese eyes were fixated more frequently than Indian eyes (p=.001), Indian noses and mouths were fixated more frequently than those on Chinese faces (p=.02 and p<.001, respectively). There was also a significant three-way interaction between Phase, Face Race and Feature (see *Figure 5.6*), F (10.03, 862.49) = 3.44, p<.001, η_p^2 =.04. Split analyses by Face Race showed that the Phase by Feature interaction was significant for Chinese faces, F (1.99, 177.49) = 3.23, p=0.04, η_p^2 =.04., Malay faces, F (2.16, 192.37) = 2.29, p=.04, η_p^2 =.03, and Caucasian faces, F (2.46, 218.97) = 10.93, p<.001, η_p^2 =.11, but not for Indian faces, F (1.93, 171.82) = 1.17, p=.32. When compared to the recognition phase, Chinese faces received fewer fixations to the mouth (p=.001) and other (p<.001) regions in the learning phase. Malay faces received fewer fixations on the mouth (p=.04) and other regions (p=.001) but more on the eyes (p=.005) during learning phase. Caucasian faces, on the other hand, received more fixations on the eyes (p=.005), ears (p<.001), and hair (p<.001), but fewer fixations on the mouth (p<.001) in the learning phase. However, the

average total number of fixations made to Indian features did not differ significantly between the learning and recognition phase.

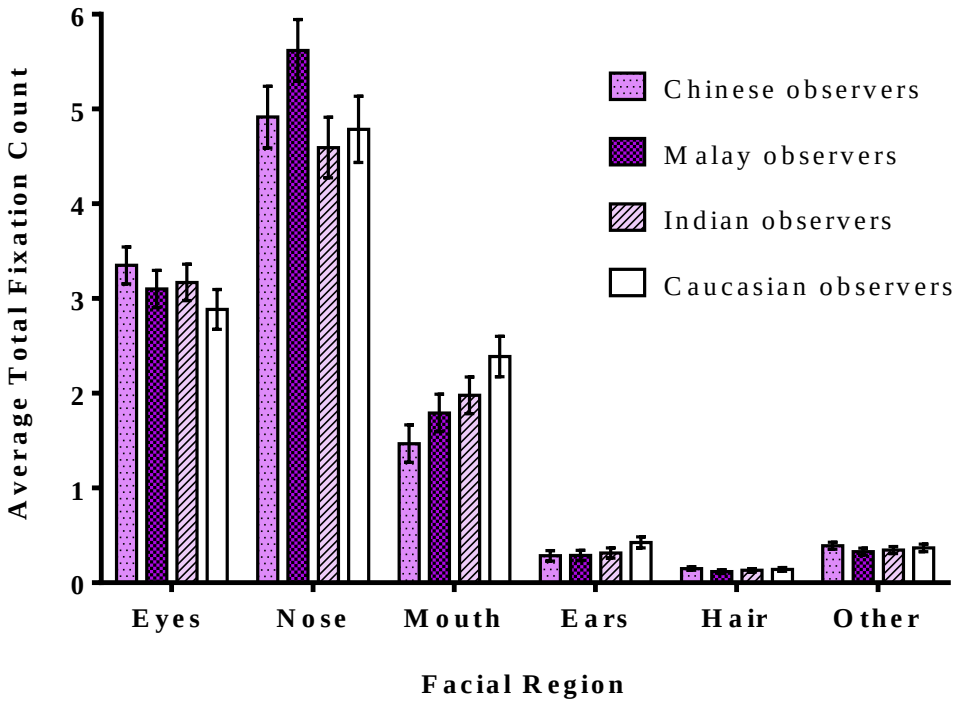


Figure 5.5. Average total fixation count (area-normalised) on the six predefined AOIs in different *races of observers*: Chinese, Malay, Indian and Caucasian. Error bars represent standard error of mean.

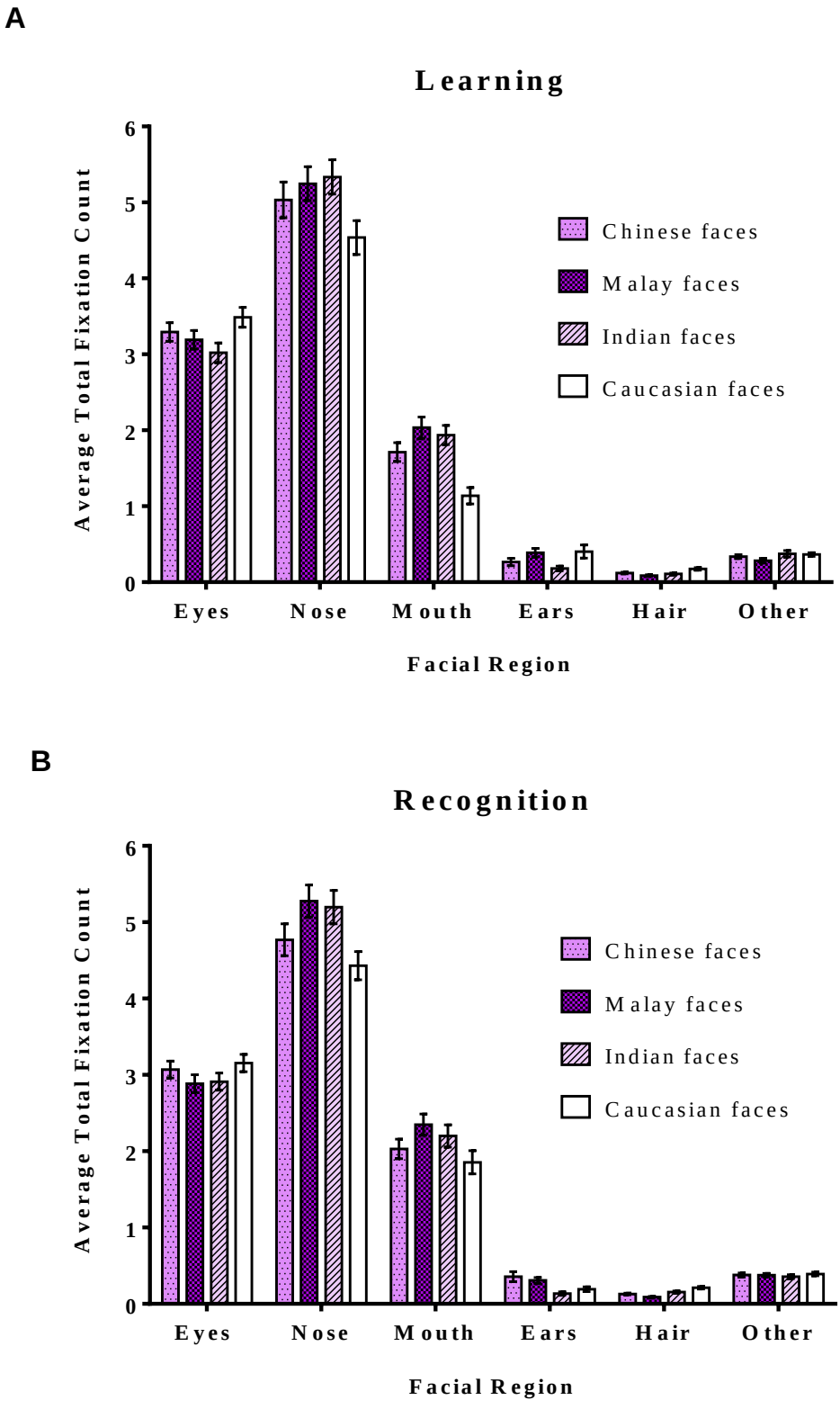


Figure 5.6. Average total number of fixations (area-normalised) on the six predefined AOIs for different *face races* in the (A) learning and (B) recognition tasks. Error bars represent standard error of mean.

5.6 Discussion

Although there has been extensive research on the contributions of external features to face memory, only a handful of studies have directly tested its effect on own- and other- race recognition accuracy. This experiment further investigated the effect of external features on the magnitude of ORB by employing whole-face stimuli with external features. It was predicted that adding the external features would improve recognition accuracy, as external features are useful for recognising unfamiliar faces (Axelrod & Yovel, 2010; Sporer & Horry, 2011). As expected, the results showed that the ORB disappeared when participants were presented with whole faces with external features but not when shown only internal features, suggesting that the external features contain important input information. Given the significant role of internal features in the representation of familiar faces compared to unfamiliar faces (Ellis, Shepherd, & Davies, 1979; Megreya & Bindemann, 2009), I also hypothesized that such internal feature advantage could extend to faces of familiar race versus unfamiliar race. This hypothesis received strong support in a highly significant three-way interaction involving face type, face race, and race of observer. As a result, the presence of external features has a negligible effect for own-race face recognition, but its advantage emerges for other-race faces. Comparisons between Experiment 1 (Chapter 3) and Experiment 3 revealed a general trend towards higher accuracy for other-race faces whereas for own-race faces it was almost unaffected in the whole-face condition as compared to the egg-shaped condition. This indicates a more efficient processing of internal features with own-race faces, so that the addition of external features did not drastically improve own-race face recognition.

Several face recognition studies employing face images with external features have reported evidence of the ORB (Tan et al., 2012; Tanaka & Pierce, 2009; Wright et al., 2003), but the current study failed to uncover this effect. An explanation for the discrepant findings

is that different photos (with changes in expression) of the same individuals were used at study and test phases, whereas the previous studies used the identical photos during both phases (Tan et al., 2012; Tanaka & Pierce, 2009; Wright & Sladden, 2003). For example, Tan et al. (2012) and Wright et al. (2003) used identical pictures in the study and test phases whereas Tanaka & Pierce (2009) placed internal features in a standard face template with identical hairstyle and facial contour. The current recognition task differed from these studies, in a way that the same individual with different facial expressions (neutral or smiling) was presented between study and test phases in order to promote recognition strategies (e.g. structural coding) based on internal facial features. It is reasoned that such change may have increased the task difficulty to encode holistic/configural information from internal features, especially on other-race faces (Crookes, Favelle, & Hayward, 2013; Tanaka et al., 2004). Given that my whole-face sets include external features with a considerable degree of within-race variability, this may have increased participants' tendency to adopt non-face strategies based on external cues and consequently masked the ORB in face memory. This hypothesis would need further investigation. An alternative explanation for the external feature advantage for other-race faces is that the external facial features are less affected by facial dynamics (e.g. facial expressions or motion). Thus, external features may be more reliable recognition cues when observers have to discriminate between other-race faces with which they have less experience.

The current results bring an interesting perspective to our understanding of the mechanisms by which own- and other-race faces are processed; own-race face recognition is less affected by the absence/presence of external features possibly due to the precision and flexibility of facial representations. Previous research has shown that participants are less accurate at processing internal features (Hayward, Favelle, Oxner, Chu, & Lam, 2017; Rhodes, Ewing, et al., 2009) and configural relationships between internal features (Michel,

Caldara, & Rossion, 2006; Tanaka et al., 2004) of other-race faces than own-race faces. This could have led to a reliance on processing external features of other-race faces, thus reducing accuracy when external features were removed. It appears that other-race face recognition requires considerably more external cues (e.g. hair, facial contour) in order to fully activate the facial representations, and may even practically need the whole face stimulus to appropriately perform the task (Herrera, Mcquiston, Maclin, & Malpass, 2000; MacLin & Malpass, 2001; Valentine, 1991).

Recognition studies on unfamiliar faces have revealed that accurate identification can be partly hindered by perceivers' tendency to encode external features from a face at the expense of its internal morphology (Frowd, Bruce, McIntyre, & Hancock, 2007; Frowd et al., 2012; Toseeb et al., 2012). When encoding unfamiliar faces, people are easily distracted by external cues which are poor and unreliable markers of one's identity. The effect of the hair – a rather unstable cue – was investigated by Toseeb et al. (2012) by using face stimuli with and without hair in a classic old-new recognition task. Although the authors observed no significant performance difference when the participants were shown faces with and without hair, an inconsistency between study and test phase (i.e. the presence or absence of hair) disrupted face recognition, suggesting that faces are represented in a holistic manner.

Overall, my data lend further support to the idea that external features, which comprise featural characteristics of information, play a more important role in other-race face recognition. While most face recognition studies have ignored the additional effects of external features, there is mounting evidence from behavioural and neuroimaging studies indicating that external features are encoded alongside internal features within a holistic face representation (Andrews et al., 2010; Axelrod & Yovel, 2010; Toseeb, Bryant, & Keeble, 2014). Even though accurate face recognition can be achieved when only the internal features are presented (Anaki, Boyd, & Moscovitch, 2007), altering external features can often disrupt

face recognition (Fletcher, Butavicius, & Lee, 2008; Toseeb et al., 2014, 2012). An important goal for further research would be to investigate the extent to which altered external and/or internal features differentially affect facial representation (e.g. holistic representation) of own- and other-race faces and how this occurs.

The current study bears on the issue of whether the contribution of external features changes as a function of perceived face race. The ORB seemed to disappear when faces were presented with external features, such that the absence of external features was disruptive to recognition of other-race faces but not own-race faces. This lends support to the notion that external features are more useful for face recognition than internal features in other-race face recognition (Sporer & Horry, 2011). This interesting finding is compatible with the perceptual expertise account of the ORB (see Chapter 2). According to this account, own-race faces are distinguished and recognised based on precise individuating information, whereas other-race faces are processed shallowly based on categorical information. In the same vein, Levin (2000) advocates an explanation for the ORB in which own-race face processing involves the most diagnostic individuating information, whereas other-race face processing relies more on categorical information (e.g. race-specific features - hair). Sporer (2001) proposed an in-group/out-group model, suggesting that perception of own- race faces automatically initiates a finer level of perceptual encoding processing that emphasizes the internal features of a face that help distinguish the target from similar faces in memory. In contrast, other-race face perception promotes a categorisation process that accentuates race-specific features at the expense of individuating information. Based on these models, the observed recognition performance differences between own-race and other-race faces may be attributed to the efficacy of feature encoding, with internal features of own-race faces being processed more efficiently while external features dominate representations of other-race faces.

The relative importance of external versus internal features has significant methodological implications for research in face recognition. The limited ecological validity of the laboratory use of stimuli displaying only internal features has been addressed and criticised frequently because the generalizability of the obtained results is questionable (Andrews et al., 2010; Axelrod & Yovel, 2010; Bernard & Chung, 2017; Blake, Michael, Frowd, & Mahoney, 2017; Chan & Ryan, 2012; Frowd et al., 2007; Jarudi & Sinha, 2003; Young et al., 1985). Although results reported with face images free from any cropping (e.g., with hair and facial contour) are arguably more representative of performance in real-world viewing conditions, my study suggests that using this type of stimulus may encourage reliance on local feature strategies for other-race faces (Megreya & Bindemann, 2009; Sporer & Horry, 2011), thereby masking the genuine ORB in face memory. In contrast, cropped face images without external features may accentuate the ability to process configural information from faces. Since the removal of external features is more detrimental with other-race faces, a face memory task that utilized internal features only faces could be more sensitive in picking up a potentially subtle ORB. Hence, very different conclusions could have been drawn from studies due to the selection of stimulus type, highlighting that subtle methodological differences may modulate the detection of ORB. Future replications of the ORB should take the stimulus type into account when comparing the results between studies.

Chapter 6

Holistic Processing of Own- versus Other-Race Faces

6.1 Introduction

Faces are thought to be processed in a more holistic or integrated manner than other objects. Evidence from neuropsychological (e.g., Ramon, Busigny, & Rossion, 2010), experimental (e.g., Hole, 1994; Tanaka & Farah, 1993), neurophysiological (e.g., Eimer, 2000), neuroimaging (e.g., Schiltz & Rossion, 2006) and developmental (e.g., Pellicano & Rhodes, 2003) studies suggests that holistic processing is a hallmark of adults' expert face recognition (Maurer et al., 2002; Rossion, 2013) and contributes to our remarkable capacity to discriminate and recognise faces (DeGutis, Wilmer, Mercado, & Cohan, 2013; Richler, Cheung, & Gauthier, 2012; Wang, Li, Fang, Tian, & Liu, 2012). While the exact definition of "holistic processing" of a face remains somewhat unclear, it is widely agreed to involve (a) some sort of integrative processing that combines facial components (e.g., eyes, nose, mouth) into a single coherent representation (Rossion, 2013), or (b) processing of the relationships between features (e.g., distance between the eyes or between the nose and the mouth), instead of the individual features themselves (for review see Maurer, Le Grand, & Mondloch, 2002). Some researchers believe that a single holistic representation includes both spacing information and second-order information about exact shape of local features (e.g., eye shape, nose size) (McKone & Yovel, 2009; Tanaka & Farah, 1993) while some propose that encoding configural information is a separate subcomponent from perceptual integration (Maurer et al., 2002). To date, researchers continue to debate what holistic processing is and is not; for example, whether information about spacing between features (e.g., distance between the eyes) is the same as holistic processing or different (Behrmann & Richler, 2014;

Singer & Sheinberg, 2006; Tanaka & Sengco, 1997), whether holistic processing includes explicit representation of features or not (Chua et al., 2016), and whether it occurs in particular brain areas (as indexed by specific ERPs correlates such as the N170) or in a more distributed fashion (Rossion et al., 2000).

Despite these debates, there is substantial evidence showing that holistic processing matures early (Nakabayashi & Liu, 2014; Schwarzer & Zauner, 2003) and can be affected by early visual deprivation (Le Grand et al., 2004). Developmental studies found that holistic processing, which plays a greater role in the perception of faces (particularly upright faces) than other objects, develops early and emerges between 4 and 6 years of age (de Heering, Houthuys, & Rossion, 2007; Nakabayashi & Liu, 2014). Another piece of evidence for mandatory, face-specific holistic face processing mechanisms derives from the observations that the ability to perceive faces holistically is critically impaired in patients who suffer from prosopagnosia – the inability to recognise people by their faces (Busigny et al., 2014; Ramon, Busigny, Gosselin, & Rossion, 2016; Van Belle, De Graef, Verfaillie, Busigny, & Rossion, 2010; Verfaillie, Huysegems, De Graef, & Van Belle, 2014; but see Nishimura, Rutherford, & Maurer, 2008; Susilo et al., 2010). In this chapter, I adopt the term "holistic processing" to refer to the perceptual integration of facial information, including spatial relations between features, into a unitary representation or "face template" (Maurer et al., 2002; Tanaka & Farah, 1993; Young et al., 1987).

In spite of the unequivocal evidence for a holistic mode of processing for faces, the question whether own- and other-race faces are processed holistically to the same degree has recently received extensive empirical investigation (Crookes et al., 2013; Hayward et al., 2013; C Michel, Rossion, Han, Chung, & Caldara, 2006; Michel, Caldara, & Rossion, 2006; Mondloch et al., 2010; Rhodes, Ewing, et al., 2009; Wang et al., 2015). Researchers have sought to manipulate holistic processing directly, attempting to determine whether observers

are equally affected by these manipulations in own-race and other-race faces. The rationale behind these tests is that, if own-race faces are processed more holistically than other-race faces, then manipulations that facilitate or disrupt holistic processing should produce a greater impact on participants' recognition performance for own-race faces. Three experimental paradigms have been widely employed as standard measures of face-specific holistic processing: the inversion task (Yin, 1969), the whole-part task (Tanaka & Farah, 1993), and the composite face task (Hole, 1994).

6.1.1 Inversion task

Compared to non-face stimuli, faces are poorly recognised when shown inverted rather than upright (Yin, 1969) – this face inversion effect (FIE) is believed to be due to a disruption of holistic face information (e.g. spatial relationships between the facial features; Ellis et al., 1975), while featural information stays relatively intact (Richler et al., 2012; Young, Hellawell, & Hay, 1987). It is well-documented that face recognition is more heavily affected by inversion than recognition of other types of stimuli (Diamond and Carey, 1986), suggesting that face recognition may employ more holistic processing than general object recognition (Le Grand et al., 2004). Inversion studies have provided support for the view that expertise is needed to make use of holistic cues for recognition (Civile, Obhi, & Mclaren, 2018). It has been reported that prosopagnosics, who have difficulty in individuating faces, do not show an inversion effect in the recognition of faces (Busigny & Rossion, 2010; but see Klargaard, Starrfelt, & Gerlach, 2018). The inability to take advantage of holistic processing in the processing of upright faces may explain the lack of an inversion effect in prosopagnosics. It has been suggested that prosopagnosic patients identify faces using a feature-by-feature analysis.

In addition, event-related potentials (ERP) studies of the inversion effect on own-race faces have produced mixed results. The N170 component, which peaks around 170ms after

the onset of a face stimulus, is thought to be associated with the early encoding of the configural facial information because inverting faces leads to a delay in the peak of the N170 (e.g., Rossion et al., 2000). Gajewski, Schlegel, & Stoerig (2008) found that the delay in the N170 was larger for own-race faces than other-race faces in Caucasian participants, but not in Asian participants. Interestingly, there was a positive correlation between the latency of the N170 evoked by both upright and inverted Caucasian faces and the amount of time that the Asian participants had lived in Europe, suggesting that the face inversion effect for other-race faces can be enhanced through extensive visual experience. Wiese, Stahl, & Schweinberger (2009) found similar delays in the peak of the N170 for own- and other-race faces. However, researchers have found that inversion disrupts not only holistic processing, but also featural processing (Michel et al., 2006; Yovel & Kanwisher, 2005). This has raised concern about whether the face-inversion paradigm is an appropriate test of holistic processing (Diamond & Carey, 1986). Several ORB studies have found that face inversion impaired own-race face recognition (high experience) more than other-race face recognition (low experience) (Hancock & Rhodes, 2008; Sangrigoli et al., 2005), suggesting that own-race faces are processed configurally, while other-race faces are processed featurally. Notably, this difference could be reduced via familiarization with other-race faces (McKone et al., 2007), which may explain why interactions between the ORB and inversion effect have not always been observed (e.g., Valentine & Bruce, 1986).

6.1.2 Whole-part task

In laboratory settings, the whole-part task (Tanaka & Farah, 1993) is one of the most widely used approaches to measure the strength of holistic processing. Tanaka and Farah (1993) created an experimental design in which participants initially studied whole faces, and then had to perform a two-alternative discrimination task in one of two conditions: (a) between two isolated face parts (e.g., two noses), where one was from the original face and

one was a distractor, or (b) between two faces where one was the studied face and the other was identical except for a single feature (e.g., a different nose). The view that face recognition is holistic has been strongly backed with well-replicated empirical demonstrations of the 'whole-part effect' (WPE), which refers to an advantage where individuals recognise the features from an individual's face more easily when presented in the context of entire studied face (e.g., John's nose in John's face) than when presented in isolation (Michel, Rossion, et al., 2006; Wang et al., 2012). This effect has been taken as compelling evidence that face parts are integrated into a holistic representation.

Developmentally, children as young as 4-6 years of age demonstrate a whole-part advantage of similar magnitude to that found in adults (de Heering et al., 2007; Nakabayashi & Liu, 2014), a finding that is consistent with the findings using the composite face paradigm (Pellicano & Rhodes, 2003; Pellicano, Rhodes, & Peters, 2006). Furthermore, this pattern was not found for inverted faces or non-face objects, suggesting that holistic processing is selectively linked to the processing of upright faces (Crookes et al., 2013; for a review, see Tanaka, Simonyi, Tanaka, & Simonyi, 2016).

Many ORB researchers have also used the whole-part task to investigate the relative strength of holistic processing for own-race and other-race faces. Tanaka et al. (2004) tested German-Caucasians and Mainland-Chinese living in Canada by using both Caucasian faces and Asian faces. The Caucasian participants exhibited the predicted whole-face advantage for own-race faces but showed no difference between the whole face and isolated part conditions for Asian faces, suggesting no holistic processing of other-race faces. In contrast, the Asian participants showed holistic processing for both races of face; a whole face advantage was observed for Asian and Caucasian stimuli. Based on the differential experience hypothesis, the authors explained the racial differences in holistic processing between Caucasians and Asians by reasoning that the Caucasian participants were from rural areas of Southern

Germany and had very limited exposure to Asian faces in either daily life or the media whereas the Asian participants who were students at a Canadian university, reported having similar amount of social contact with own-race and other-race individuals.

More recent studies using the whole-part paradigm, however, have cast some doubt on this experience-based explanation for holistic processing. Michel et al. (2006) conducted a similar experiment, testing Caucasians and Asians living in Belgium, a Caucasian-dominated country. Note that the Asian participants tested by Michel et al. were foreign students, but the experimenters limited them to those who had been in Belgium for around 12 months. This brief period in Belgium was likely to be enough time for them to meet many Caucasians, but still their lifetime experience with faces was more strongly in favour of Asians, evidence for which came from significantly better performance at recognising own-race compared to other-race faces in a recognition memory test (a pattern of ORB also shown by Caucasian participants).

Despite the typical recognition deficit for other-race faces by Asian participants, the results of the whole-part task were very similar to those of Tanaka et al. (2004); Asians displayed a robust whole-part effect, and therefore holistic processing, for both own-race and other-race faces, whereas Caucasians showed a whole-part effect only for own-race faces. Since the two groups showed similar patterns for the ORB but different patterns for the whole-part effect, there seems little support for the claim that experience determines the magnitude of holistic processing and a lack of holistic processing. Further evidence against the experience-based holistic account was the lack of a correlation between each participant's ORB (the extent to which they were better at recognising own-race over other-race faces) and difference in the extent of holistic processing for own-race and other-race faces. Participants who were particularly poor at recognising other-race relative to own-race faces did not show

any larger difference in the size of the whole-part effect for own-race and other-race faces, compared to participants who recognised the two races of faces equally well.

Indeed, Michel et al.'s (2006) study provides some challenge to the notion that differences in the relative size of the whole-part effect were due to differences in experience with own-race and other-race faces; however, since they tested Asian participants who were living in Belgium it remains possible that these participants had quickly developed expertise with Caucasian faces via daily-life contact with Caucasian people. Results from two recent studies provide more direct evidence that the pattern of Asians showing holistic processing for both own-race and other-race faces is not simply due to experience (Crookes et al., 2013; Mondloch et al., 2010). Mondloch et al. (2010) tested American-Caucasians in rural Pennsylvania and Chinese participants in Guangzhou, China, where each group was part of a largely homogenous population of the participants' ethnic group. Consistent with the previous studies, the Caucasians showed a whole-part effect for own- race faces but not for other-race faces, whereas the Asian participants showed the effect for both races of face.

A similar result has also been reported by Crookes et al. (2013) who tested Caucasians from Wollongong, Australia and Chinese participants from Hong Kong. Despite being moderately multicultural, both cities are still evidently dominated by a large population of participants' own-race people. The obtained results parallel earlier findings, demonstrating a whole-part effect for own-race but not other-race faces in Caucasian participants, whereas a whole-part effect of similar magnitudes for both races of faces in Asian participants. These two latter studies are strong tests of the experience hypothesis, given that all participants had grown up and were tested in environments in which they had relatively little interracial experience (as verified by contact questionnaire). Hence, Asians' holistic processing of Caucasian faces cannot be readily explained by more frequent exposure with Caucasian faces.

To recap, four studies employing the whole-part task with Caucasian participants have discovered a considerable whole-face effect for Caucasian but not Asian faces (Crookes et al., 2013; Michel et al., 2006; Mondloch et al., 2010; Tanaka, Kiefer, & Bukach, 2004), suggesting that holistic processing is effectively applied to own-race but not to other-race faces. In contrast, a whole-part effect has been consistently found with Asian participants for faces of both races. These observations suggest that the difference in magnitude of holistic processing between different races of faces can be determined by the race of observer.

One proposed explanation for the whole-part effect of roughly equivalent size for own-race and other-race faces found in the Asian samples is that Asian participants may have obtained sufficient individuating experience with Caucasians to process Caucasian faces holistically, likely because the Asian participants tested in two of the previous studies resided in predominantly Western countries (Michel et al., 2006; Tanaka et al., 2004). Another possibility is the cultural differences in cognitive processing styles between Easterners and Westerners, such that Asians process general objects more globally than Caucasians (Kelly, Liu, et al., 2011; Yan, Andrews, Jenkins, & Young, 2016). Accumulated evidence from visual attention research shows that East Asians are more sensitive than Western Caucasians to the global context of a stimulus in a series of perceptual tasks (e.g., centre-surround size illusion, Doherty, Tsuji, & Phillips, 2008; rod-frame illusion, Ji et al., 2000; change blindness paradigm, Masuda & Nisbett (2001). Recently, McKone et al. (2010) who employed the typical Navon (1977) task found that Asian participants exhibited a stronger global processing bias towards general objects than did Caucasian participants. These findings not only underline the cultural differences in cognitive styles between Caucasians and Asians, but also imply that holistic processing detected for other-race faces in Asian participants may be attributable to domain-general global processing bias instead of specialised higher-level mechanisms for face recognition, as argued by Michel et al. (2006a, 2006b).

Despite the importance of eye movements in many visual–cognitive tasks, it is not clear that they must play a functional role in face learning, because faces are thought to be processed holistically (for a review see Tanaka & Farah, 2003). Schwarzer, Huber,and Dümmler (2005) conducted two experiments examining children's and adults' gaze behaviour when processing faces analytically (focusing on a single feature) or holistically (comparing the overall similarity of the faces). Their results revealed that when processing faces analytically, participants showed a more feature-specific gaze behaviour, focusing their fixations upon the particular feature used for subsequent processing. On the other hand, participants who adopted holistic processing bias fixated the whole area of the eyes and nose most and longest. Thus, the authors concluded that differences in analytical and holistic face processing can be detected early in gaze behaviour—that is, at the face encoding stage.

However, Crookes et al. (2013) later pointed out that the lack of difference in holistic processing of own- and other-race faces may not result from a general cognitive style (global vs. local processing) because of the absence of holistic processing for inverted faces in the whole-part task. So far, very few studies have directly examined the association between domain-general attentional processes and face-specific holistic processing.

6.1.3 Composite-face task

More recently, another well-known paradigm, the composite-face task (Hole, 1994) has been considered a more reliable and direct measure of holistic face processing. In this task, participants are required to judge whether the top halves of two sequentially presented composite faces are the same or different when the task-irrelevant bottom face halves are manipulated. Holistic processing is indexed by an inability to preferentially process just the target face half. When faces are processed as wholes, one's judgements on the target face half (e.g. top half) are influenced by a failure to completely ignore the task-irrelevant face half. Thus, participants might demonstrate a tendency to answer 'different' (false alarm) when the

top halves of two sequentially presented faces are the same and when the bottom halves are different relative to when both halves stay the same. The composite face effect (CFE) is revealed when observers have more difficulty recognising the identity of one of the face halves when they are aligned than when they are misaligned (Hole, 1994; Taubert & Alais, 2009). The idea behind this effect is that holistic processing will interfere with identification of one face half from the other if they are aligned to form an individual representation of the face as a whole; likewise, this interference is reduced when the two face halves are misaligned, since the halves will not be perceived as a whole face. Therefore, there is consensus that the observation of a composite face effect indicates the presence of holistic processing, while a lack of this effect suggests the presence of featural processing.

Support for the holistic account also comes from several lines of research showing that this 'composite-face effect' disappears after inversion (Hayward, Crookes, Chu, Favelle, & Rhodes, 2016; McKone et al., 2013; Susilo, McKone, & Edwards, 2010) and does not occur for non-face objects (e.g., McKone et al., 1993). This effect has been replicated in children (4 – 6 years old), who manifest a composite face effect at least as strong as that shown by young adults tested in the same studies (de Heering et al., 2007; Mondloch, Pathman, Maurer, & Grand, 2007). Previous investigations on differences between holistic processing of own-race and other-race faces using the composite-face task have yielded mixed results. The findings of Michel et al. (2006b) are consistent with those for the whole-part effect: Belgium-Caucasian participants showed a significant composite-face effect for Caucasian but not Asian faces, whereas Korean participants displayed a significant composite-face effect for both Asian and Caucasian faces (although the effect was greater for own-race faces). However, there is no direct evidence supporting an expertise account because the presence of the other-race recognition deficit did not correlate its size with any difference in magnitude of the composite-face effect between own-race and other-race faces.

In contrast, Mondloch et al. (2010) and Hayward et al. (2013) both found similar sized composite effects for Asian and Caucasian faces in both Asian and Caucasian participants suggesting no race of face effect on holistic processing.

Similarly, a study by Bukach, Cottle, Ubiwa, & Miller (2012) also failed to find stronger holistic processing for own-race faces, by either Caucasian Americans or African Americans. It is worth mentioning that the complete design of Bukach et al.'s (2012) composite-face task was slightly different to those discussed earlier, in that both target (top half) and irrelevant (bottom half) information could be same or different in each stimulus pair (in the earlier studies where the partial design was used, irrelevant bottom halves were always different). The main advantage of this complete paradigm is that it allows calculation of a bias-free measure of sensitivity – *d'* (Richler et al., 2012; Richler et al., 2008). Two other recent studies using the same composite design as Bukach et al. (2012) have failed to find cross-race differences in the strength of holistic coding. Harrison, Gauthier, Hayward, & Richler (2014) tested Hong Kong Chinese and American-Caucasian, with both being tested in their home country. It was found that Asians and Caucasians showed similar composite effects for both races of face. Hayward et al. (2013) conducted a similar experiment using Australian-Caucasians and Hong Kong Chinese, also finding no cross-race difference in the magnitude of the composite-face effects.

Overall, the results from the composite task are very inconsistent, and certainly not as consistent as those from the whole-part task. In some studies, the associations between the magnitude of holistic processing and the size of the ORB was found, such that Caucasian participants showed a larger composite-face effect for own-race faces (Bukach et al., 2012; Michel, Caldara, et al., 2006). Yet, many other studies have failed to find evidence for such an association, for example the failure to find larger own-race composite effects across several participant race groups (Caucasians, Asians, and African Americans) (Bukach et al.,

2012; Hayward et al., 2013; Mondloch et al., 2010). The discrepancies observed in the literature regarding the relationship between holistic face processing and ORB in face recognition have led to some researchers to argue that other-race faces may be processed in a different way from own-race faces but perhaps the composite-face effect is a crude measure of holistic processing (Ross, Richler, & Gauthier, 2014). An alternative explanation for the discrepant findings is that that holistic processing may be a necessary, but not sufficient, step in the acquisition of expertise in recognising other-race faces as an adult.

It is important to note that there are currently two versions of the composite task being used in the literature: partial design versus complete design (see *Figure 6.1*). The majority of previous composite task studies of holistic processing and the ORB have used the partial design (Michel, Caldara, & Rossion, 2006; Michel, Corneille, & Rossion, 2007, 2010; Mondloch et al., 2010). However, the partial design has been recently criticised for a few reasons. First, the measure of holistic processing in the partial design is susceptible to the impact of response biases (Richler, Mack, Gauthier, & Palmeri, 2009; Richler et al., 2012; Richler, Mack, Palmeri, & Gauthier, 2011), including response biases that are driven by manipulations of participant strategy (Richler et al., 2011). Second, holistic processing measured in the partial design, in most cases, is not directly related to face recognition ability (Konar, Bennett, & Sekuler, 2010; Richler et al., 2012), which is incompatible with the presumed role of holistic processing as a hallmark of face perception. In contrast, the complete design provides a measure of holistic processing that is independent of response biases (Meinhardt et al., 2014; Richler, Mack, Palmeri, & Gauthier, 2011) and correlates with face recognition performance (McGugin, Richler, Herzmann, Speegle, & Gauthier, 2012; Richler et al., 2012).

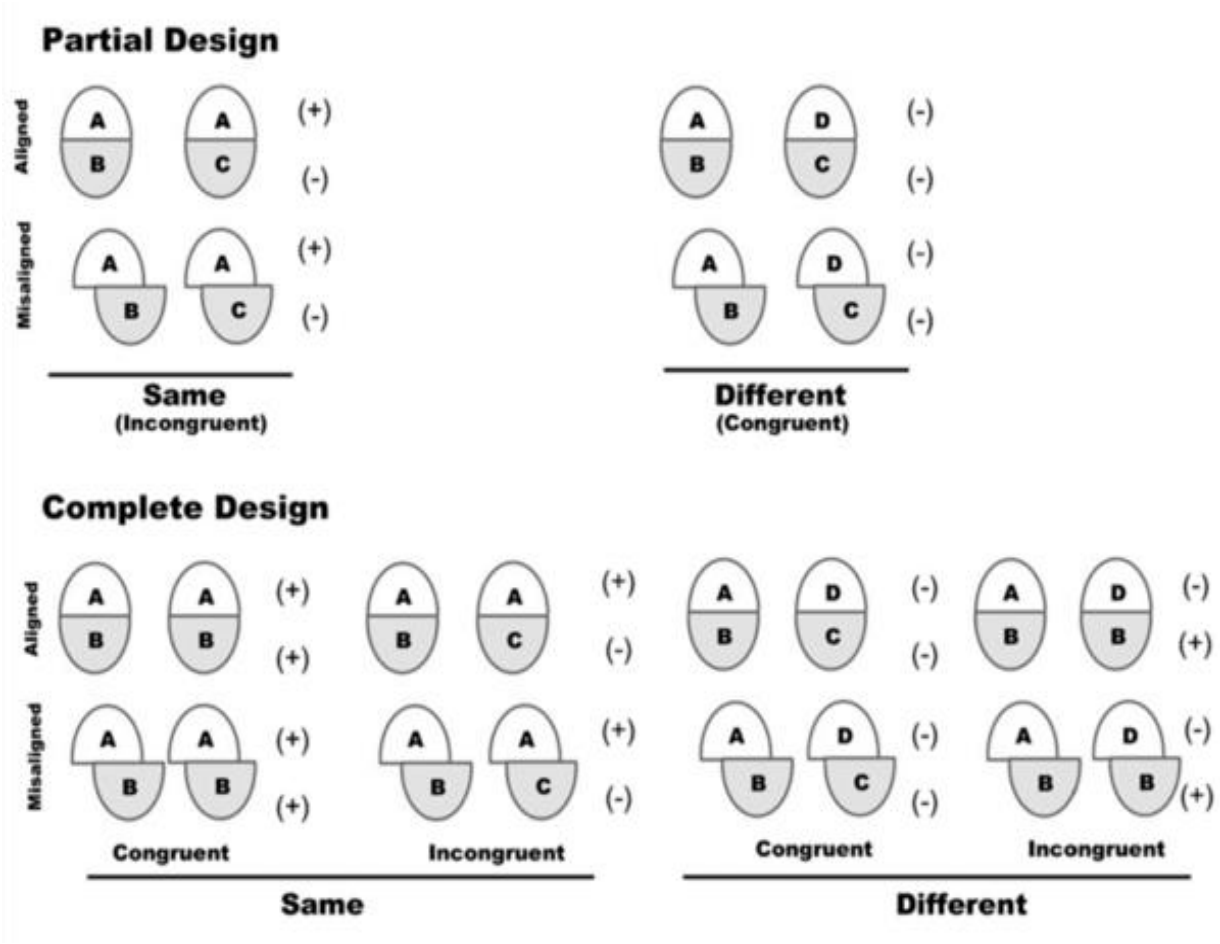


Figure 6.1. Partial versus complete design of composite face task. Adapted from Gauthier and Bukach (2007).

6.2 Holistic processing and ORB

Not all faces are recognised equally well even in typically-developing individuals; people tend to recognise own-race faces more accurately than faces from other races. The own-race bias (ORB; also known as other-race effect) is a well-documented phenomenon that exists across different countries and ethnic groups (see Chapter 2; for review, see Meissner & Brigham, 2001) not only in the laboratory settings but also in the real-world situation. Yet, its underlying mechanisms are still poorly understood. According to the holistic account of ORB, a relative lack of experience with other-race faces impairs our ability to extract holistic information from them. There is support that adults employ greater holistic processing when recognising own-race faces compared to other-race faces, perhaps due to greater experience

with own-race faces (Harrison et al., 2011; Hayward, Crookes, & Rhodes, 2013; Michel, Rossion, Han, Chung, & Caldara, 2006). Tanaka & Pierce (2009) demonstrated that the ORB can be ameliorated by engaging participants in more holistic processing of other-race faces via individuating training, but not categorisation training, for several hours. This finding highlighted the possibility that reduced holistic processing for other-race faces may underlie the ORB in face recognition.

Most studies have claimed that individuating experiences are necessary for holistic processing to develop; yet so far only a few studies have evaluated this idea's validity by comparing between multiple ethnic groups with the use of face stimuli of different races. For instance, DeGutis, Mercado, Wilmer, & Rosenblatt's (2013) and Wang et al.'s (2012) conclusions that recognition ability is strongly linked to the magnitude of holistic processing lacks external validity as the former study only tested Caucasian participants with Caucasian faces whereas the latter study did not report the race/ethnicity of participants and only used Asian faces. To my knowledge, only one recent study employed both the composite-face effect and whole part effect to index holistic processing while comparing between two different race groups (Caucasian vs. Chinese) (Mondloch et al., 2010). Mondloch et al. (2010) reported evidence that the magnitude of holistic processing for own-race and other-race faces did not differ in either Caucasian or Chinese adults; however, participants with minimal experience with other-race faces were less sensitive to both featural and relational differences in other-race faces than in own-race faces. However, this cross-cultural study did not measure participants' face memory and therefore it remains unclear to what extent holistic processing affects the ORB in recognition memory.

6.2 Experiment 4: The Own-Race Bias and Holistic Processing Across Racial Groups

The first aim of this study was to determine the extent to which individual differences in holistic processing predict face recognition ability (as reported in Richler, Cheung, &

Gauthier, 2012; Wang et al., 2012). If the widespread assumption that holistic processing underlies one's face recognition abilities is true, holistic processing, as indexed by the composite-face and whole-part effects, would be significantly associated with accuracy in a face recognition task. Most studies have claimed that individuating experiences are necessary for holistic processing to develop; yet so far only a few studies have evaluated its validity comparing between multiple ethnic groups with the use of face stimuli of different races. For instance, DeGutis, Mercado, Wilmer, & Rosenblatt's (2013) and Wang et al.'s (2012) conclusions that recognition ability is strongly linked to the magnitude of holistic processing lack external validity as the former study only tested Caucasian participants with Caucasian faces while the latter study did not report the race/ethnicity of participants and only used Asian faces. To my knowledge, only one recent study employed both composite-face effect and whole part effect to index holistic processing while comparing between two different race groups (Caucasian vs. Chinese) (Mondloch et al., 2010). Mondloch et al. (2010) reported evidence that the magnitude of holistic processing for own-race and other-race faces did not differ in both Caucasian and Chinese adults; however, participants with minimal experience with other-race faces were less sensitive to both featural and holistic information in other-race faces than in own-race faces. Unfortunately, this cross-cultural study did not measure participants' face memory and therefore it remains unclear to what extent holistic processing affects the ORB in recognition memory.

Thus, the second aim of the study was to investigate whether the ORB in face memory can be attributed to reduced holistic processing of unfamiliar other-race faces. In order to address this question, I tested face recognition and holistic processing in Malaysian-Chinese, African, European-Caucasian, and Australian-Caucasian young adults. According to the experience-based holistic account of ORB (Hancock & Rhodes, 2008), individual-level face discrimination experience is crucial for holistic processing to develop and the own-race

advantage in face memory reflects stronger holistic coding of own-race than other-race faces. Therefore, I expected that African, European-Caucasian, and Australian-Caucasian participants from less racially diverse populations are likely to show the typical ORB in face memory and stronger holistic processing for own-race faces than other-race faces, in both the composite-face and the whole-part tasks. Unlike most Asian groups (e.g., Mainland Chinese, Japanese), Malaysian-Chinese live in a highly multiracial, but not Western-dominated country. Given their everyday exposure to faces from multiple races, it was predicted that Malaysian-Chinese participants may maintain a very broad facial representation and learn to use a more holistic face processing style that is advantageous for recognising both own- and other-race faces as compared to African and Caucasian participants. In contrast, if holistic face processing can generalise to other-race faces without extensive face discriminating experience, both own- and other-race faces would show holistic effects of similar magnitudes across race groups.

6.3 Methods

6.3.1 Participants

31 Malaysian-Chinese (16 female; M_{age} = 21.65, SD = 2.6), 30 European-Caucasian (14 female; M_{age} = 22.40, SD = 3.10), 30 Australian-Caucasian (23 female; M_{age} = 21.03, SD = 4.45), and 30 African (12 female; M_{age} = 26, SD = 5.5) young adults took part in this study. Physical race was determined by self-report of continent of ancestry; all participants were (as far as they knew) of single rather than mixed physical-race descent. Malaysian-Chinese were students at the University of Nottingham Malaysia Campus. They were all born and grew up in Malaysia (Southeast-Asia country). None of them reported spending more than 9 months in a predominantly Western country (e.g., UK). Both European-Caucasian and African participants were international students recruited at the University of Nottingham Malaysia Campus. European-Caucasian were mostly British (1 Italian, 1 Dutch) who had resided in

Malaysia for 6.5 months on average (*SD* = 10.40). None reported spending more than two years in a predominantly Asian country. On the other hand, African participants were mostly Nigerians (5 Kenyans, 2 Zimbabweans, 1 Zambian, 1 Somali) who had resided in Malaysia for 2.5 years on average (*SD* = 2.25). Australian-Caucasian participants were recruited from Macquarie University, Sydney. All were born in Australia and had not lived in a predominantly Asian country for more than 4 months (*M* = 0.18 months, *SD* = 0.7, range = 0-4 months). All participants reported having normal or corrected-to-normal vision and having no difficulty with face recognition. They received either course credit or monetary compensation of RM10 for their participation in the one-hour experiment.

6.3.2 Stimuli and Apparatus

Three races of faces were used as stimuli: Chinese faces, Caucasian faces and African faces. I chose to use three different race categories so that I could include an additional other-race category that was not familiar to either participant group; for instance, Malaysian-Chinese are likely to be familiar with Caucasian faces but not with African faces (Tan et al., 2012). Chinese facial images were collected from a student population at the University of Nottingham Malaysia Campus whereas Caucasian faces were obtained from the Macquarie University, Australia. African faces were requested from Coetzee's (2010) face database. All stimuli used in the face tasks were frontal images of young adult faces (both male and female) with neutral expression (no glasses, facial hair, or distinctive blemishes). The original images were first cut to form an ellipse that excluded external features (leaving an oval shape with no hair on the top and sides) to avoid ceiling effects, evidently because easily perceived differences in outline shape and distinctiveness of hairstyle could provide a reliable basis for low-level image matching. To minimise the low-level image cues (e.g., skin colour information) for the task, all face images were transformed into 8-bit grayscale images in Adobe Photoshop CS6 and were aligned on the eyes' position using PsychoMorph software.

Examples of the final stimuli were shown in *Figure 6.2*. The experiment was designed and run using the presentation software PsychoPy(Peirce, 2007). Stimuli were presented on a 15.6" LED backlit FHD monitor (resolution 1366 × 768) controlled by an ASUS computer.



Figure 6.2. Examples of the three races of faces (i.e. Chinese, African and Caucasian faces) used in the face tasks.

6.3.2.1 Yes-no recognition task.

48 faces were selected to form the experimental set, comprising three sets of face stimuli: 16 Chinese faces (8 males, 8 females), 16 Caucasian faces (8 males, 8 females), and 16 African faces (8 males, 8 females). Faces were presented on a light grey background and sized 7.5° horizontal by 10.5° vertical at an approximate viewing distance of 60cm.

6.3.2.2 Whole-part task.

Stimuli were created from 36 face images: 12 target faces (two Chinese females, two Chinese males, two Caucasian females, two Caucasian males, two African females, and two African males) and 24 distractor faces containing 4 faces of each race and sex. Within each race and sex category, a standard face outline template was used and each target face was created by aligning eyes, nose, and mouth features into the template. Distractor faces for the whole trials were created by replacing one feature (i.e., eyes, nose, or mouth) in the target face with the respective feature of another face of the same race and sex. Part stimuli were created by extracting the eye, nose, or mouth region from each of the target faces and the distractor faces. Target and distractor stimuli for the part trials displayed only the critical feature (see *Figure 6.3*). At a viewing distance of approximately 60cm, whole faces were of

7.5° horizontal by 10.5° vertical and for isolated features the sizes were: eyes 6.5° × 2.2°; nose 2.6° × 2.2°; mouth 3.8° × 1.9°.

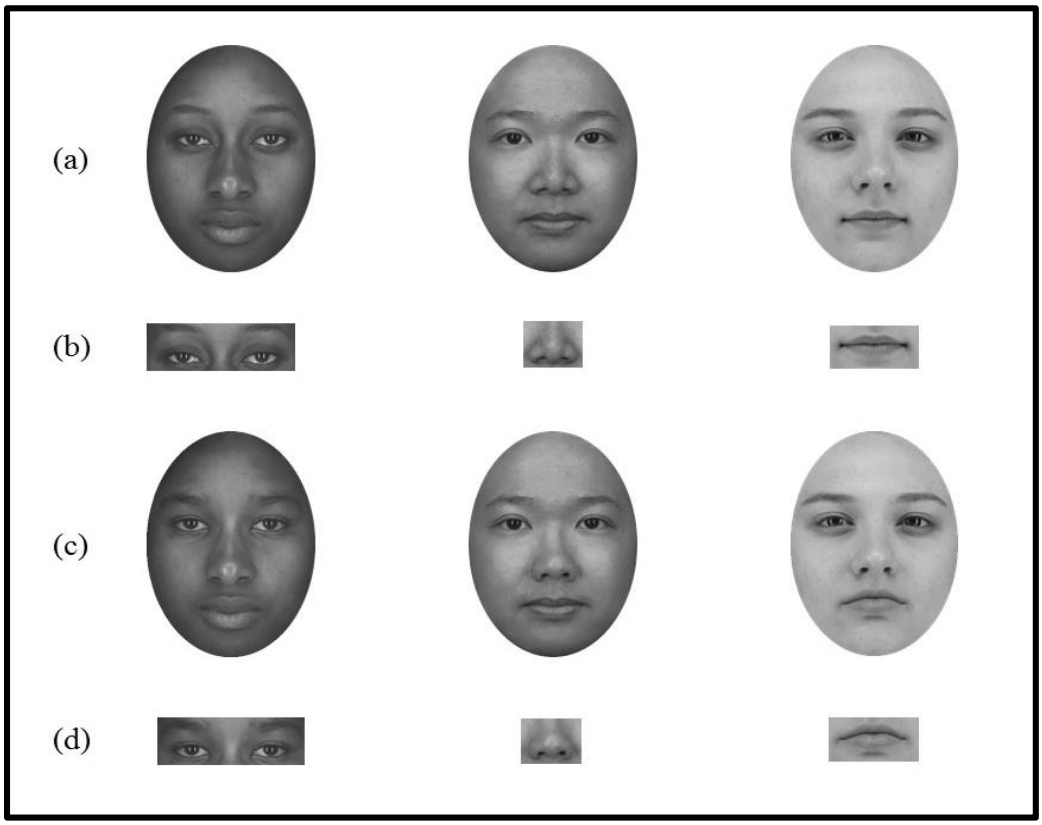


Figure 6.3. Example images of different races used in the whole-part task: (a) original intact faces; (b) isolated target eyes, nose, and mouth; (c) distractor faces, with either the eyes, nose or mouth being replaced; (d) isolated distractor eyes, nose, and mouth.

6.3.2.3 Composite task

Face stimuli were generated from 60 images (20 for each face race) of unfamiliar Chinese, Caucasian, and African faces, half males and half females. To create composite faces, each face images was divided into two halves horizontally across the middle of the nose using Adobe Photoshop CS6. The top and bottom halves from same-gender faces of different individuals were then recombined at random, leaving a 3-pixel gap between the two parts; therefore, the cut line was clearly visible. The top half and bottom halves were

presented either aligned or misaligned. In the aligned trials, the top and bottom face parts were appropriately aligned; in the misaligned trials, the top and bottom face parts were misaligned by shifting the top half horizontally to the left by half a face width (see *Figure 6.4*). The same composite faces were used in both alignment conditions. This resulted in 40 aligned and 40 misaligned composite faces in total within each of three different racial categories (Chinese, Caucasian, and African).

The "complete" composite face paradigm, instead of the "partial" paradigm, was employed in the current study because the partial design is prone to response biases (Richler, Gauthier, Wenger, & Palmeri, 2008). In the complete design, the same/different relationship between the task-relevant parts was congruent with that of the task-irrelevant parts in 50% of the trials and it was incongruent in the other half of the trials. For example, in "congruent" trials, if the bottom parts of the two sequential faces are the same, the top parts would also be the same. On the other hand, in "incongruent" trials, if the bottom parts are the same, the top parts would differ. Stimuli in the aligned condition were 7.5° horizontal by 10.5° vertical while stimuli in the misaligned condition were 11.1° horizontal by 10.5° vertical. *Figure 6.4* below demonstrates the complete composite face task design.

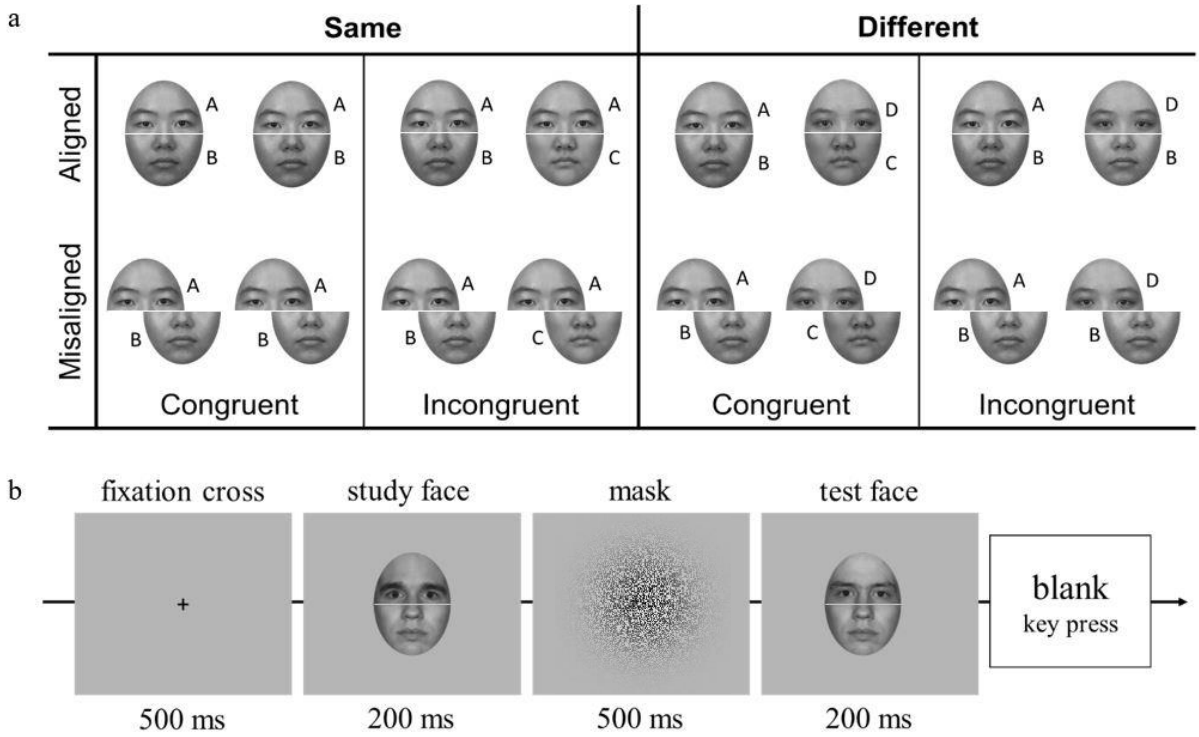


Figure 6.4. (a) Examples of the experimental design and (b) a sample of a 'different' trial used in composite-face task. The participants' task was to match the sequentially presented top halves while ignoring the bottom halves.

6.3.2.4 Global-local task

This task is a variant of Navon's (1977) task used by Wang et al. (2012). Two different types of hierarchical shapes of two types were used as stimuli: congruent shapes, in which the global and the local objects forming the shapes shared an identity (e.g., local squares forming a global square), and incongruent shapes, in which the shapes at the two levels had different identities (e.g., local circles forming a global square). In addition to congruent and incongruent conditions, I also included a neutral (baseline) condition at both global and local levels in which a task-irrelevant object (an X) forms the global or local shapes. Examples of stimuli are presented in *Figure 6.5*. The Navon stimuli consisted of shapes (circle, square or cross) with white outline presented on a black background. Each

local shape was 0.5° × 0.5°; the local shapes were arranged to form a global square (4.9° × 4.9°), global circle (5.6° × 5.6°), or a global cross (4.9° horizontal × 5.3° vertical).

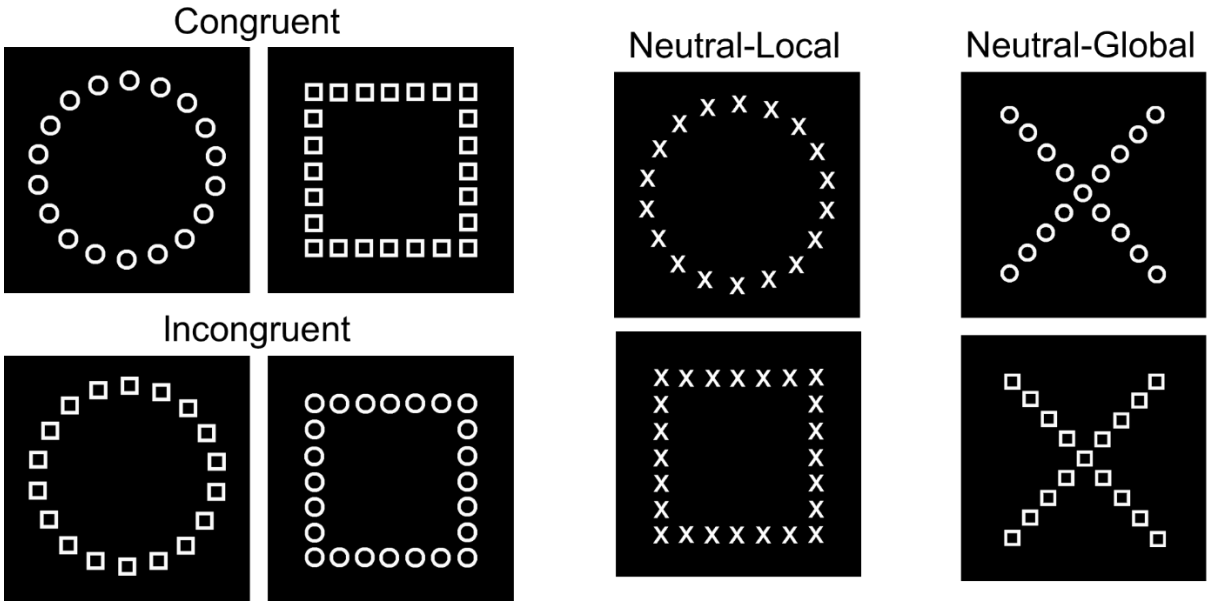


Figure 6.5. Example of Navon stimuli for global-local task.

6.3.3 Procedure

Participants were tested individually in a quiet dimly lit room laboratory and were seated approximately 60cm from the computer screen. All reported their ethnic background, place of birth, and time spent living abroad (including location). After giving written informed consent, each participant then performed four tasks (yes-no recognition task, composite task, whole-part task, and global-local task), with the presentation order of face tasks being counterbalanced and global-local task always being presented last across participants. The presentation order of the global-local task was fixed because it was previously reported that the Navon task can affect subsequent eye movement patterns, identification accuracy, and holistic processing during face recognition (Gao, Flevaris, Robertson, & Bentin, 2011).

6.3.3.1 Yes/no recognition task.

During the learning phase, participants were asked to learn 24 faces, presented one at a time, with three races of faces (8 male and 8 female Chinese; 8 male and 8 female Caucasian; 8 male and 8 female African). On each trial, a face was presented randomly in one of the four quadrants for 5 seconds, preceded by a central fixation cross of 1 second. Participants were asked to remember as many faces as possible. After the learning task, they proceeded to perform a recognition task in which 16 of the learned faces were randomly intermixed with 16 novel faces. On each trial, participants were asked, "Do you recognise this face?". Each face was presented for up to 5 seconds depending on the key press and participants were required to respond as quickly and as accurately as possible by pressing either 'Y' (yes) or 'N' (no) on the keyboard to indicate if they had seen the face before in the learning phase. Both response times and answers were recorded. The facial images were presented in a random order, with the constraint that no more than three trials involving a given race occurred in immediate succession. The experimental procedure is illustrated in *Figure 6.6.*

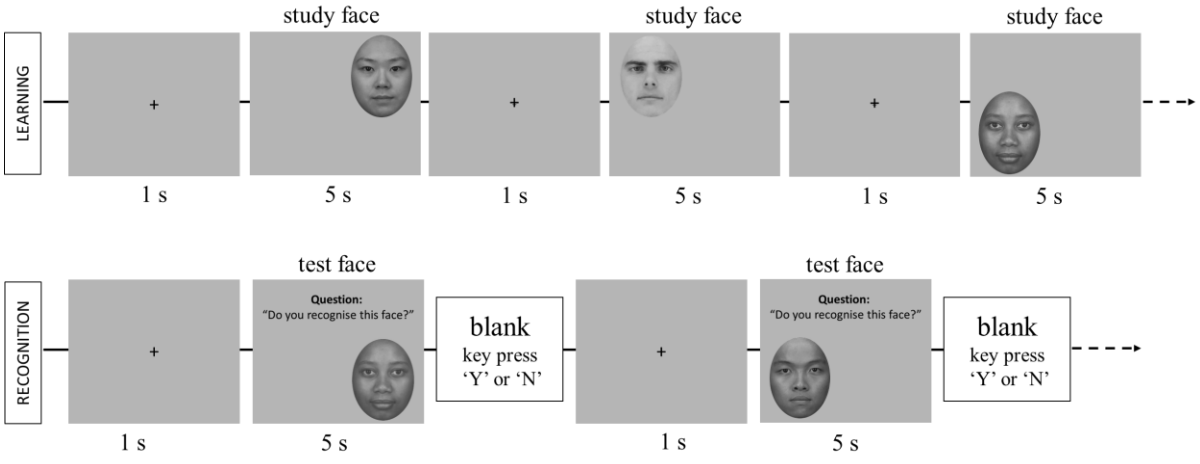


Figure 6.6. Experimental procedure for the learning and recognition stages in the yes-no recognition task.

6.3.3.2 Whole-part task.

The whole-part task assesses how much participants integrate individual facial features into the whole face context. Specifically, holistic face processing was assessed in this task by comparing participants' ability to identify a face part (eyes, nose, or mouth) in the context of the whole-face in which it was learned with their ability to recognise the same face part in isolation. It consisted of three study-test blocks, each consisting 48 trials per face race (Chinese, Caucasian or African). During the study phase of each block, participants were instructed to memorise four faces (2 male, 2 female) and their associated names (common surnames; e.g., John, James, and Jack). Each face-name pair was shown for 5 seconds with an inter-stimulus interval of 1 second. Participants were allowed to enter the test phase only when they could correctly identify all face-name pairs. This was to ensure that they were familiarised with each face in order to actually perform the subsequent task. On each trial in the test phase, a question was presented (e.g. "Which is John's nose?), followed by a choice of two alternative images presented on the left and right sides of the screen. The image pair remained on the screen until a response was made. For each test pair, participants were required to indicate if the target stimulus was on the left (press left arrow key) or on the right (press right arrow key). The face part was tested either in isolation or in the context of the whole face. For the part condition, the display consisted of two isolated features (two eyes, two noses, or two mouths): One was from the target face, and the other was from the distractor face. For the whole condition, the display contained two whole faces, with the target and a distractor face differing only with respect to one face part (see *Figure 6.7*). Stimuli were matched between the two conditions, such that facial parts tested in the part condition were also tested in the whole condition. The trials of whole and part conditions were randomly intermixed. There were three blocks in total, each consisting of 24 part and 24 whole trials. The order of block presentation was counterbalanced across participants.

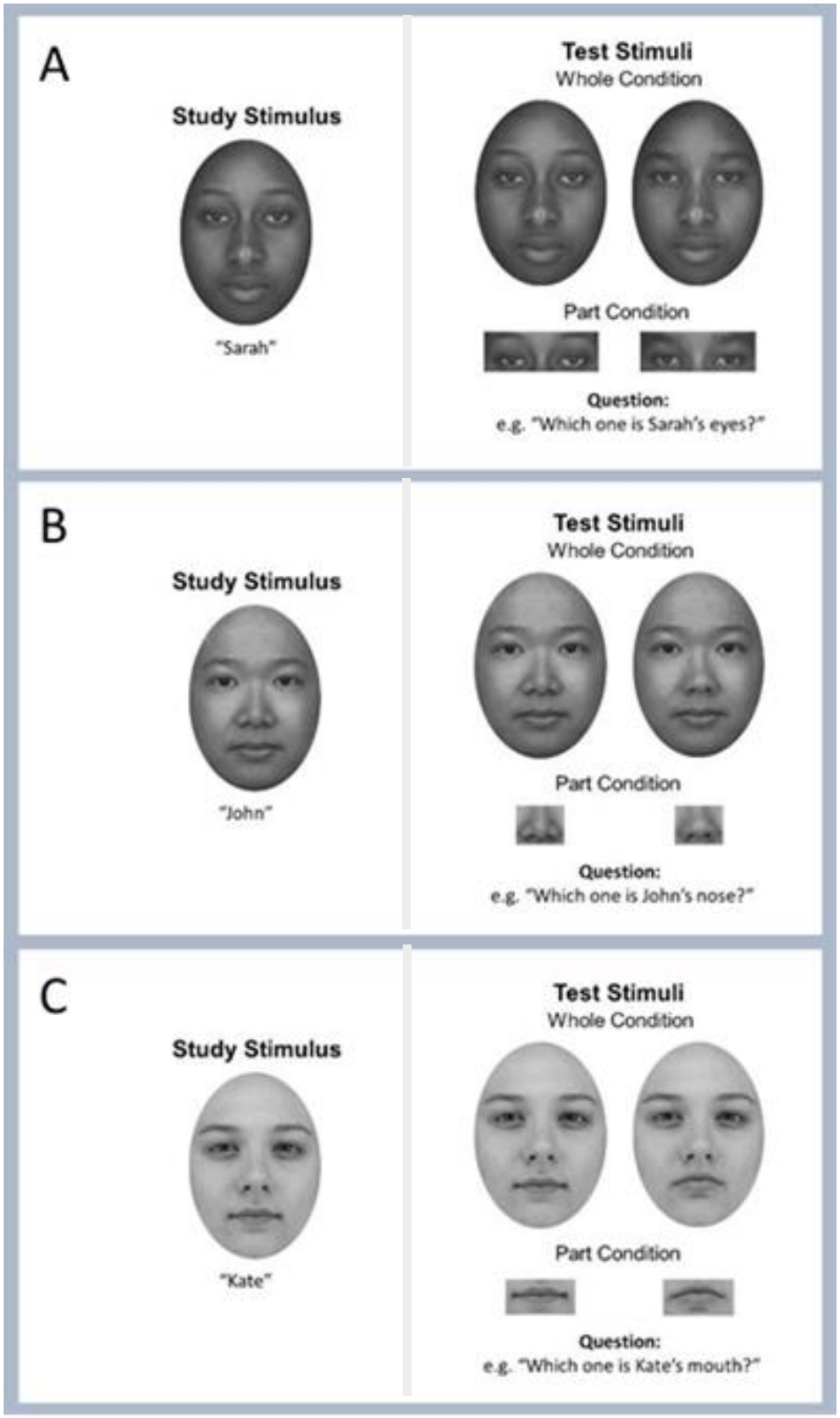


Figure 6.7. Example of the stimuli of three different races used in the whole-part task. The whole-part effect (*WPE*) relies on the assumption that it is much easier to identify the eyes (A), nose (B), or mouth (C) of the target face when the features are shown in the context of the whole face than when they are shown in isolation.

6.3.3.3 Composite face task.

Two different paradigms of composite-face tasks have commonly been used to test holistic face perception in adults: partial design versus complete design. It is worth noting that the procedure used in this current study was identical to the one used by Wang et al. (2012), except that I employed a complete design rather than a partial design of composite face task. Compared to the partial design, the additional conditions in the complete design are: (1) pairs where the tops are the same and the bottoms are the same and (2) pairs where the tops are different but the bottoms are the same. The complete paradigm not only takes response bias into account, but also provides an alternative way to address the composite-face effect through congruency analysis.

Prior to the test trials, participants completed 12 practice trials to ensure that they understood the task. Each trial started with a central fixation cross for 500ms, followed by a study face displayed in the centre of the screen for 200ms. Then, after a Gaussian noise mask of 500ms, a test face appeared randomly in any of the eight different locations, 1.2° away from the centre of the screen, for 200ms. Next, a blank screen was presented until a response was made. Participants' task was to judge as quickly and accurately as possible whether the top half of the test face was identical to the preceding study face while ignoring the task-irrelevant bottom half. They were instructed to indicate their decision by pressing two keys on a keyboard. The test phase could only be terminated by a key press (see *Figure 6.6* for an example of trial sequence). On each trial, both faces within a pair were either aligned or misaligned, and these two conditions were intermixed. Trials were blocked by race of face, and the order of blocks was counterbalanced across participants. Hence, each participant performed three experimental blocks of 80 trials (40 aligned and 40 misaligned), half of which consisted of face pairs that shared an identical top half (same trials), and half of which

consisted of face pairs with different top halves (different trials). Again, order of trial presentation was fully randomised across participants.

6.3.3.4 Global-local task.

Following the face tasks, participants performed the global-local task. This task assesses participants' bias to attend to the global shapes versus local shapes, and vice versa. There were two blocks of trials, with each containing 18 practice and 108 test trials. Each block is preceded by instructions to identify the target shapes (circle and square) at either the global or local level as quickly and accurately as possible. In each block, there were 36 congruent trials, 36 incongruent trials and 36 neutral trials. The three types of trials were randomly intermixed. Each trial began with a blank screen (500ms), followed by a central fixation cross (700ms), Then, a shape stimulus appeared randomly in one of the eight possible locations (0.49° away from the centre of the screen) for 150ms, followed by a mask (48 × 48 array of squares each 0.19°× 0.19°) for 500ms. Participants were asked to indicate whether the target shape they saw was a circle or a square as quickly as possible. This task took approximately 3 minutes. Each participant completed 216 trials in total (108 local-level and 108 global-level), with 18 practice trials in each block. The measure was the time spent to respond for targets appearing at each level.

6.3.4 Data analyses

6.3.4.1 Yes-no recognition task.

Signal detection measure of sensitivity (*d'*) was used as an index of face recognition sensitivity for each participant. Data from the recognition phase were first sorted into four conditions for each race of faces: hits (correctly identified learned faces), misses (learned faces wrongly classified as new), correct rejections (new faces correctly identified as new), and false alarms (new faces wrongly classified as learned). To overcome infinite values of *d'*

in the case where hit rate or false alarm rate equals 1.0, the Snodgrass & Corwin (1988) correction factor was applied by using the following formulas:

$$Hit\ rate = \frac{number\ of\ hits + 0.5}{total\ number\ of\ trials\ with\ signal\ present + 1}$$

$$False\ alarm\ rate = \frac{number\ of\ false\ alarms + 0.5}{total\ number\ of\ trials\ with\ signal\ absent + 1}$$

Participants' corrected hit and false alarm rates from the face recognition task were then combined into *d'* scores, where *d'* is equal to z-score for hit rates (Z_H) minus z-score for false-alarm rates (Z_{FA}) (Macmillan & Creelman, 1991). A higher *d'* score represents more sensitivity to a target, whereas a score that approaches 0 represents chance performance. An additional measure of each participant's response bias (*c*; Macmillan & Creelman, 1991) was used to assess participants' tendency to favour one response over the other. This basic bias measure is defined as $c = -0.5 (Z_H + Z_{FA})$. For the ideal observer $c = 0$; when the observer adopts a more liberal strategy *c* is negative, and when the observer adopts a more conservative strategy *c* is positive. Two separate two-way repeated measures analysis of variance (ANOVAs) were performed on recognition sensitivity *d'*, response criterion *c*, and correct response times, with face race (Chinese, Caucasian, and African) as within-subjects factor and participant race (Malaysian-Chinese, European-Caucasian, African, and Australian-Caucasian) as between-subjects factor.

6.3.4.2 Composite face task.

Holistic processing in the complete design of composite-face task was indicated by the performance differences between the congruent trials (both tops and bottoms are the same or different) and incongruent trials (same for one part and different from the other). I first performed a 4 (Race of Observer: Malaysian-Chinese, African, Australian-Caucasian, and European-Caucasian) × 3 (Face Race: Chinese, African and Caucasian) × 2 (Alignment:

aligned vs. misaligned) × 2 (Congruency: congruent vs. incongruent) mixed factorial ANOVA on participants' discrimination sensitivity (*d'*) and response bias (*c*). Note that, in this task, positive values of *c* mean that the participant prefers "different" responses, while negative values of *c* indicate a preference for the "same" responses. As participants were instructed to respond as quickly as possible, I also analysed response time (RT) data based on an identical ANOVA to check for speed-accuracy tradeoffs. RTs for individual trials were excluded if the response was incorrect or if the RT was less than 250ms or more than 3 standard deviations of the mean for a given participant. Mean RT was computed separately for each race of faces. To further determine whether there was a difference in holistic face processing between own- and other-race faces within each race group, I then computed the composite-face effect (CFE) score for each race of faces separately using the following formula:

Congruency effect = d' congruent trials – d' incongruent trials

Composite-face effect (CFE) = congruency effect $_{(aligned)}$ – congruency effect $_{(misaligned)}$

The magnitude of CFE between race groups was then examined with a mixed ANOVA, involving Face Race as within-subjects variable and Race of Participant as between-subjects variable.

6.3.4.3 Whole-part task.

Two repeated-measures ANOVAs with Race of Participant (Malaysian-Chinese, European-Caucasian, African, and Australian-Caucasian), Race of Face (Chinese, Caucasian, and African), Feature (eyes, nose, and mouth), and Whole-part Condition (whole vs. part trials) were performed separately on participants' identification accuracy (percentage correct) and response time. Next, another index of holistic face processing – the whole-part effect (WPE) – was calculated by subtracting accuracy scores for part trials from those for whole

trials. I compared the whole-part effect for all features combined and then for each feature separately. To control for any differences in baseline accuracy, I computed the standardized WPE scores for own- and other-race faces by using the formula below:

$$WPE = \frac{(\%\ correct\ whole - \%\ correct\ part)}{(\%\ correct\ whole + \%\ correct\ part)}$$

After examining the WPE between race groups with a mixed ANOVA, involving Face Race as within-subjects variable and Race of Participant as between-subjects variable, I broke the analysis into eyes, nose, and mouth trials to determine whether patterns of holistic processing differ in separate areas of the face.

6.3.4.4 Global-local task.

Participants' performance measures were expressed by percentage of correct responses as well as response times (RT). I first performed two mixed factorial ANOVAs separately on both measures, with Stimulus Level (global vs. local) and Congruency (congruent, incongruent and neutral) as within-subjects variables and Race of Participant as between-subjects variable. Only RTs for correct responses were included in the analysis and RTs for trial were discarded if they were shorter than 200ms or longer than 2000ms. To measure participants' tendency to globally process general objects, the global-local interference (GLI) score was calculated for each participant by examining the degree to which global features interfere with RT on the local incongruent trials. The following formula was used:

$$GLI = \frac{Congruent\ (global - local) - Incongruent\ (global - local)}{Congruent\ (global + local) + Incongruent\ (global + local)}$$

Positive GLI scores indicate a global processing bias whereas negative GLI scores mean a local processing bias.

6.3.4.5 Cross-task correlations.

Pearson correlation analyses were performed on the results of each participant group in order to examine the association between their face recognition ability and the magnitude of holistic processing for own- and other-race faces. More specifically, I wished to determine if the two behavioural markers of holistic processing – the CFE and the WPE – could reliably predict face recognition scores. The WPE was calculated for each participant by subtracting the score in the part condition from the score in the whole condition for each race of faces (Zhu, Li, Chow, & Liu, 2009). On the other hand, the CFE was computed by subtracting the congruency effect in the misaligned condition from congruency effect in aligned condition (de Heering & Rossion, 2008). Thus, a large score of WPE and CFE reflects a stronger holistic face processing. Splitting the analyses by participant race, the Pearson's correlations between face recognition performance and the magnitude of holistic processing were calculated.

6.4 Results

Before running each mixed-factorial ANOVA, preliminary analyses of assumption testing were conducted to check if the data met parametric assumptions of normality and homogeneity of variance. Distributions were normal or very close to normal as indicated by Kolmogorov-Smirnov test ($p \geq 0.1$). Assumptions of homogeneity of variance was met in the three main measures (i.e., *d'*, accuracy, and mean response time) and no serious violations were detected (Levene's test $p > .05$). Prior to each analysis, outliers further than two standard deviations from the mean were removed. For each ANOVA, Greenhouse-Geisser corrections were applied whenever sphericity was violated. Follow-up tests were conducted using post-hoc tests with Bonferroni correction for significant main effects and planned comparisons for significant interaction effects. In addition, all significant statistics were reported along with effect size (i.e., partial eta squared η_p^2).

6.4.1 Yes-no recognition task

6.4.1.1 Recognition accuracy (*d'*)

Results from the ANOVA revealed a significant main effect of Face Race, F (2,230) = 24.14, p <.001, η_p^2 =.17, but no main effect of Race of Observer was found, F(2,87)=1.80, p=.15, η_p^2 = .05. There was a significant Face Race × Race of Observer interaction, F (6,230) = 8.06, p <.001, η_p^2 = .20, indicating the presence of ORB. Bonferroni-corrected pairwise comparisons confirmed that participants of four ethnicities manifested an own-race recognition advantage (see *Figure 6.8*). Malaysian-Chinese were better at recognising own-race faces than African faces (p=.02), but no difference was found between own-race and Caucasian faces (p=.95). European-Caucasians showed higher recognition sensitivity towards own-race faces relative to Chinese and African faces (both $p\leq$.001), but no difference between Chinese and African faces (p=1). Africans performed better for African and Caucasian faces than for Chinese faces (both p <.001) while no difference was detected between African and Caucasian faces (p=1). Australian-Caucasians recognised own-race faces better than Chinese (p<.001) and African faces (p=.008).

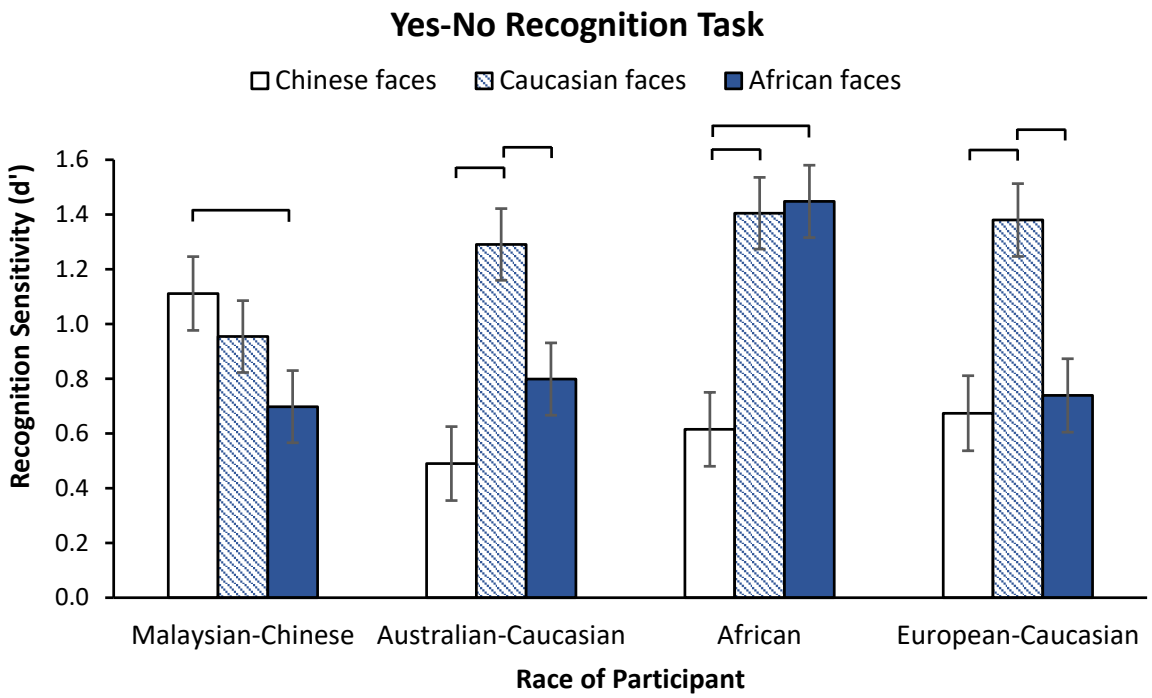


Figure 6.8. d' scores for the yes-no face recognition test of own- and other-race faces in Malaysian-Chinese, Australian-Caucasian, African, and European-Caucasian participants. Error bars represent standard errors of the mean.

6.4.1.2 Response bias *c*

Participants' response bias for both target and distractor faces was assessed. A positive *c* value suggests a tendency to answer 'No' (i.e., conservative strategy), whereas a negative *c* value indicates a tendency to answer 'Yes' to faces (i.e., liberal strategy). Results from mixed factorial ANOVA on the response bias measure (criterion *c*) with Race Group as between-subject variable and Race of Face as within-subject variable showed no significant main effects of Face Race [F (2, 234) = 0.80, p=.45, η_p^2 = .01] and Race of Observer [F (3, 117) = 2.09, p =.11, η_p^2 =.05]. However, there was a significant Face Race × Race of Observer interaction, F (6, 234) = 2.45, p=.03, η_p^2 = .06]. Post-hoc Bonferroni test revealed that African and Australian-Caucasian participants manifested a higher tendency to indicate a Chinese face as seen before (i.e. adopting a more liberal strategy) regardless of whether they had actually seen the face before, as compared to Chinese participants (p=.009 and p=.03,

respectively). Also, European-Caucasian had a higher tendency to respond 'No' to own-race faces than African participants (p=.04). No between-group difference was observed for African faces (all p>.05).

6.4.1.3 Reaction times

The main effect of Face Race was significant, F (2, 234) = 9.29, p<.001, η_p^2 = .07, showing that Caucasian faces (M=1.41s) received shorter response times compared to Chinese (M=1.52s) (p=.003) and African faces (M=1.53s) (p<.001). There was also a significant main effect of Race of Participant, F (3, 117) =7.15, p=.002, η_p^2 =.12, such that African participants (M=1.78s) made slower responses than Chinese (M=1.43s) (p=.04) and Australian-Caucasian (M=1.28s) (p=.002) participants did, and marginally slower than European-Caucasians did (M=1.45s) (p=.08). However, the interaction between Face Race and Race of Observer interaction was not significant, F (6,234) = 0.21, p=.97.

6.4.2 Composite task

6.4.2.1 Discrimination sensitivity *d'*.

A main effect of Face Race was found, F (2, 234) =40.14, p<.001, η_p^2 = .30, with Caucasian faces being better recognised than Chinese and African faces across race groups. A significant main effect of Race of Participant, F (3, 117) = 7.22, p<.001, η_p^2= .16, also revealed that African participants performed worse than the other three race groups (all p<.05) in the composite task. There was also a significant interaction between Face Race and Race of Observer, F (6, 234) = 2.60, p=.04, η_p^2 =.06, suggesting a superior recognition performance on own-race over other-race faces (see *Figure 6.9*). Both European- and Australian-Caucasian participants performed better for own-race faces than Chinese and African faces (all p<.001), while Malaysian-Chinese participants tended to achieve better performance for own-race faces than Caucasian (p=.08) and African faces (p=.06). However, no difference was found in African participants (all p>.05). A main effect of Alignment was

also found, F (1, 117) =18.86, p<.001, η_p^2 =.14. Higher performance for misaligned (M=1.87) than aligned trials (M=1.73) (p<.001) indicates that disrupting configural/holistic information impairs overall face discrimination. A main effect of Congruency was also detected, F (1, 117) =116.65, p<.001, η_p^2= .50, revealing a higher level of performance in the congruent trials (M=1.98) than incongruent trials (M=1.62) (p<.001). The interaction between Alignment and Congruency also reached significance, F (1, 117) = 89.75, p<.001, η_p^2 =43. The congruency effect was significant for aligned trials (p<.001) but not for the misaligned trials (p=.36), suggesting the composite face effect (i.e. inability to selectively attend to the top half) was eliminated when the top half was misaligned with the bottom half. This pattern is the hallmark of holistic face processing. A significant interaction between Face Race and Alignment was found, F (2, 234) =4.30, p=.02, η_p^2 =.04. Participants were generally better at matching the top halves of misaligned rather than aligned Caucasian faces (p<.001), but such difference was not found for Chinese and African faces (p=.13 and p=.29, respectively). Based on my hypothesis, an ORB in holistic processing at the group level would be reflected by a three-way interaction between Alignment, Congruency, and Face Race, with a more prominent Alignment by Congruency interaction for own-race than other-race faces. However, the interaction was not statistically significant, F (6, 234) = 0.91, p=.49, indicating that the magnitude of holistic face processing did not differ between own- and other-race faces.

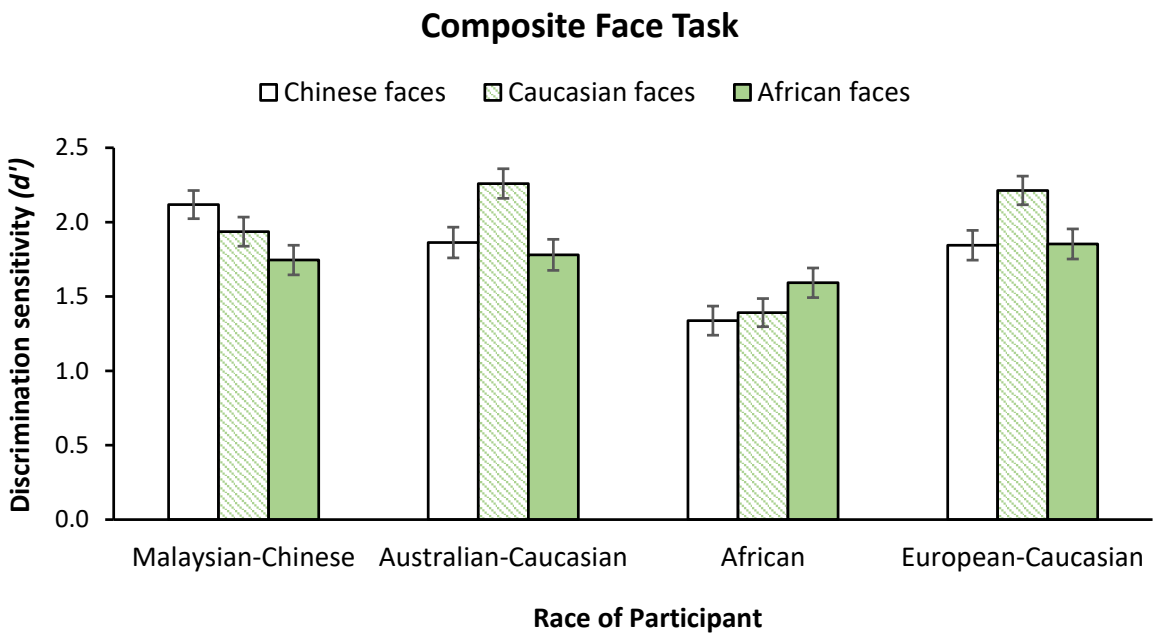


Figure 6.9. d-prime in the composite task for Chinese, Caucasian and African faces in Malaysian-Chinese, Australian-Caucasian, African, and European-Caucasian participants. Error bars represent standard errors of the mean.

6.4.2.2 Response bias

The main effect of Face Race was significant, F (2, 234) = 10.56, p<.001, η_p^2= .09, with a stronger "same" bias for African faces (M= -0.13) than for Chinese (M=-0.04) (p<.007) and Caucasian faces (M=-0.01) (p<.001). There was also a significant interaction between Face Race and Alignment, F (2, 234) =4.01, p=.02, η_p^2 =.04. Caucasian faces (M=0.10) received a more conservative response criterion (i.e., tendency toward "different" responses) than Chinese (M=0.006) and African faces (M=-0.05) (p=.03 and p<.001, respectively) when the composite faces were aligned; however, there was a pronounced tendency toward "yes" responses for African faces (M=-0.21) as compared to Chinese (M=-0.09) and Caucasian faces (M=-0.11) (p=.001 and p=.007, respectively) when the composite faces were misaligned. The significant main effects of Alignment, F (1, 117) = 39.83, p<.001, η_p^2 = .26, and Congruency, F (1, 117) = 25, p<.001, η_p^2 =.18, were accompanied by a two-

way interaction between Alignment and Congruency, $F(1, 117)=14.45$, $p<.001$, $\eta_p^2 =.11$. There was a significant response bias in the aligned condition where a tendency toward "different" responses existed for incongruent (M=0.08) than congruent trials (M=-0.04) (p<.001). In contrast, response bias did not differ between incongruent (M=-0.13) and congruent (M=-0.14) trials in the misaligned condition (p=.43).

6.4.2.3 Reaction times

An analysis of mean correct response times confirmed that differences in accuracy scores could not be attributed to speed-accuracy trade-offs. An ANOVA revealed significant main effects of Alignment, F (1,112)=35.63, $p<.001$, $\eta_p^2 = .23$, and Congruency, $F(1,112)= 15.00$, $p<.001$, $\eta_p^2 = .11$, accompanied by a significant Alignment × Congruency interaction, F (1,112)=30.96, $p<.001$, $\eta_p^2 = .21$. Participants generally responded more quickly on congruent (M=701ms) than incongruent (M=728 ms) trials (p<.001) when faces were aligned, but not when faces were misaligned (p=.40). A significant main effect of Face Race was also found, F (2, 224) = 4.06, p=.02, $\eta_p^2 = .03$. Participants tended to make slower responses to Chinese faces (M=726ms) than African faces (M=699ms) (p=.05), while there was no difference between Chinese and Caucasian faces (M=709ms) (p=.19), or between African and Caucasian faces (p=.71). There was also a main effect of Race of Participant, F (3, 112)=4.38, p=.006, $\eta_p^2 = .10$. Both European-Caucasian (M=672ms) and Australian-Caucasian (M=678ms) participants responded significantly faster than Chinese (M=750ms) and African participants did (M=747ms) (all $p< .05$), while the response time did not differ between Chinese and African participants (p=1). A significant Face Race × Race of Participant interaction was also found, F (6,224) =2.41, p=.05, $\eta_p^2 = .05$, with African participants being considerably faster for own-race faces than for Chinese (p=.004) and Caucasian faces (p=.01). No other main effects and interactions were significant (p>.05).

6.4.2.4 Composite face effect (CFE)

A 3 (Face Race) by 4 (Race of Participant) ANOVA performed on the *CFE* scores showed that neither the main effect of Race of Participant nor the main effect of Face Race was significant, F (3, 117) =0.44, p=.72, η_p^2 = .01, and F (2, 234)=0.14, p=.87, η_p^2 = .001, respectively. No crossover interaction between Race of Participant and Face Race was found, F (6, 234)=.91, p=.49, η_p^2 = .02, indicating that holistic processing was as strong for other-race as own-race faces in each race group (see *Figure 6.10*).

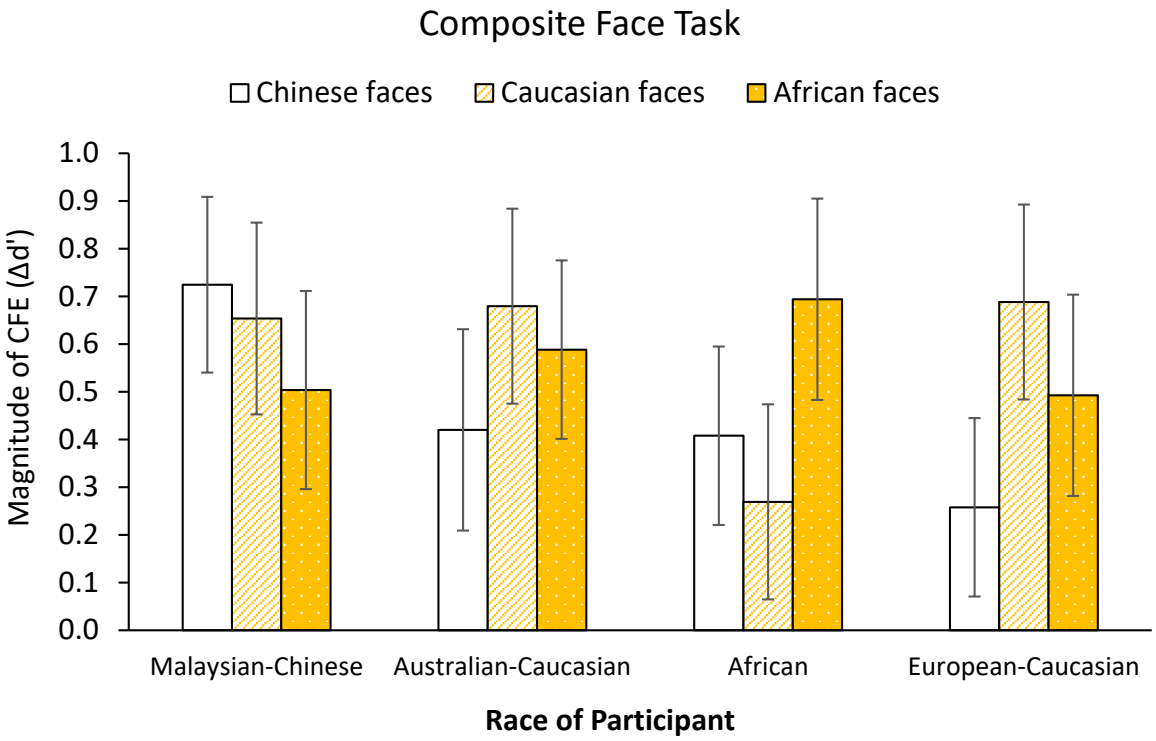


Figure 6.10. The magnitudes of the composite face effect (CFE) for own- and other-race faces for each ethnic group in the composite face task. The CFE was calculated by subtracting congruency effect observed in misaligned condition from that observed in aligned condition (i.e., the alignment by congruency interaction). Error bars indicate standard errors of the mean.

Table 6.1.

Mean d' scores (and standard errors) on the composite-face task as a function of face race, alignment and congruency by race group.

	Malaysian-Chinese (n=31)			Australian-Caucasian (n=30)			African (n=30)			European-Caucasian (n=30)		
	CHI	CAU	AFR	CHI	CAU	AFR	CHI	CAU	AFR	CHI	CAU	AFR
Aligned												
Congruent	2.32 (0.14)	2.36 (0.13)	2.02 (0.14)	2.06 (0.14)	2.49 (0.13)	2.28 (0.15)	1.58 (0.14)	1.66 (0.13)	1.62 (0.15)	1.87 (0.14)	2.41 (0.13)	1.92 (0.15)
Incongruent	1.62 (0.12)	1.65 (0.13)	1.41 (0.13)	1.40 (0.12)	1.70 (0.13)	1.46 (0.14)	1.05 (0.12)	1.28 (0.13)	1.15 (0.14)	1.49 (0.12)	1.52 (0.13)	1.29 (0.14)
Misaligned												
Congruent	1.93 (0.15)	2.32 (0.14)	1.92 (0.14)	2.02 (0.15)	2.32 (0.14)	1.88 (0.15)	1.28 (0.15)	1.78 (0.14)	1.43 (0.15)	1.86 (0.15)	2.40 (0.14)	1.86 (0.15)
Incongruent	1.95 (0.13)	2.27 (0.14)	1.80 (0.13)	1.79 (0.13)	2.21 (0.14)	1.64 (0.13)	1.45 (0.13)	1.66 (0.14)	1.36 (0.13)	1.76 (0.13)	2.22 (0.14)	1.73 (0.13)
CFE *(d')*	0.72 (0.19)	0.66 (0.20)	0.50 (0.21)	0.43 (0.19)	0.68 (0.21)	0.59 (0.21)	0.40 (0.19)	0.26 (0.21)	0.70 (0.21)	0.27 (0.19)	0.70 (0.21)	0.50 (0.21)

Notes: CHI = Chinese faces, CAU = Caucasian faces, AFR = African faces. Composite-face effect (CFE) = *d'* [(aligned-congruent – aligned-incongruent) – (misaligned-congruent – misaligned incongruent)].

Table 6.2

Mean response times in ms (and standard errors) on the composite-face task as a function of face race, alignment and congruency by race group

	Malaysian-Chinese (n=29)			Australian-Caucasian (n=29)			African (n=29)			European-Caucasian (n=29)		
	CHI	CAU	AFR	CHI	CAU	AFR	CHI	CAU	AFR	CHI	CAU	AFR
Aligned												
Congruent	743.99 (25.14)	721.76 (19.04)	718.72 (18.53)	678.73 (25.14)	650.64 (19.04)	662.10 (18.53)	806.98 (25.14)	753.00 (19.04)	729.48 (18.53)	665.98 (25.14)	643.06 (19.04)	637.30 (18.53)
Incongruent	769.27 (22.79)	765.13 (23.39)	754.37 (20.59)	697.54 (22.79)	683.16 (23.39)	699.15 (20.59)	822.90 (22.79)	798.11 (23.39)	741.02 (20.59)	672.60 (22.79)	665.27 (23.39)	666.45 (20.59)
Misaligned												
Congruent	740.12 (23.79)	718.03 (19.19)	733.25 (19.79)	682.72 (23.79)	646.42 (19.19)	660.19 (19.79)	780.99 (23.79)	748.66 (19.19)	686.55 (19.79)	659.75 (23.79)	640.82 (19.19)	635.75 (19.79)
Incongruent	733.98 (24.23)	711.42 (19.06)	722.99 (19.42)	670.27 (24.23)	652.44 (19.06)	662.36 (19.42)	770.90 (24.23)	754.90 (19.06)	702.65 (19.42)	663.24 (24.23)	641.81 (19.06)	639.67 (19.42)
CFE (ms)	21.07 (12.19)	55.82 (14.63)	10.86 (11.75)	16.36 (12.19)	32.25 (14.63)	12.44 (11.75)	61.28 (12.19)	58.67 14.63	41.25 11.75	17.95 (12.19)	32.59 (14.63)	24.58 (11.75)

Notes: CHI = Chinese faces, CAU = Caucasian faces, AFR = African faces. Composite-face effect (CFE) = *RT* [(aligned-congruent – aligned-incongruent) – (misaligned-congruent – misaligned incongruent)].

6.4.3 Whole-part task

6.4.3.1 Accuracy (%).

The main effects of Feature, F (2,234)=181.03, p<.001, η_p^2 = .61] and Condition, F(1,117) = 165.17, p<.001, η_p^2 = .59, and the interaction between the two variables were significant, F (2, 234) = 10.32, p<.001, η_p^2 = .08, suggesting the performance accuracy varied by feature. For every race group tested, participants were more accurate at picking out a previously seen face from one in which a feature had been altered than they were at discriminating between the isolated parts. Furthermore, the main effect of Face Race was significant, F (2,234) = 45.07, p<.001, η_p^2 =.28, whereas the main effect of Race of Participant did not reach significance, F(3,117) = 1.10, p=.35, η_p^2 = .03. Participants generally performed best for Caucasian faces (M=86.60%), followed by African faces (M=84.25%) (p=.05), and then Chinese faces (M=78.04%) (p<.001), with African faces being performed better than Chinese faces (p<.001). As expected, there was a significant interaction between Face Race and Race of Participant, F (6,234) =5.16, p<.001, η_p^2 = .12 (see *Figure 6.11*). Comparisons between face races within each race group showed that participants overall exhibited significantly higher accuracy for own-race than other-race faces. More specifically, Malaysian-Chinese participants were better at identifying Chinese faces, both in the part and in the whole conditions, than African faces (p=.02), but displayed equal performance for Chinese and Caucasian faces (p=1). In contrast, both European- and Australian-Caucasian participants were more accurate at identifying Caucasian faces than Chinese (both p <.001) and African faces (p=.003 and p=.002, respectively). Moreover, Australian-Caucasian participants were better with African faces than Chinese faces (p<.001). For African participants, African faces were identified better than Chinese faces (p<.001), and Caucasian faces being recognised better than Chinese faces (p <.001); however, no significant difference was found between African and Caucasian faces (p=1).

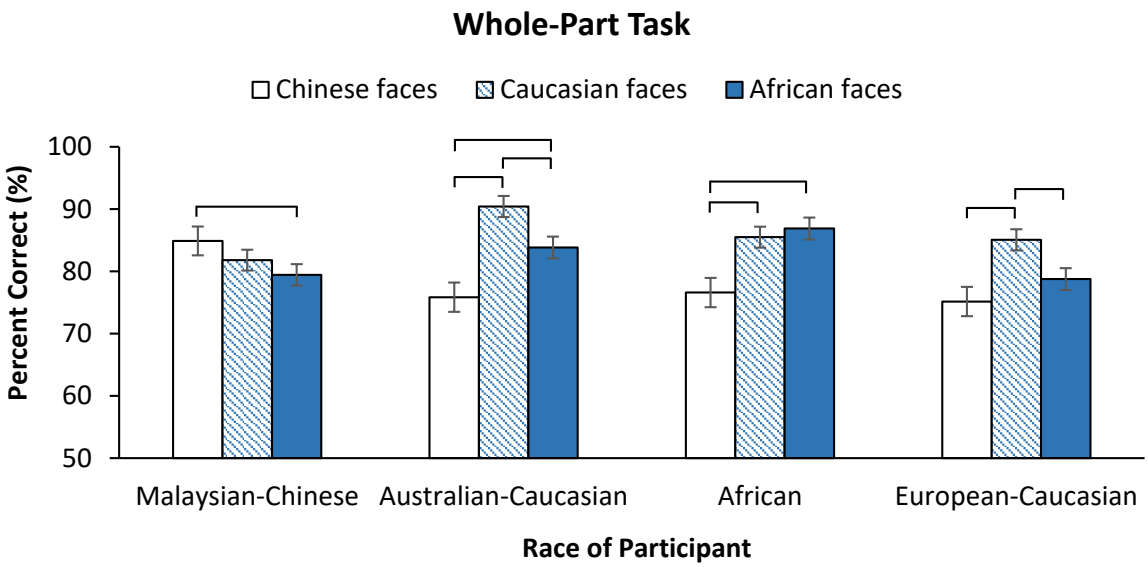


Figure 6.11. Mean percentages of correct responses as a function of stimulus race and participant race. Error bars represent standard error.

There was a significant Feature by Race of Participant interaction, F(6,234)= 2.78, p=.01, η_p^2 = .07. Post hoc comparisons (Bonferroni corrected) showed that African participants' identification accuracy of the mouth part was significantly better than European-Caucasian participants (p=.05), and marginally better than Australian-Caucasian participants (p=.09). Surprisingly, two-way interactions between Face Race and Feature, F(4, 468) = 15.85, p<.001, η_p^2 = .12, and between Face Race and Condition also reached statistical significance, F (2,234) = 12.49, p<.001, η_p^2 = .10, accompanied by a significant three-way Face Race × Feature × Condition interaction, F (4,468) = 2.79, p=.03, η_p^2 = .03. Separate univariate ANOVAs for each of the three races of faces revealed that the interaction between Condition and Feature was significant for Chinese, F(2,240)=11.05, p<.001, η_p^2 = .09, and African faces F(2,240) = 3.11, p=.04, η_p^2 = .03, but not for Caucasian faces, F(2,240)=0.27, p=.76. Post-hoc tests using Bonferroni pairwise comparisons revealed that for both Chinese and African faces, participants were significantly better at identifying the eyes than the nose and mouth (all $p \leq .001$), irrespective of the context of presentation (i.e. whole vs. part

condition). In addition, there was a higher discrimination performance across race groups for the mouth than for the nose of Chinese faces when the face parts were presented in isolation (p=.01) but not when they were presented in the context of the whole face (*p*=.14). Most interestingly for my hypothesis, the three-way interaction between Race of Participant, Face Race, and Condition did not reach significance, $F(6, 234) = 1.13$, p=.35.

6.4.3.2 Response time (ms)

A mixed factorial ANOVA revealed significant main effects of Face Race, $F(2, 234)=11.23$, $p<.001$, $\eta_p^2 = .09$, and Race of Participant, $F(3,117)=12.08$, $p<.001$, $\eta_p^2 = .25$, on mean response time (RT). The main effect of Face Race was driven by a significantly longer RT made in trials composed of Chinese faces (*M*=3.52s) relative to trials composed of either Caucasian (*M*=3.24s) (p<.001) or African faces (*M*=3.34s) (p=.01). The main effect of Race of Participant was driven by a significantly longer RT made by African participants (*M*=4.08) compared with Chinese (*M*=3.35s), European-Caucasian (*M*=3.00s), and Australian-Caucasian participants (*M*= 3.04s) (all $p \leq .001$). However, the interaction between Face Race and Race of Participant failed to reach statistical significance, $F(6,234)=1.55$, $p=.16$, suggesting that participants did not respond significantly faster to own-race faces than to other-race faces. There was also a main effect of Feature, $F(1.89, 209.57)=37.22$, $p<.001$, $\eta_p^2=.25$, Greenhouse-Geisser corrected. Participants generally made faster responses on eye trials (*M*=3.15s), followed by mouth (*M*=3.38s) and nose trials (*M*=3.57s) (all $p <.001$).

The main effects mentioned above were qualified by a significant three-way interaction involving Face Race, Race of Participant, and Feature, $F (12, 444) = 2.57$, $p=.003$, $\eta_p^2 =.07$. Bonferroni-corrected post hoc tests revealed that Chinese participants had tendencies to respond more slowly to the mouth of Chinese faces than that of African and Caucasian faces (both *p*=.06). African participants made slower responses to Chinese-eyes than Caucasian- and African-eyes (both p=.01), but no significant difference was found for

the nose and mouth trials (all p>.05). European-Caucasian participants spent less time on Caucasian mouths than Chinese mouths (p=.05), and more time on Chinese eyes than Caucasian (*p*=.03) and African eyes (p=.01). Australian-Caucasian participants spent significantly less time on the eyes of Caucasian faces than those of Chinese and African faces (*p*=.001 and *p*=.003, respectively), and less time responding to Caucasian mouths than to Chinese mouths (*p*<.001). Moreover, they showed a tendency to respond faster to African mouths than to Chinese mouths (*p*=.06). Taken together, this indicates that the effect of face parts on RT depends on the combination of participant and stimulus race.

In addition, there was a significant main effect of Condition, F (1, 117)=233.66, p<.001, η_p^2 =.68, with longer RTs in the whole condition(M=3.66s) than in the part condition (M=3.07s). The two-way interactions between Feature and Condition, F(2, 234) = 28.11, p<.001, η_p^2 = .20 , and between Face Race and Condition, F(2,234) = 9.16, p<.001, η_p^2 = .08, were significant, accompanied by a three-way interaction, F(3.72, 435.09)=2.11, p=.04, η_p^2 = .02, Greenhouse-Geisser corrected. To investigate this interaction in more detail, multiple pairwise comparisons (Bonferroni-corrected) between Feature and Condition were carried out within each stimulus race. It was found that, for Chinese faces, participants generally responded faster to the eyes than to the nose and mouth (both p<.001) particularly in the whole condition, while no difference between features was detected in the part condition (all p>.05). For Caucasian faces, regardless of the whole-part conditions, participants spent more time on the nose trials than the eye and mouth trials (all $p\leq$.001). Also, their responses towards the eyes were faster than the mouth when those face parts were presented in the context of whole faces (p=.001) rather than when presented alone (p=1). For African faces, participants made the fastest responses to the eyes, followed by the mouth and then the nose (all $p\leq$.001) in the whole condition; however, no significant difference between face parts was observed in the part condition (all p>.05).

6.4.3.3 Whole-part effect (WPE)

When comparing the magnitude of WPE collapsed across features, the main effect of Face Race was significant, $F(2, 234) = 17.61$, $p < .001$, $\eta_p^2 = .13$, such that WPE was stronger for Chinese faces than African ($p < .001$) and Caucasian faces ($p = .002$) while no difference was found between African and Caucasian faces ($p = 1$). Neither the main effect of Race of Participant, $F(3,117) = .11$, $p = .95$, $\eta_p^2 = .003$, nor the critical two-way interaction between Face Race and Race of Participant was significant, $F(5.74,223.86) = 1.21$, $p = .30$, $\eta_p^2 = .03$, Greenhouse-Geisser corrected, indicating that other-race faces could produce a WPE of comparable magnitude to those from own-race faces (see *Figure 6.12*).

When splitting the analysis by facial feature (i.e., eyes, nose, and mouth trials), the significant main effects of Feature, $F(1.83, 214.21) = 14.01$, $p < .001$, $\eta_p^2 = .11$, and Face Race, $F(2, 234) = 17.61$, $p < .001$, $\eta_p^2 = .13$, were qualified by a Face Race × Feature interaction, $F(3.60,421.44) = 3.03$, $p = .01$, $\eta_p^2 = .03$, Greenhouse-Geisser corrected. Further simple effect analyses comparing between the trial types (eyes, nose, and mouth) for each of the face races showed that participants demonstrated a significantly greater holistic advantage for nose and mouth trials of Chinese faces than those of Caucasian (nose: $p = .001$, mouth: $p = .01$) and African faces (nose: $p = .003$, mouth: $p = .03$). However, for eye trials, the magnitude of WPE did not differ between races of faces (all $p > .05$), indicating a complete absence of a holistic advantage for the eye region across face races.

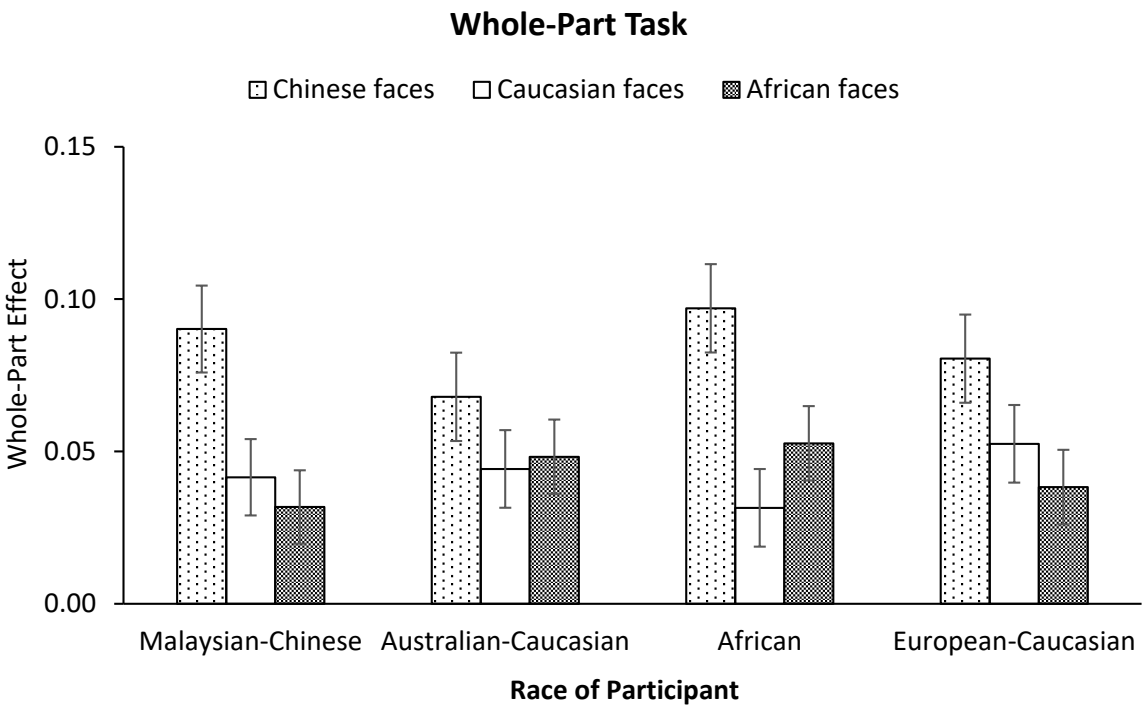


Figure 6.12. The magnitudes of the whole-part effect (CFE) for own- and other-race faces for each ethnic group in whole-part face task. Error bars indicate standard errors of the mean.

	Malaysian-Chinese (*n=31*)				Australian-Caucasian (*n=30*)				African (*n=30*)				European-Caucasian (*n=30*)			
	Eyes	Nose	Mouth	All	Eyes	Nose	Mouth	All	Eyes	Nose	Mouth	All	Eyes	Nose	Mouth	All
Whole trials																
Chinese faces	94.36 (12.81)	76.21 (14.84)	91.53 (12.55)	87.37 *(9.58)*	92.92 (13.17)	73.75 (18.56)	75.83 (17.70)	81.11 (12.59)	89.17 (13.17)	81.25 (18.56)	78.75 (17.70)	83.06 (12.59)	92.92 (13.17)	71.67 (18.56)	78.75 (17.70)	80.83 (12.59)
Caucasian faces	91.94 (11.03)	77.42 (18.86)	86.69 (11.86)	85.35 (10.76)	97.92 (11.03)	90.00 (18.86)	95.00 (11.86)	89.31 (10.76)	90.00 (11.02)	81.67 (18.86)	92.92 (11.86)	88.19 (10.76)	95.42 (11.03)	82.50 (18.86)	90.00 (11.86)	94.31 (10.76)
African faces	94.36 (13.17)	78.23 (18.56)	85.48 (17.70)	86.02 (12.59)	93.33 (12.81)	79.17 (14.84)	90.42 (12.55)	81.67 *(9.58)*	95.83 (12.81)	85.00 (14.84)	92.50 (12.55)	91.11 *(9.58)*	87.92 (12.81)	73.75 (14.84)	83.33 (12.55)	87.64 *(9.58)*
Part trials																
Chinese faces	91.13 (15.37)	72.98 (19.41)	83.07 (16.93)	82.39 (12.14)	90.83 (16.68)	61.25 (21.14)	60.42 (21.67)	69.17 (14.95)	80.42 (16.68)	59.58 (21.14)	70.42 (21.67)	70.14 (14.95)	85.42 (16.68)	58.33 (21.14)	63.75 (21.67)	70.83 (14.95)
Caucasian faces	84.27 (14.27)	69.36 (18.43)	81.05 (15.32)	78.23 (10.77)	93.75 (14.27)	79.17 (18.43)	86.67 (15.32)	80.83 (10.77)	87.50 (14.27)	75.83 (18.43)	85.00 (15.32)	82.78 (10.77)	87.08 (14.27)	75.00 (18.43)	80.42 (15.32)	86.53 (10.77)
African faces	89.92 (16.68)	59.27 (21.14)	69.36 (21.67)	72.85 (14.95)	90.83 (15.37)	69.17 (19.41)	80.00 (16.93)	75.83 (12.14)	87.50 (15.37)	75.42 (19.41)	85.00 (16.93)	82.64 (12.14)	86.25 (15.37)	67.92 (19.41)	73.33 (16.93)	80.00 (12.14)
WPE																
Chinese faces	0.03 (0.10)	0.15 (0.19)	0.13 (0.17)	0.10 (0.09)	0.01 (0.10)	0.09 (0.19)	0.13 (0.17)	0.08 (0.09)	0.06 (0.10)	0.19 (0.19)	0.06 (0.17)	0.10 (0.09)	0.05 (0.10)	0.12 (0.19)	0.11 (0.17)	0.09 (0.09)
Caucasian faces	0.05 (0.10)	0.05 (0.16)	0.03 (0.10)	0.04 (0.08)	0.02 (0.10)	0.07 (0.16)	0.05 (0.10)	0.05 (0.08)	0.02 (0.10)	0.04 (0.16)	0.05 (0.10)	0.03 (0.08)	0.05 (0.10)	0.06 (0.16)	0.07 (0.10)	0.06 (0.08)
African faces	0.02 (0.10)	0.02 (0.16)	0.06 (0.12)	0.03 (0.07)	0.02 (0.10)	0.09 (0.16)	0.07 (0.12)	0.06 (0.07)	0.05 (0.10)	0.08 (0.16)	0.05 (0.12)	0.06 (0.07)	0.01 (0.10)	0.05 (0.16)	0.07 (0.12)	0.04 (0.07)

Table 3.3*. Mean accuracy scores in percentages (and standard deviations) on the whole and part trials (broken down by eyes, nose, and mouth), and the magnitude of whole-part effect (WPE) for each race of face split by participant race*

6.4.4 Global-local task

6.4.4.1 Accuracy (%)

There was a significant main effect of Stimulus Level, F (1,117)=12.50, p=.001, η_p^2 = .10, such that all groups of participants were much better at global (M=96.06%) than local trials (M=93.44%) (p=.001). The main effect of Congruency was also significant, F(2, 234)=37.33, p<.001, η_p^2 = .26, with highest performance for congruent trials (M=96.54%), followed by neutral (M=92.44%), and then incongruent trials (M=95.26%) (all ps <.05). However, no main effect of Race of Participant was observed, F(3,117)=0.97, p=.41. Importantly, a three-way interaction between Stimulus Level, Congruency, and Race of Participants was significant, F(6, 234)= 2.66, p=.02, η_p^2 = .07. Splitting the analyses by Race of Participant, multiple pairwise comparisons (Bonferroni-corrected) showed that the interaction between Stimulus Level and Congruency was significant only in Malaysian-Chinese, F(2,60)= 4.67, p=.01, η_p^2 =.14, and Australian-Caucasian participants, F(2,58)=7.44, p=.001, η_p^2 = .22. In Malaysian-Chinese participants, neutral trials were performed significantly better at global level (M=98.26%) than at local level (M=93.33%) (p=.01) while no between-level difference was found for congruent (p=.31) and incongruent trials (p=.54). In contrast, Australian-Caucasian participants were more accurate at identifying the target for congruent trials when performing the task at local level (M=97.41%) than at global level (M=94.57%) (p=.02), but no significant difference was found for neutral and incongruent trials (both p>.05). It should be noted that participants' proportion of correct responses was near ceiling across trial types (mostly above 90%). Considering that this near-perfect performance could potentially mask the global-local interference effect and render the results less reliable, my subsequent analyses emphasise the response time instead to calculate the global-local interference (GLI) scores, as is traditionally done (e.g., Dale & Arnell, 2014; Navon, 1977; Wang et al., 2012).

6.4.4.2 Response time.

A mixed factorial ANOVA was performed on response times (RT) with Stimulus Level (global vs. local) and Congruency (congruent, incongruent and neutral) as within-subjects variables and Race of Participant as between-subjects variable. Unsurprisingly, there was a main effect of Stimulus Level, $F(1,117)=122.05$, $p<.001$, $\eta_p^2 = .51$. Participants made faster responses to global targets (M=476ms) relative to local targets (M=563ms). The main effect of Race of Participant was significant, $F(3,117)=10.81$, $p<.001$, $\eta_p^2 = .22$, such that African participants (M=583ms) spent more time responding to the target shapes than Malaysian-Chinese *(*M=528ms; p=.01), European-Caucasian (M=482ms; $p<.001$) and Australian-Caucasian participants did (M=484ms; $p<.001$). There was also a significant main effect of Congruency, $F(2,234)=96.49$, $p<.001$, $\eta_p^2 = .45$. Participants made slower responses in incongruent trials (M=536ms) than in neutral trials (M=520ms) and congruent trials (M=503ms) (all $p <.001$), with neutral being faster than congruent trials (p=.01), suggesting that neutral trials can serve as a baseline measure. More interestingly, there were significant interactions between Congruency and Race of Participant, $F(6, 234) =3.79$, p=.001, $\eta_p^2 =.09$, Stimulus Level and Congruency, $F(2,234)=50.36$, $p<.001$, $\eta_p^2 =.30$, Stimulus Level and Race of Participant, $F(3,117) = 7.61$, $p<.001$, $\eta_p^2 = .16$, and there was a three-way interaction between Stimulus Level, Congruency, and Race of Participant, $F(6,234) = 4.38$, $p<.001$, $\eta_p^2=.10$ (see *Figure 6.13*). Separate analyses for the four race groups revealed that the two-way interaction between Stimulus Level and Congruency was significant for all race groups. When Chinese participants were asked to identify target shapes at local level, they responded faster in congruent trials than in incongruent and neutral trials (both $p<.001$) but this difference was not observed at global level (all $p>.05$). This indicates that global shapes which conflicted with the local shapes did inhibit the responses to the local shapes. Similar to Chinese participants, African participants responded more slowly in incongruent trials than in

congruent and neutral trials (both $p<.001$) when identifying the target shapes at local level while no difference was detected between congruent and incongruent trials at global level ($p=.81$). In both European- and Australian-Caucasian participants, the mean RT was significantly higher in incongruent trials than in congruent trials not only at local level (both $p<.001$), but also at global level (both $p=.02$).

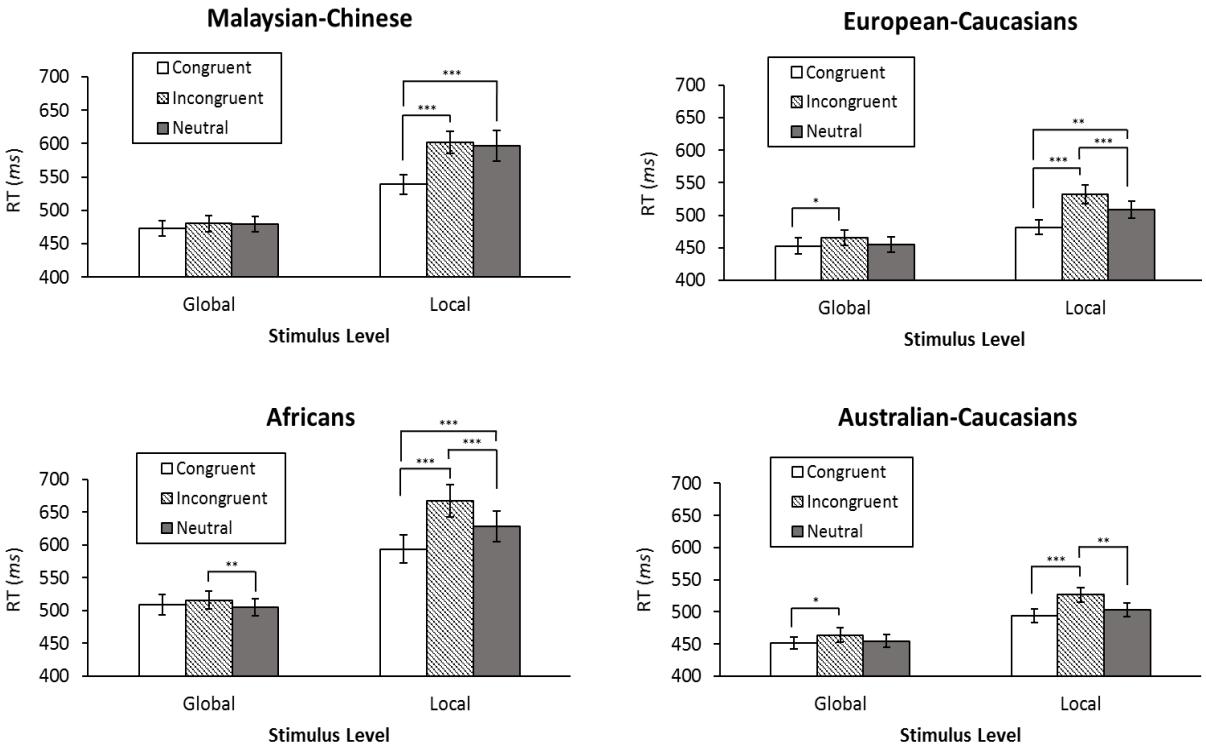


Figure 6.13. Mean response time (in milliseconds, *ms*) for congruent, incongruent, and neutral trials at both global and local levels. Error bars denote standard errors of the mean and asterisks indicate significant differences between trial types (***p<.001, **p<.01, *p<.05).

6.4.4.3 GLI scores

Paticipants' tendency to process general objects more globally than locally was also measured, using the global-to-local interference (GLI) scores. As determined by one-way ANOVA, there was a statistically significant difference between race groups, F (3,117) =

7.29, *MSE*=.002, *p*<.001 (see *Figure 6.14*). The magnitude of GLI in Malaysian-Chinese was significantly greater than Australian-Caucasians (*p*<.001) and marginally higher than European-Caucasians (*p*=.09). Similarly, Africans showed significantly stronger GLI than European- (*p*=.04) and Australian-Caucasians (*p*<.001) did. No significant difference was found between Chinese and African (*p*=.65), or between European- and Australian Caucasian (*p*=.25).

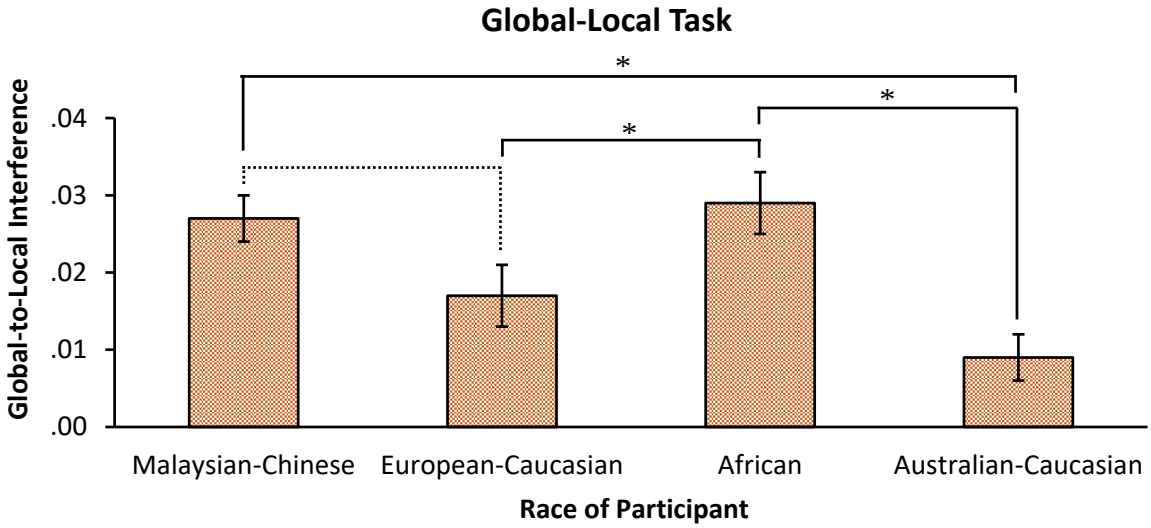


Figure 6.14. The magnitude of global-local interference (GLI) as a function of participant group. Error bars indicate standard errors of the mean. Asterisks indicate significant differences between race groups (**p<.01; *p<.05).

6.4.5 Correlation Analyses

Although participants across race groups showed equally large whole-part and composite effects for own-race and other-race faces, they all presented a significant ORB not only in the yes-no recognition task, but also in the whole-part and composite tasks, in terms of accuracy. To address my primary question of whether the magnitude of holistic processing predicts recognition performance of own- versus other-race faces, Pearson's correlation analyses were performed to determine whether the face recognition ability (FRA) for own- versus other-race faces were related to the three holistic processing indices: composite-face

effect (CFE), whole-part effect (WPE), and global-local interference (GLI). Rather than completely excluding outliers with many valid observations from the inter-task correlational analyses, cases identified more than 2.5 SDs from the mean for a particular measure were replaced by a score plus two times the standard deviations. On this basis, less than 2% of the data were replaced within each task (yes-no task: 1.38%; whole-part task: 1.93%; composite-face task: 1.1%; global-local task: 0.83%).

27 correlations were explored within each race group; I therefore adopted a Bonferroni-corrected critical value (α) of 0.002 (.05/27), two-tailed, for all correlations. After adjusting the α for multiple correlations, the correlations in the opposite direction than theoretically expected were no longer statistically significant (see *Figure 6.15*). While most of the correlations were non-significant, I detected two seemingly moderate correlations between WPE and FRA. That is, among Chinese and African participants, a negative correlation was found between WPE and yes-no recognition performance for their own-race faces (r=-.50, p=.004 and r= -.40, p=.03, respectively). Further analyses showed that these correlations were mainly driven by the *whole-part advantage* on the eye trials (Chinese: r=-.40, p=-.03; African: r= -.47, p=.009). Such an ambiguous pattern is difficult to interpret because it simply reflects that the better participants were at recognising own-race faces, the less holistically they processed own-race faces, particularly the eye region. However, the same pattern did not hold for European- and Australian-Caucasian participants (all p>.05).

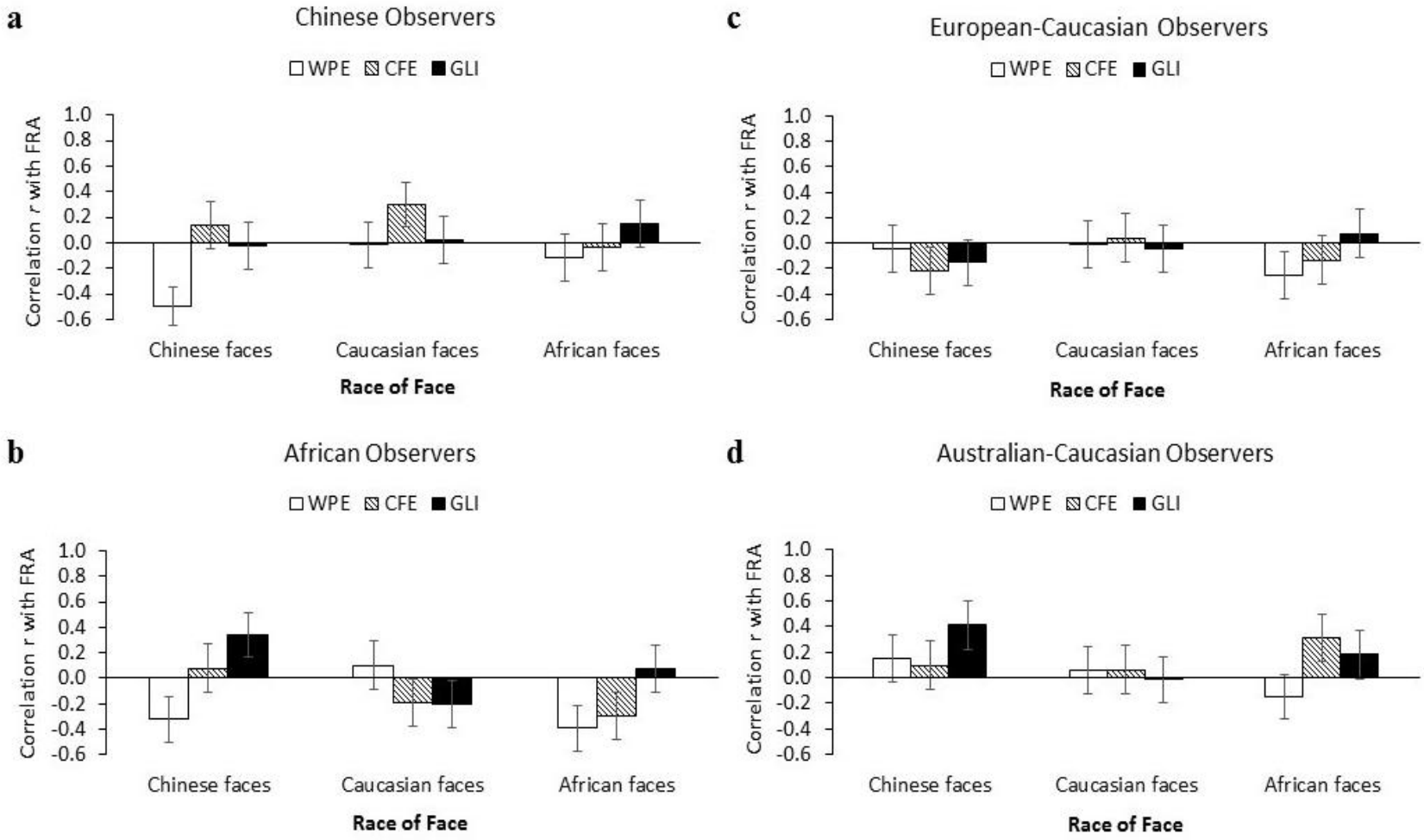


Figure 6.15. Correlations of the holistic processing indices – whole-part effect (WPE), the composite-face effect (CFE), and global-local interference (GLI) – with face recognition ability (FRA) as a function of stimulus race in each race group: (a) Malaysian-Chinese, (b) African, (c) European-Caucasian and (d) Australian-Caucasian. Error bars represent standard errors [$SE_r = \sqrt{(1-r^2)/(n-2)}$].

6.5 Discussion

This cross-cultural study aimed to directly and systematically examine the relationship between holistic processing and recognition of own- and other-race faces, by using Malaysian-Chinese, African, European-Caucasian, and Australian-Caucasian participants. The current experiment yielded four main results. First, the ORBs were pronounced in all face-related tasks (i.e., face recognition, composite-face and whole-part tasks). Second, participants across race groups generally showed holistic processing – as indexed by both composite-face effect (CFE) and whole-part effect (WPE) – not only for own-race faces, but also for other-race faces. Third, in a global-local task, both European- and Australian-Caucasian participants were less susceptible to the global-local interference effect (GLI), indicating a stronger local processing bias as compared to Malaysian-Chinese and African participants. Fourth, for both WPE and CFE measures there was no substantial correlation with face recognition performance, indicating that the ORB in face recognition cannot be solely accounted for by reduced holistic face processing for other-race faces.

Across four race groups, participants generally exhibited a robust ORB in face recognition memory, although less prominently for Caucasian faces. Most interestingly, Malaysian-Chinese participants, who had grown up in a highly multi-ethnic and Western-influenced Asian country, performed equally well at recognising Chinese and Caucasian faces, but less well at recognising African faces. This is consistent with the finding by Tan, Stephen, Whitehead, & Sheppard (2012), who further explained the observed deficit in the recognition of African faces as a product of inefficient eye movement strategy (i.e., fixations clustered around the nose and eyes more than the mouth). On the other hand, African participants recognised African faces as well as they recognised Caucasian faces, but were

less good at recognising Chinese faces. In contrast, both European- and Australian-Caucasian participants recognised Caucasian faces better than Chinese and African faces.

The majority of the population of Malaysia is either Malay (50.1%), Chinese (22.6%), Indian (6.7%) or indigenous (11.8%) (The World Factbook, 2015); fewer are Africans or Caucasians (mostly non-citizens). Considering the relatively high proportion of Chinese in the society, it was initially anticipated that Africans and European-Caucasian participants, who had resided in Malaysia for half a year or more on average prior to participating in this study, would recognise Chinese faces well. However, this was not the case. The results showed that African and European-Caucasian participants were typically poor at recognising Chinese faces, indicating that staying in a multi-ethnic environment does not necessarily allow them to develop sensitivity to facial features which are essential for recognising unfamiliar other-race faces. Perhaps the reduction of ORB requires sufficient individuating experience and social interaction, rather than mere exposure to other-race faces (Walker & Hewstone, 2006a). The current finding that Malaysian-Chinese and African participants could recognise Caucasian faces equally as well as their own-race faces should not be too surprising because Malaysian-Chinese and African participants, who were students attending a branch campus of a British university, were more likely to have increased social contact with Caucasian people and Western culture than they did with each other. Besides, a larger exposure to Caucasian faces in the mass media (e.g., western movies) and perhaps more experience in actively individuating them in everyday life may also lead to improvements in perceptual sensitivity to diagnostic features on Caucasian faces.

To test the holistic account of ORB, I extended previous research by using both composite-face and whole-part tasks which have been widely used as direct measures of holistic processing. In the complete composite task, regardless of race of faces, participants generally made more mistakes and were slower at matching identical top face halves in the

incongruent trials than congruent trials and such congruency effect was reduced when the top and bottom face halves were misaligned (i.e., an interaction between alignment and congruency), suggesting a robust composite-face effect (CFE). According to the experience-based holistic account of ORB, a larger CFE would have been obtained for own-race faces than other-race faces (Bukach et al., 2012; de Heering & Rossion, 2008). My results did not provide support for this account: in the current data, I did observe a sizable CFE for other-race faces in each ethnic group. Although there seemed to be trends for greater magnitude of CFE for own-race faces than other-race faces, none of these differences was close to reaching statistical significance and the size of the difference was so weak as to suggest that there was no difference. Some previous studies reported evidence of weak or no CFE for other-race faces when faces are unfamiliar (Bukach, Cottle, Ubiwa, & Miller, 2012; Rhodes, Ewing, et al., 2009; Tanaka et al., 2004), but there is an increasing number of recent studies that have failed to replicate this effect (Horry, Cheong, & Brewer, 2015; Konar, Bennett, & Sekuler, 2010; Michel, Rossion, et al., 2006). Consistent with the latter, my results clearly demonstrated that even other-race faces were still processed somewhat holistically in multiple ethnic groups, calling into question whether own-race faces are perceived more holistically than other-race faces.

In the whole-part task, I detected ORBs in identification accuracy for all ethnic groups, indicating that both configural and featural information in own-race faces were identified significantly better than in other-race faces. This result is in line with previous claims that both individual facial features (e.g., eyes, nose, mouth) and configural information are better processed for own-race faces as compared to other-race faces (Hayward et al., 2013; Hayward, Rhodes, & Schwaninger, 2008), raising the possibility that the key feature of own-race face processing is not stronger holistic processing per se, but rather more effective processing of both featural and configural information. While faces

were processed holistically, participants must also have access to face parts to some extent because their recognition of isolated features was above chance level (at least 69% accurate), supporting the notion that featural processing co-exists with holistic processing. Most interestingly, African participants tended to be selectively more sensitive to both featural and configural changes around the mouth region as compared to both European- and Australian-Caucasian participants. Such an advantage for the bottom part of the face may have resulted from experience-based tuning of the face processing system for identifying own-race faces (although this may not necessarily be due to a more rich, detailed holistic representation of own-race faces). This demonstrates the importance of race in terms of directing where one looks at a face – in this case, the lower parts of an African face could be more diagnostic of identity than the lower parts of a Caucasian face (Arizpe, Kravitz, Walsh, Yovel, & Baker, 2016; see also Ellis, Deregowski, & Shepherd, 1975). Perhaps, for African participants, scanning or studying the lower parts with more weight facilitates the processing of own-race faces but not other-race faces, consequently driving the ORB in identification accuracy.

Across race groups, participants exhibited the whole-part effect; they were generally much better at recognising target face parts presented in a whole face than when the same part was presented in isolation. This finding indicates that their feature identification performance could have benefited by the presence of configural information. Assuming a holistic account of the ORB, holistic processing could generally be more efficient if the perceived face is of own race, which would in turn predict a stronger whole-part effect. Contrary to my expectations, the magnitude of whole-part effect for other-race faces was comparable to that of own-race faces. These results are inconsistent with previous reported findings that own-race faces could produce a whole-part effect of greater magnitude than other-race faces (DeGutis, Mercado, Wilmer, & Rosenblatt, 2013; Michel, Caldara, & Rossion, 2006), but are partly consistent with those presented by Crookes et al. (2013) and

Mondloch et al. (2010) where holistic processing of own-race and other-race faces did not differ in strength.

When tested with unfamiliar faces, participants exhibited CFE and WPE of similar magnitudes for both own- and other-race faces, despite the typical recognition deficit for other-race faces (although less so for Caucasian faces). Similar magnitude of holistic processing for own- and other-race faces echoes results of previous studies, and concurs with the previous reports that expertise with own-race faces may improve the ability to process face features and their spatial relations rather than merely augment holistic processing (Hayward, Rhodes, & Schwaninger, 2008). These data therefore cast doubt upon the role of holistic processing in the ORB. In fact, considerable evidence has accumulated showing that holistic processing can sometimes be generalised to facial morphologies that are less visually experienced without extensive individuating (e.g., Harrison et al., 2014; Hayward et al., 2008; Horry et al., 2015; Mondloch et al., 2010). The current results provide compelling evidence that holistic facial representation is able to accommodate faces of different races to a certain extent and the magnitude of the holistic processing may depend on facial morphology (Wang et al., 2015; Zhao, Bülthoff, & Bülthoff, 2015).

Wang et al. (2012) reported that the magnitude of holistic processing measured by composite-face and whole-part tasks consistently predicts how well own- and other-race faces are recognised. In the present study, however, participants' memory for own- and other-race faces did not seem to be affected by the magnitude of holistic processing. The failure to find evidence for a correlation is surprising given the prevalent postulation in the literature that holistic processing is important for both perceiving and recognising faces. This null finding cannot be attributed to any confound derived from the stimulus variability because multiple crossover interactions between participant race and race of stimulus in terms of performance accuracy were observed in each face task. Instead, it suggests that the magnitude

of holistic processing may be related only indirectly to differences in recognition memory performance for own- and other-race faces. Extensive individuating experience with own-race faces could enhance face recognition ability (Rhodes, Ewing, et al., 2009), but such experience may not be required to generalise holistic processing to other races of faces. Such an interpretation is 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 (McKone et al., 2007). Alternatively, it is possible that certain non-configural cues (e.g. race-specific diagnostic features) can also be more readily extracted from own-race than from other-race faces and therefore reduce the holistic effects.

This is first study to use Navon figures to compare global-local processing differences between Malaysian-Chinese, African, Australian-Caucasian, and European-Caucasian participants. My results extended the previous findings by demonstrating that both Malaysian-Chinese and African groups were more susceptible to global-local interference (GLI) than Caucasian groups (European and Australian), indicating a reduced ability to inhibit the influence of holistic information on piecemeal processing. This result is in agreement with numerous studies that provided evidence of stronger global processing in East Asians, and weaker local processing, as compared to Western Caucasians (Masuda & Nisbett, 2001). It also provides strong support for the notion that information-gathering strategy (global versus local processing) for general stimuli can be culture-dependent (Lao, Vizioli, & Caldara, 2013; McKone et al., 2010). In line with the domain-specificity hypothesis, the magnitude of GLI did not significantly correlate with holistic face processing measures and face recognition ability, suggesting that such low-level perceptual biases for information processing may not necessarily be generalizable to high-level face processing tasks.

For several reasons, the present study provides compelling evidence for a lack of ORB in holistic processing. First, many studies which reported that other-race faces are processed less holistically than own-race faces involved a single race of stimulus or just one participant race, and therefore limit the generalisation of their findings to other populations. Given the large amount of variability between observers, and the fact that the variability between stimulus sets could affect the performance outcome, it is crucial to collect empirical evidence from multiple ethnic groups using an identical experimental paradigm. In order to bolster the external validity of my conclusions, I tested participants of four different ethnic groups with three races of faces. This helps to verify that any own-race recognition advantage or difference in holistic processing between race groups is likely to be due to differential experiences with own- and other-race faces, and that one race of face is not simply easier to discriminate relative to other races of faces. Indeed, the ORBs in performance accuracy were found across face tasks, and therefore it is very unlikely that the lack of differences in holistic processing between own- and other-race faces obtained in the current study was due to an intrinsic difference in the difficulty of the faces used to represent the three races.

The current finding that holistic processing can in fact be employed for other-race faces despite lower recognition performance in the face memory task has implications for the possible mechanisms underlying a perceptual account of the ORB. It seems that merely perceiving a face stimulus to be an own-race face is not sufficient to process it more holistically than other-race faces. Also, the lack of association between either CFE or WPE and face recognition performance (Rezlescu et al., 2014) has two important implications. The first is that holistic processing is not the only factor contributing to accurate face identification, and the second is that the process of perceiving faces holistically may be a critical stage of the initial face matching or detection but does not necessarily lead to accurate identification at the individual level. Under this assumption, the advantage of early holistic

processes would be that it would quickly bind facial features into a coherent global stimulus that could then be further processed by a specialised face recognition mechanism (Taubert & Alais, 2009). In this way, holistic processing may be necessary but not sufficient for adequate discrimination of individual faces (Watson, 2013; Watson & Robbins, 2014).

The current finding that own- and other-race faces were processed holistically raises a few methodological concerns regarding the stimulus characteristics as well as the typical task performed on the face stimuli. Holistic processing can be sensitive to different types of facial stimuli (Riesenhuber & Wolff, 2009; Rossion & Rossion, 2015). In Wang, Hu, Short, & Fu, (2012), faces were cropped roughly to the hairline but this clearly leads to variation in the shape of the cropping, which may serve as an extra-facial clue that could be used by participants to perform the face tasks without relying on the face identity. Therefore, in the present experiment, 'egg-shaped' faces were used rather than the whole-head stimuli. Even though this practice has been recently criticised by Rossion (2013) in that it could lead to poor alignment of faces and a reduction in the size of the composite-face effect, the observation of composite-face effect for both own- and other-race faces rules out the possibility that the oval shape mask used to conceal face outline attenuates the difference of holistic effect between own- and other-race faces. As previous studies reported that unfamiliar face recognition relies more on external features (e.g., Ellis, Shepherd, & Davies, 1979; Sporer & Horry, 2011; Toseeb, Keeble, & Bryant, 2012), it would be interesting to further investigate whether the removal of outer features and facial outline affects one's capabilities to process faces holistically, and if so, to what extent.

Hills & Lewis (2008) found that participants' face identification accuracy was significantly poorer following the processing of the local elements of Navon letters, and also when inducing a local bias in participants using global/local shapes. In addition, it was also found that the Navon task can affect subsequent eye movement patterns, identification

accuracy, and holistic processing during face recognition (Gao et al., 2011). Given that whichever global/local level the participants attended to last affected their face identification accuracy, in the present study, participants always performed the global-local task last so that only the order of the three face tasks was counterbalanced. Yet, the malleability of own- and other-race face processing under different task contexts that promote different perceptual strategies should not be overlooked.

I am aware of potential issues with the counterbalanced task order which could have masked the genuine cross-race differences in holistic processing. In DeGutis, Mercado, et al. (2013) , the authors presented the five tasks to their participants in a fixed order: other-race effect contact survey, Cambridge Face Memory Test (CFMT) Caucasian, CFMT Asian, part-whole task (PW) Caucasian, and PW Asian. The authors reasoned that performing these tasks in a fixed order decreases the between-subjects variance attributable to different test orders but leaves open the possibility of order effects. In the present experiment, the order of face tasks was completely counterbalanced across participants. This could have resulted in the lack of difference in holistic processing measures between own- and other-race faces. Specifically, presenting yes-no recognition task, either preceded or followed by a holistic task could induce strong modulations of behavioural performance due to some sort of task-specific strategy that carried over to the subsequent tasks. This potential issue could be addressed in future work by exploring whether there is a difference in recognition performance over own- versus other-race trials as well as in the magnitude of holistic effects when the face tasks were presented in a complete counterbalanced order and when the tasks are presented in a fixed order.

6.6 Summary

Despite a long-standing controversy over the role of holistic processing in cross-race face recognition, memory deficits for other-race faces have often been attributed to the fact

that other-race faces are processed less holistically than own-race faces. Perhaps the most striking finding of the current work is that the holistic effects, as indexed by composite-face effect and whole-part effect, for other-race faces were similar in size to that observed for own-race faces. In other words, participants processed all face stimuli holistically independent of stimulus race. Although I detected the robust nature of ORB in recognition accuracy, the emergence of holistic processing for other-race faces did not predict smaller ORB in face recognition memory in any of the four ethnic groups. These observations directly counter to my prediction derived from the experience-based holistic account of ORB in face recognition.

Notably, my current results resonate with several recent studies showing that holistic processing is not directly linked with face recognition ability (Richler, Wong, & Gauthier, 2011; Richler, Floyd, & Gauthier, 2015) and can sometimes be elicited by both own- and other-race faces without extensive individuating experience (e.g., Harrison et al., 2014). Taken together, these observations refute the assertion that the ORB in face recognition is a consequence of reduced holistic processing for other-race faces. Holistic processing may play a significant role in the early stages of face recognition, possibly at the level of face detection or face matching that place lower cognitive demands on memory; however, it is not sufficient for removing the other-race recognition deficit. This rather varied evidence also suggests that the degree of holistic processing applied to a face stimulus may not be as strongly modulated by its perceived race identity as commonly expected; instead, it seemed to be somewhat dependent on the facial physiognomy, stimulus characteristics and tasks performed on them.

In conclusion, the current study employed both composite-face task and whole-part task, demonstrating that own- and other-race faces are subject to similar magnitudes of holistic processing. Most strikingly, the emergence of holistic effects for other-race faces did not preclude the observation of ORBs in face recognition performance. The current findings

not only contrast with general assumptions that holistic processing is always stronger for own-race faces, but also question the commonly claimed evidence in support of a strong association between the face memory and holistic face processing systems. These results converge with recent studies suggesting that the ORB in face recognition is not fully explained by a reduced magnitude of holistic face processing. This would tentatively suggest the generalisation of holistic processing to different races of faces has been underestimated in the literature and the holistic processing mechanisms underlying own- and other-race faces may be more malleable than previously thought. Further research needs to clarify the role of holistic processing in face recognition and to unravel how exactly holistic processing could be generalised to other-race faces without extensive individuating experience with other-race people.

Chapter 7

The Effects of Attentional Shift towards Diagnostic Features on the ORB

7.1 Introduction

Many researchers propose that the ORB, a robust phenomenon characterised by better recognition of own-race compared to other-race faces, is caused by expert face processing mechanisms being employed for own-race faces but not for other-race faces (Michel et al., 2006; Valentine & Endo, 1992), whereas other researchers have proposed that people are more motivated to process own-race faces more accurately than other-race faces (Sporer, 2001). Meanwhile, socio-cognitive accounts suggest that own-race faces are processed in an effortful individuating manner that is resource demanding, whereas other-race faces are processed in a shallow categorical manner (MacLin & Malpass, 2000; but see Kloth, Shields, & Rhodes, 2014). Although these accounts are not mutually exclusive, the specific mechanism by which perceptual expertise elicits differential recognition of other-race faces is a matter of some debate and requires further elucidation.

It has been proposed that the ORB can be accounted for by the perceptual expertise hypothesis: with experience, individuals develop a learned prototype which reflects useful features for accurately recognising own-race faces (Valentine, 1991). The more exposure to faces of different races, the more familiar the system becomes with different races and the more the ORB diminishes. Evidence for this perceptual expertise hypothesis in explaining the ORB has been mixed. On the supportive side, practice distinguishing between other-race faces can reduce the ORB. For example, (Malpass, Laviguer, & Weldon (1973) found that practice at perceptual discrimination between own-race and other-race faces in the laboratory can at least temporarily reduce the magnitude of the ORB (see also Elliott, Wills, &

Goldstein, 1973; Goldstein & Chance, 1985). More recently, work by Sangrigoli and colleagues (2005) has found that with increasing exposure and experience with other race faces, particularly during childhood, the direction of ORB could be reversed. In their study, individuals of Korean heritage who were adopted as children by Caucasian families in Europe showed a reversal of the ORB by adulthood. Despite their Korean heritage, these adopted participants who grew to maturity among Caucasian families showed effects similar to their adoptive Caucasian parents, finding it more difficult to correctly recognise Asian than Caucasian faces. These findings indicate that a lack of contact may lead to a lack of expertise with the dimensions on which other-race faces vary (see MacLin & Malpass, 2001). This is consistent with the recent findings that lower levels of expertise with other-race faces may elicit less holistic and relatively more feature-based processing of other-race faces (Hayward et al., 2013; Michel et al., 2006; Zhao et al., 2014).

Although the idea that own-race faces are processed more holistically than other-race faces due to perceptual expertise seems logical, there is another potential perceptual explanation for the ORB based on the types of features processed and physiognomic differences between races. Based upon Valentine's (1991) face-space model, every face is stored within a multidimensional face-space along relevant dimensions. Other-race faces do not vary consistently along these dimensions and as such are clustered close together farther away from the mean. This makes them more difficult to distinguish from each other, but easy to differentiate from own-race faces. As the dimensions of face-space guide how well faces are encoded, Hills and Lewis (2006) proposed that the ORB can be attributed to the physiognomic characteristics of faces of different races. For instance, African and Caucasian faces have different physiognomic variability for different features (McClelland & Chappell, 1998): African faces have more variability in the nose and mouth shape than the eye and hair colour, whereas Caucasian faces have the reverse pattern.

Ellis, Deregowski, & Shepherd (1975) have shown that African and Caucasian participants tend to describe faces based on these differences. Caucasian participants described the hair colour, hair texture, and eye colour more frequently; however, these features would not be good for discriminating between different African faces since most African faces share similar eye colour, hair colour and hairstyle. Their data show that African participants described lips, mouth, and nose more frequently, especially when describing African faces. Furthermore, African participants produced more varied descriptions, using more features than Caucasian participants. This may represent an important differentiation between the face recognition abilities of African and Caucasian participants or physiognomic differences between African and Caucasian faces. Such an inherent difference in the most diagnostic cues for individualisation of own- and other-race faces could lead to a reduced sensitivity to diagnostic features for other-race faces (Furl, Phillips, & O 'Toole, 2002). Thus, the utility of the facial dimensions (featural and/or configural information) for individualisation may vary between races. For example, eye colour could be less useful for discriminating between Asian than Caucasian faces.

7.1.1 Face Training Studies

Finding methods to ameliorate the ORB is an important contemporary research topic because of its practical implications in forensic settings (e.g. eyewitness identifications). One of the most frequently discussed behavioural interventions for reducing the ORB in face training studies is with perceptual experience. Lavrakas, Burl, & Mayzner (1976) conducted a training study, in which Caucasian participants were given a concept-learning visual training task. The training faces were made from an IdentiKit, and the two concepts that participants had to learn were either light eyes or a conjunction of dark eyes and thick lips. The magnitude of the ORB was reduced by hours of extensive training with trial-by-trial feedback. However, the effect was short-lived, and one week later there was no difference between trained and

untrained participants, demonstrating the robust and persistent nature of the ORB (Meissner & Brigham, 2001). Lavrakas et al. also tested whether the type of contact was relevant in the ORB of the participants. Their results indicated that those Caucasian participants who had African friends had a lower ORB than those who simply knew more African participants.

Tanaka & Pierce (2009) trained Caucasian participants to distinguish Hispanic and African-American faces either at an individual level or at a categorical level by race. Results showed that, compared to basic-level training, individuation training improved their performance in a subsequent recognition test and evoke a larger face-selective ERP component (posterior N250). More interestingly, the N250 generalised from trained faces to unfamiliar within-category faces after individuation training but not categorisation training. The authors argued that the recognition of other-race faces by adults is not inflexible and unresponsive to perceptual experience: but is plastic and receptive to the effects of perceptual training. Both behavioural and neural evidence provide support for the relationship between increased perceptual expertise and observed ORB in recognition memory; meanwhile, it seems possible that the ORB can be temporarily eliminated in adults through an individuation training for other-race faces (e.g., Tanaka & Pierce, 2009).

Many laboratory training studies have based their findings on a popular perceptual model of the ORB: the face-space model of face memory (Valentine's, 1991; see Chapter 4 for more discussion). In this model, all faces are stored in some form of multi-dimensional space in which the dimensions represent physiognomic features. The dimensions are tuned towards the most frequently encountered faces throughout development (Lewis, 2004). This means that physiognomic differences across races are implicitly represented in the face-space such that the dimensions used for encoding and recognising own-race faces will be more diagnostic than for other-race faces (Hills & Lewis, 2006, 2011). Hence, individuals from own-race groups tend to fixate on certain diagnostic features (Caldara, Zhou, & Miellet,

2010) which are useful for individuating between own-race faces, but depend more on race-specific features for other-race faces making them "look the same" (Valentine & Endo, 1992).

Levin (2000) proposed a feature selection theory in which observers extract the most diagnostic facial features that contain individuating information from own-race faces. However, they extract a race feature as the most diagnostic for other-race faces. By this theory, other-race faces are thought to be processed according to a prototype and therefore are not individuated, thus making them more difficult to recognise. It is important to note that this feature-selection account (Levin, 1996, 2000) has been interpreted by some authors as being inconsistent with an expertise account as it proposes that the ORB may not be a consequence of a lack of perceptual expertise with other-race faces, but rather as arising from the fact that people tend to socially and perceptually process individuals from other races at the category level, failing to engage available subordinate-level processing strategies. Evidence in support of a default difference in processing strategies includes the finding that the recognition memory effect can be reduced simply by warning observers about the ORB and asking them to individuate other-race faces (Hugenberg et al., 2007).

Hugenberg et al. (2007) found that simply instructing participants to ‘‘pay close attention to what differentiates one particular face from another, especially when that face is not of the same-race as you’’ improved Caucasian participants' recognition accuracy for African faces. With this instruction, they recognised African faces equally as well as Caucasian faces. Hugenberg et al. argued that this was not due to an increased motivation because participants who were more motivated to be accurate to all faces still manifest the ORB. These results suggest that the ORB may not necessarily be due to an inability of the perceptual system to encode other-race faces. Rather, it could be due to the differential allocation of attentional resources to own-race and other-race faces where own-race faces are

individuated more effectively than other-race faces. However, Bornstein, Laub, Meissner, & Susa (2013) failed to replicate Hugenberg et al.'s finding regarding the effectiveness of special instructions at encoding. Instead, they found that instructing participants on the ORB prior to retrieval did not reduce the ORB; that is, it did not improve performance particularly for other- race faces. The authors offered an explanation to account for the discrepant findings: they used different photos of the same individual at encoding and retrieval (therefore more ecologically valid), whereas the previous study used the identical photos at encoding and retrieval.

Hills and Lewis (2006) adopted a perceptual learning paradigm to examine if the ORB can be reduced by training observers to attend to diagnostic features critical for African and Caucasian faces in a face recognition task. They trained Caucasian participants to attend to the lower parts of the faces (e.g., nose and mouth), which had previously been identified as those features used by African participants to describe African faces (Ellis et al., 1975). The rationale for this training is that if the lower regions of the face are more diagnostic of identity among African faces than are features in the higher regions, then attending to those identity-diagnostic features in the lower regions should enhance recognition performance for African faces. As a result, the ORB was reduced when Caucasian participants were given training directing them to the lower parts of African faces, suggesting that attending to a more detailed representation of the dimensions on which other-race faces systematically vary can improve recognition. However, this study did not assess whether the attentional training improved the recognition of African faces or worsened the recognition of Caucasian faces. To assess this further, Hills and Lewis (2011) did another experiment where they trained Caucasian observers to look at features critical for identifying African faces and Caucasian faces. Their results showed that the lower portion of the face was critical for identifying Black faces and the upper portion of the face for White faces, suggesting that attending to the

diagnostic features that are critical for identification of individuals of a particular race reduces the ORB.

While individuation training (Hussain, Sekuler, & Bennett, 2009; McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2011; Tanaka & Pierce, 2009) and instructions (Hugenberg et al., 2007; Megreya, 2018; Rhodes, Locke, Ewing, & Evangelista, 2009) do sometimes lead to a reduction in the ORB, Hills and Lewis (2011) extended these findings by demonstrating that extensive training was not required to alter the nature of the ORB. Based on the evidence that the initial fixations are important for accurate recognition of faces (Hsiao & Cottrell, 2008), they used fixation crosses to guide Caucasian participants' attention to either the nose or the eyes of African and Caucasian faces. Given that the nose is more diagnostic in differentiating between African faces, the authors hypothesised that recognition of African faces would be superior following a fixation cross preceding the nose, whereas recognition of Caucasian faces would be inferior. Conversely, following a fixation cross preceding the eye region, recognition accuracy of Caucasian faces would be superior to the recognition of African faces. As expected, Caucasian participants showed a reduced ORB when they were cued to attend to the lower region of the face for African faces and the upper region for Caucasian faces.

To address a limitation of Hills and Lewis' (2011) study that only Caucasian participants were tested, Hills, Copper and Pake (2013) conducted a similar study on both Caucasian and African participants. They recorded participants' eye movements while looking at Caucasian and African faces following fixation crosses that preceded the bridge of the nose (between the eyes) or the tip of the nose. Consistent with the previous finding, Caucasian faces were more accurately recognised when following high fixation crosses (that preceded the bridge of the nose) than when following low fixation crosses, and vice versa for Black faces. Furthermore, these effects were independent of participant race.

In this chapter, two experiments were designed to test the hypothesis that directing initial fixations to diagnostic features would reduce the ORB by taking both the race of face stimuli and observers into consideration. Although Experiment 5A and 5B employed identical procedures, they included different participant race groups. I tested not only Caucasian and African participants, as reported in Hills et al. (2013b), but also the three major races in Malaysia (Chinese, Malay and Indian) who have frequent direct and indirect exposure to four face races (Chinese, Malay, Indian, and Caucasian). Experiment 5A explores any effect the fixation crosses have on the recognition performance for own- and other-races faces in Malaysian-Chinese, compared with Australian-Caucasians and Black South Africans. Experiment 5B further investigates whether the cueing effect would be stronger for Malaysians within the range of faces typically experienced in the multiracial population.

7.2 Experiment 5A

One limitation of Hills and Lewis' (2006) study is that only Caucasian participants were tested. Although Africans were later included as a comparison group by Hills, Cooper, & Pake (2013), their African participants had extensive exposure to Caucasian faces (i.e., they had lived in the UK for more than 2 years on average). It also remains unknown whether the fixation cross findings of Hills et al. (2013) can be generalised to Southeast Asian population. Given that East Asians tend to process faces more holistically than Caucasians (Blais et al., 2008; Crookes et al., 2013; McKone et al., 2010), this cultural difference may render the fixation cross training inappropriate for improving the ORB in non-Western-Caucasian individuals.

The first aim of this experiment was to fill the literature gap by investigating the cueing effect in Malaysian-Chinese participants who were born and raised in a multiracial country but had relatively low direct contact with Caucasian and African people. Using a similar design to Hills and Lewis (2011), Malaysian-Chinese, Australian-Caucasian, and

Black South African participants' ORB was measured in a classic old/new recognition paradigm when viewing Chinese, Caucasian, and African faces, following fixation crosses preceding either the eyes (a high fixation cross), nose (a centre fixation cross) or mouth (a low fixation cross).

The second aim of this experiment is justified by the need to replicate and extend Hills, Cooper, & Pake's (2013) study. It must be noted that in Hills et al. (2013) and Hills & Lewis (2011), full faces with external features were used. Given that the inclusion of external features (e.g. hair) can affect the representation of internal features on unfamiliar faces (Axelrod & Yovel, 2010) and the magnitude of ORB (Sporer & Horry, 2011; see Chapter 5 for more discussion), I used face stimuli cropped into an ellipse shape to ensure that participants were not merely relying on the hairstyle or hair shape cues to recognise faces. Furthermore, it is also unclear why Hills and colleagues (2013) only presented fixation crosses preceding the eyes and nose but not the mouth. Given that the mouth can be diagnostic for African faces (Ellis et al., 1975), in this study, I compared participants' recognition accuracy between a high fixation cross (between the eyes), a middle fixation cross (on the tip of the nose), and a low fixation cross (on the mouth).

To the best of my knowledge, the position of the face stimulus remained the same across trials in Hills et al. (2013), allowing their participants to predict the location of presentation of the next face. The general position of the face may have contributed to the effect of start position. In the current study, I increased the variation in the relative location of facial features with respect to the preceding fixation cross (for more details, see 7.2.1.4 section), to prevent participants from planning any eye movements until the face appears on the screen. To eradicate low-level pictorial recognition, I used faces of two different expressions instead of only changing the size of the stimuli, as done by Hills, Ross, & Lewis (2011).

More recently, Tan, Stephen, Whitehead, & Sheppard (2012) found that Malaysian-Chinese adults showed a recognition advantage for own-race Chinese faces and other-race Caucasian faces but showed the ORB for less experienced Black African faces, with which they had less experience. The authors suggested that a reduced ORB in Caucasian faces may be explained by high exposure to Caucasian people, directly because the participants were studying in a branch campus of a British university and indirectly through media (e.g. radio, western movies). Tan and colleagues (2012) also reported that Malaysian-Chinese participants employ a combination of Eastern and Western eye-movement strategy when perceiving faces, by attending most at the eye and nose regions. The authors suggested that the lack of attention on the mouth was detrimental to Malaysian-Chinese participants' ability to recognise African faces. According to Levin's (2000) feature-selection hypothesis, the perceptual system is able to process other-race faces, provided the fixation cross directs the attentional system to encode the relevant features. A few studies have reported that training observers to fixate at a facial feature useful for identification of a particular race face improves recognition accuracy of other-race faces, thus reducing the ORB (Hills et al., 2013b; Hills & Lewis, 2006; Hills & Lewis, 2011). If there is an attentional mechanism to the ORB, then guiding attention to the lower features of an African face (e.g. mouth) should cause it to be recognised as well as guiding attention to the eyes of a Caucasian faces. If the perceptual expertise hypothesis is true, cueing Malaysian-Chinese to the mouth region will not produce any facilitative effect on the encoding of facial information on African faces.

7.2.1 Methods

7.2.1.1 Design

A 3 × 3 × 3 mixed design was used, with race of face stimuli (Chinese, Caucasian and African) and position of cued fixations (eyes, mouth, nose) as the within-subjects variables and race of participants (Chinese, Caucasian and African) as the between-subjects variable.

The dependent measures were discriminability *d'*, percent correct and response bias *c*. For eye movement data, the mean fixation duration and mean number of fixations on each AOI were exported and analysed.

7.2.1.2 Participants

20 Malaysian-Chinese (7 males; M_{age} = 20.18, SD = 1.50), 20 Western-Caucasian (4 male; M_{age} = 20.59, SD = 1.91) and 20 African (10 males; M_{age} = 23.92, SD = 3.32) young adults took part in the experiment. Chinese participants were all born and grew up in Malaysia and had not lived overseas for more than 9 months. Caucasian participants who took part were all Australian-born students recruited at Macquarie University, Sydney. None of them had lived outside of Australia for more than a month. African participants (12 Nigerian, 3 Kenyan, 3 Ugandan, 2 Sudanese) were overseas student who had resided in Malaysia for 1.5 years on average (SD = 1.45). All participants provided their written, informed consent prior to study participation. The study followed a protocol that was approved by the University of Nottingham, School of Psychology Ethics Committee.

7.2.1.3 Apparatus and materials

The experiment was conducted on a Tobii T120 eye-tracker using the Tobii Studio software. Eye movements of participants were recorded by the eye-tracker during the experimental tasks. Participants' responses were recorded using a mouse and standard computer keyboard. At a viewing distance of approximately 60cm, stimuli were displayed on a 17-inch TFT monitor with screen resolution set at 1280 x 1024 pixels.

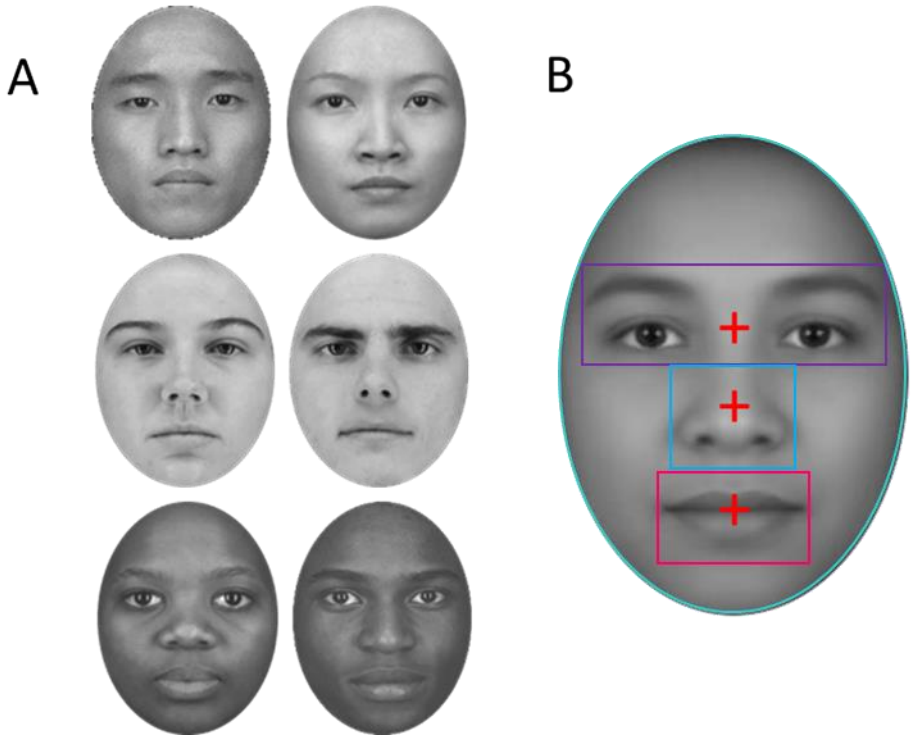


Figure 7.1. (A) Examples of egg-shaped face stimuli: Each row shows a male and a female face for each race group (Chinese, Caucasian, and African); (B) A face with the spatial position of the fixation crosses superimposed and four AOIs were defined by outlining the full face, eyes, nose, and mouth regions.

Stimuli consisted of 108 grayscale images showing 36 Chinese, 36 Caucasian and 36 African young adult faces (see *Figure 7.1A*). Chinese facial images were collected from the student population at the University of Nottingham Malaysia Campus; Caucasian faces were obtained from students at Macquarie University, Australia. African faces were requested from Coetzee's (2010) face database, consisting of students studying at the University of Pretoria, South Africa. All stimuli were full-frontal faces with two different expressions (neutral and smiling) for each. The original images were first cropped to form an ellipse shape that excluded external features (leaving an oval shape with no hair on the top and sides) to avoid non-facial clues (e.g., hairstyle). To minimise the low-level image cues (e.g., skin colour information), all face images were transformed into 8-bit grayscale images in Adobe

Photoshop CS6 and were aligned on the eyes' position using PsychoMorph software. Faces subtended visual angles of 9.4˚×13.1˚ while fixation crosses were 2mm thick and 15mm high and wide (1.4˚×1.4˚) when viewed from 60 cm. Faces were presented as grayscale images to facilitate stimulus standardisation in the light of existing evidence that skin colour plays a minor role relative to other facial features in the ORB in both adults (Bar-Haim, Saidel, & Yovel, 2009) and infants (Anzures, Pascalis, Quinn, Slater, & Lee, 2011). For eye-tracking analysis, four areas of interest (AOIs) were drawn on all the facial stimuli highlighting the eyes, nose, mouth and full face (as shown in *Figure 7.1B*).

7.2.1.4 Procedure

Participants were tested individually in an eye-tracking laboratory. A nine-point calibration procedure was administered in the beginning of both study and test phases, which required participants to track a moving red circle around a white screen. Recalibration was made whenever the drift correction error was larger than 1 degree of visual angle. Participants' eye movements were recorded during the whole experiment. Face stimuli were presented in three blocks according to the race of the faces (Chinese, Caucasian and African faces). Each involved three phases: (1) learning phase, (2) distraction phase, and (3) recognition phase. During the learning phase, 18 faces were presented for 5 seconds per image. Each trial began with a blank screen for 600ms, followed by a fixation cross for 1 second. This fixation cross cued the eyes, nose or mouth of the subsequent face stimulus. Participants were instructed to fixate on this fixation cross until the face appeared. The location of the fixation cross was randomized across trials with the prerequisite that an equal number of faces appeared at each cued location (eyes, nose, or mouth). Each face stimulus appeared randomly at one of the six possible locations (top left, top right, middle left, middle right, bottom left or bottom right) for 5 seconds so that the general position of the face was

unpredictable, preventing participants from planning any eye movements until the face had actually appeared on the screen.

For each fixation cross location, 1/3 were Chinese, 1/3 were Caucasian, and 1/3 were African. Participants were instructed to rate each face for distinctiveness on a 7-point Likert scale by responding to the question ‘How easy is it to spot this face in a crowd?’ (1 being ‘extremely easy’ and 7 being ‘extremely hard’). Next, they performed a 3-minute distracter task in which they had to fill out a demographic questionnaire. In the subsequent recognition phase, 18 previously studied faces were presented, intermixed with 18 novel faces. Each face was presented for 5 seconds. Participants had to indicate if they have seen the face before by responding with the key ‘Z’ (Yes) or ‘M’ (No) on a computer keyboard. It is important to note that, for each target face, the position of the fixation cross was always matched from learning to test. Both target and distractor faces were randomly distributed across the three cueing conditions and the order of blocks was randomised across participants.

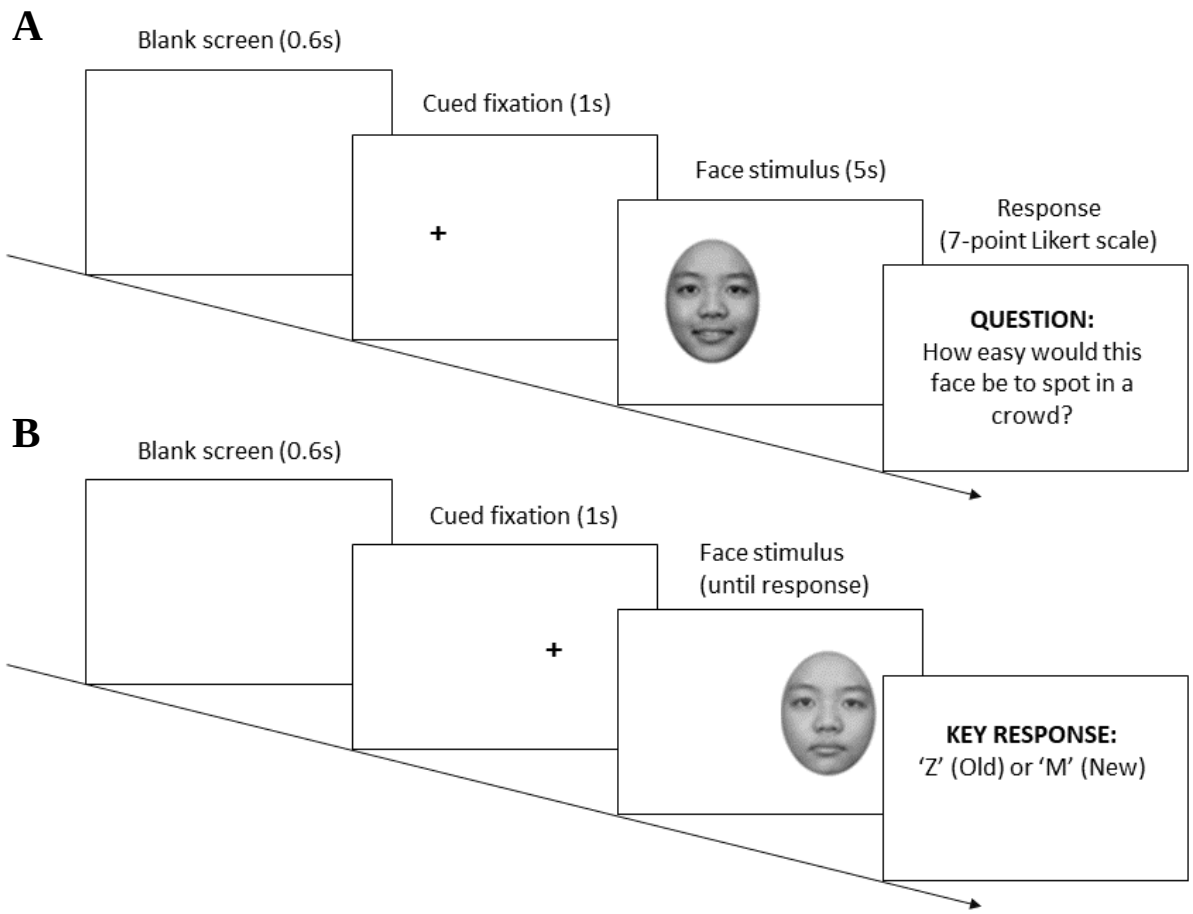


Figure 7.2. An example of trial presentation in the learning (A) and recognition (B) phases

7.2.2 Behavioural Results

The hypothesis that the location of the first fixation affects the recognition accuracy was tested by analysing recognition accuracy as a function of the location of the first fixation. The data was coded such that for each trial the location of the first fixation was either the eyes, nose or mouth. Trials in which participants did not fixate on the fixation cross presented before the face stimulus were removed from the analysis.

7.2.2.1 Recognition sensitivity.

A 3 (race of observer) × 3 (face race) mixed factorial ANOVA was performed on recognition sensitivity *d'*. No significant main effect of race of observer was found, F (2, 57)

= 0.89, p = .42. The main effect of Face Race was significant, F (2, 114) = 5.50, p = .01, η_p^2 = .09. Caucasian faces (M=1.21, SD=0.51) were recognised significantly better than Chinese (M=0.97, SD = 0.61) (p=.008) and African faces (M=1.04, SD = 0.48). The interaction between Face Race and Race of Participant was marginally significant, F (4, 114) = 1.87, p = .07, η_p^2 = .07. Simple main effect analyses revealed a significant ORB in Malaysian-Chinese and Australian-Caucasian participants, but not in African participants. Chinese participants recognised own-race faces better than African faces (p=.03). Caucasian participants recognised own-race faces better than Chinese (p=.02) and African faces (p=.02). African participants showed no significant ORB.

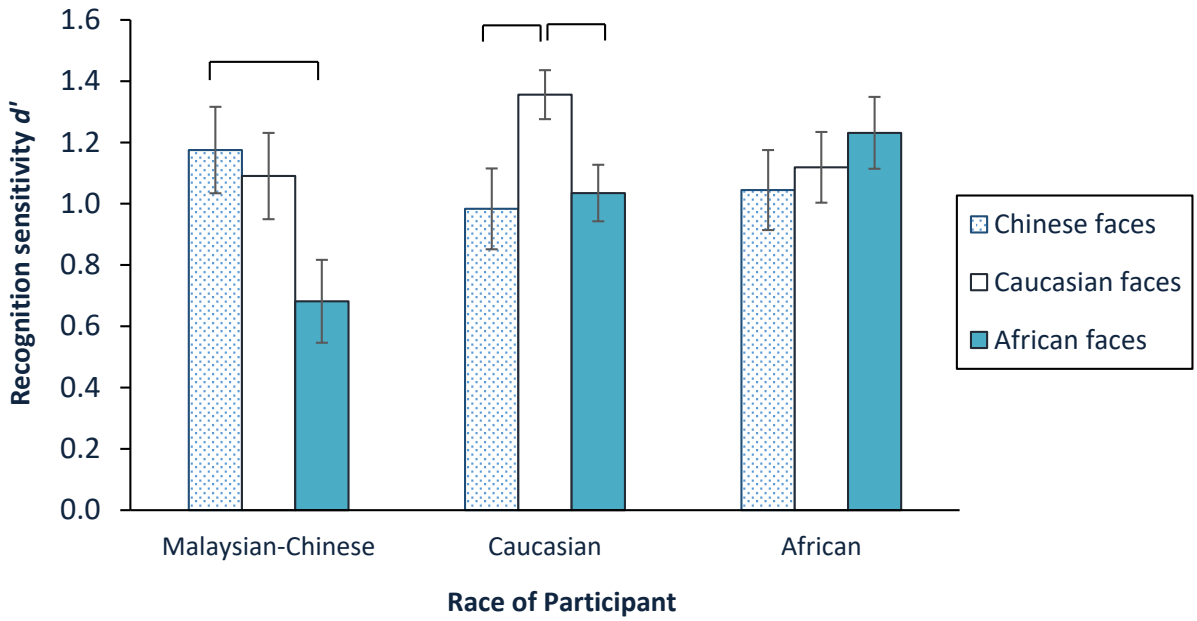


Figure 7.3. d' for Chinese, Caucasian, and African faces in Malaysian-Chinese, Caucasian, and African participants. Error bars represent standard error of the mean.

7.2.2.2 Response bias *c*.

A similar ANOVA was performed to check for any difference in response bias (c). Neither the main effect of face race, F (2, 108) = 0.34, p=.72, nor the main effect of race of

participant, F (2, 57) = 2.34, p=.12, was significant. Furthermore, the interaction did not approach significance, F (4, 108) = 0.80, p=.53, indicating that participants, regardless of their race, did not respond more or less conservatively to own-race faces than to other-race faces.

7.2.2.3 Percentage correct.

A 3 (race of participant) × 3 (face race) × 3 (cued feature) mixed factorial ANOVA was performed on the average percentage correct scores. No significant main effect of race of observer was found, F (2, 57) = 0.89, p = .17. The main effect of face race was significant, F (2, 114) = 5.84, p = .004, η_p^2 = .09, showing that Caucasian faces (M=72%, SD=9.3) were recognised better than Chinese (M=67.90%, SD = 10.85; p=.008) and African faces (M=68.50%, SD = 9.3; p=.01). The interaction between face race and race of participant was significant, F (4, 114) = 2.98, p = .02, η_p^2 = .10. Chinese participants had higher recognition accuracy for Chinese faces than for African faces (p=.002). Caucasian participants recognised Caucasian faces significantly better than Chinese (p=.007) and African faces (p=.02). However, consistent with *d'* measure, no difference between face race was found in African participants (all p>.05).

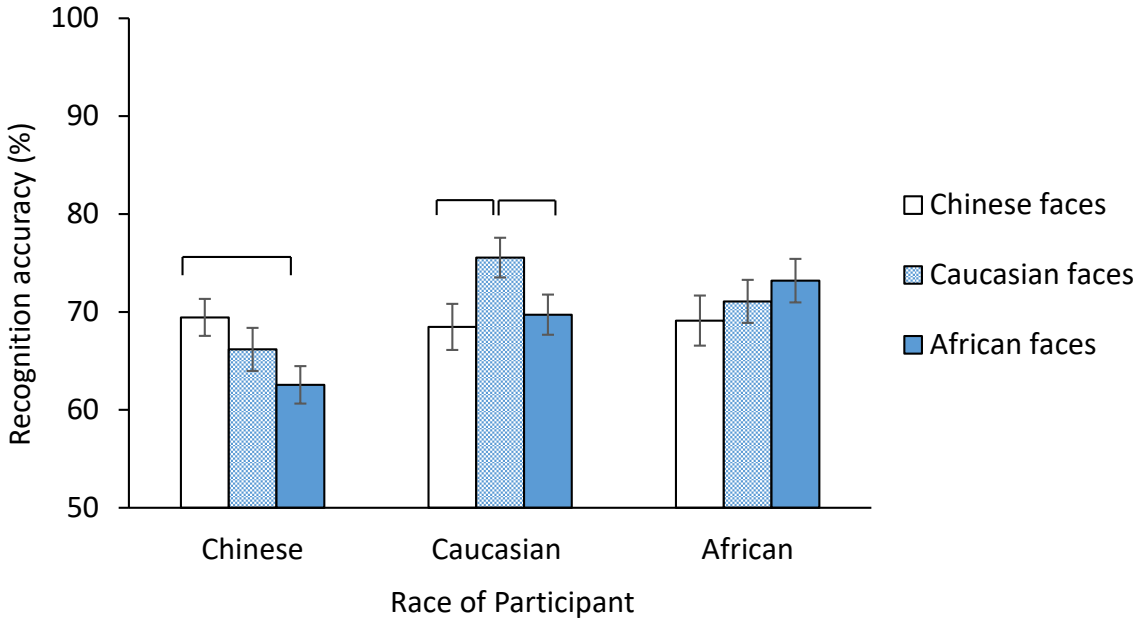


Figure 7.4. Mean recognition accuracy (%) for Chinese, Caucasian and African faces in Chinese, Caucasian, and African participants. Error bars show standard error.

Interestingly, there was a significant main effect of cued feature, F (2, 114) = 12.75, p <.001, η_p^2 = .18, where participants performed significantly better when the fixation cross was on the eye region (M=73.4%, SD=10.08) than when it was on the nose (M=68.1%, SD=10.85; p=.001) or mouth (M= 67%, SD=8.52; p<.001) regions. No significant interaction was found between cued feature and face race, F(4,228)=0.86, p=.49. Interestingly, the interaction between feature and race of participant was significant (see *Figure 7.5*), F (4, 108) =3.21, p=.02, η_p^2=.06. Bonferroni-corrected post hoc analyses revealed that Chinese participants tended to recognise faces better when cued to nose region compared to eye and mouth regions (p=0.5 and p<.001 respectively). For Caucasian participants, their recognition accuracy was higher when the eyes (p=.05) or nose (p=.02) was cued than when the mouth was cued. However, African participants did not show any effect of fixation cross position (all p>.05).

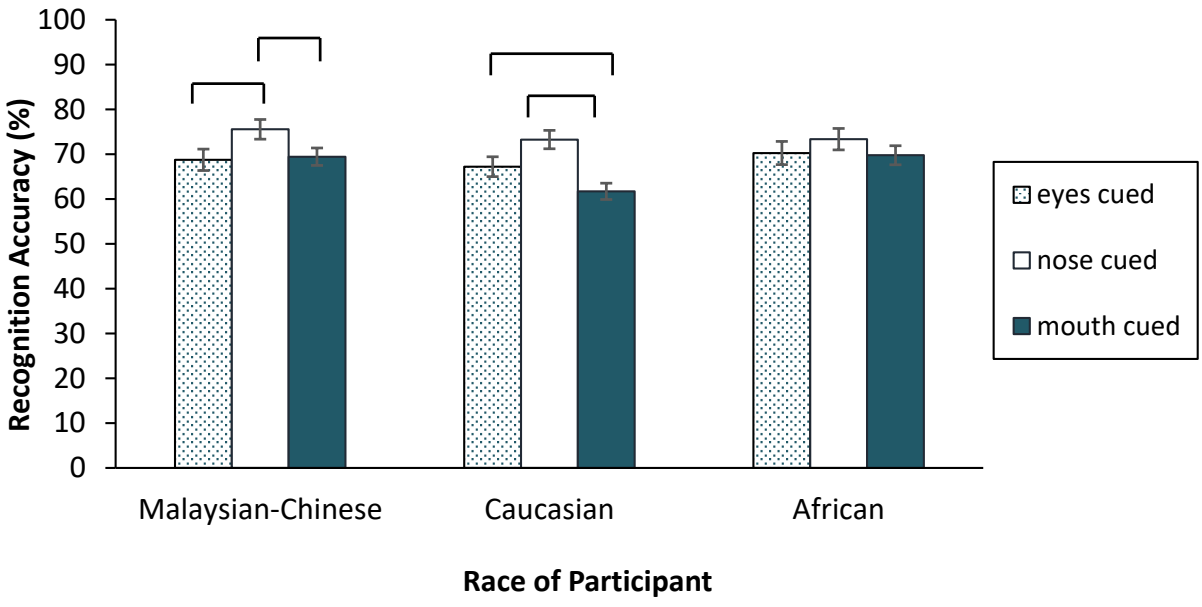


Figure 7.5. Mean percentage correct (%) for each cueing condition (eye, nose, and mouth) in Malaysian-Chinese, Caucasian, and African participants. Error bars represent standard error.

7.2.3 Eye-tracking results

Three areas of interest (AOIs; eyes, nose, and mouth) were predefined on each face stimulus independently in a similar manner to Hills and Lewis (2011; see *Figure 7.5*). These predefined areas were not visible to participants. The fixation duration and fixation count in each AOI were recorded. To deal with the unequal sizes of the AOIs, the subsequent analyses were conducted on area-normalized AOIs (calculated by dividing the proportion of time spent fixating in the AOI by the proportion of the screen the AOI occupied; see Bindemann, Scheepers, & Burton, 2009; Fletcher-Watson, Findlay, Leekam, & Benson, 2008). Two 3 (participant race) × 3 (face race) × 2 (phase: learning vs. recognition) × 3 (cued feature) × 3 (AOI) mixed factorial ANOVAs were performed separately on the average total fixation duration and average total number of fixations in each AOI.

7.2.3.1 Average total fixation duration.

The main effect of participant race did not reach significance, F (2,57) = 1.67, p=.20. The main effect of experiment phase was significant, F(1,57)=9.79, p<.003, η_p^2 =.15, in which average total fixation time was 80ms longer in the recognition phase of the experiment than the learning phase (p=.003). A significant main effect of face race was revealed, F (2, 114) = 8.91, p<.001, η_p^2 =.14, such that Chinese faces received shorter viewing time than Caucasian (p=.009) and African faces (p<.001). The main effect of feature cued was significant, F (1.64, 93.32) = 34.85, p<.001, η_p^2 =.38. The fixation duration was shorter when the eyes were cued than when the nose or mouth was cued (both p<.001). There was also a significant main effect of AOI, F (1.64, 93.67) = 38.40, p<.001, η_p^2 =.40, in which participants showed higher average total fixation duration on the nose than on the eyes

(p<.001) and mouth (p<.001), and higher for the eyes than the mouth (p=.04). This effect interacted with participant race, F (4, 114) = 3.67, p=.01, η_p^2 =.11. The pattern of this interaction suggested that there was a difference in fixation duration on each AOI between the three participant race groups. Chinese participant fixated longer on the nose than eyes (p=.001) and mouth (p<.001), with a marginally significant difference between the eyes and mouth (p=.08). For Caucasian participants, no difference was found between the eyes and nose (p=.74); however, the fixation duration on the eyes (p<.001) and nose (p<.001) was significantly longer than the mouth. For African participants, the fixations on the mouth were longer than the eyes (p<.001) and mouth (p=.001).

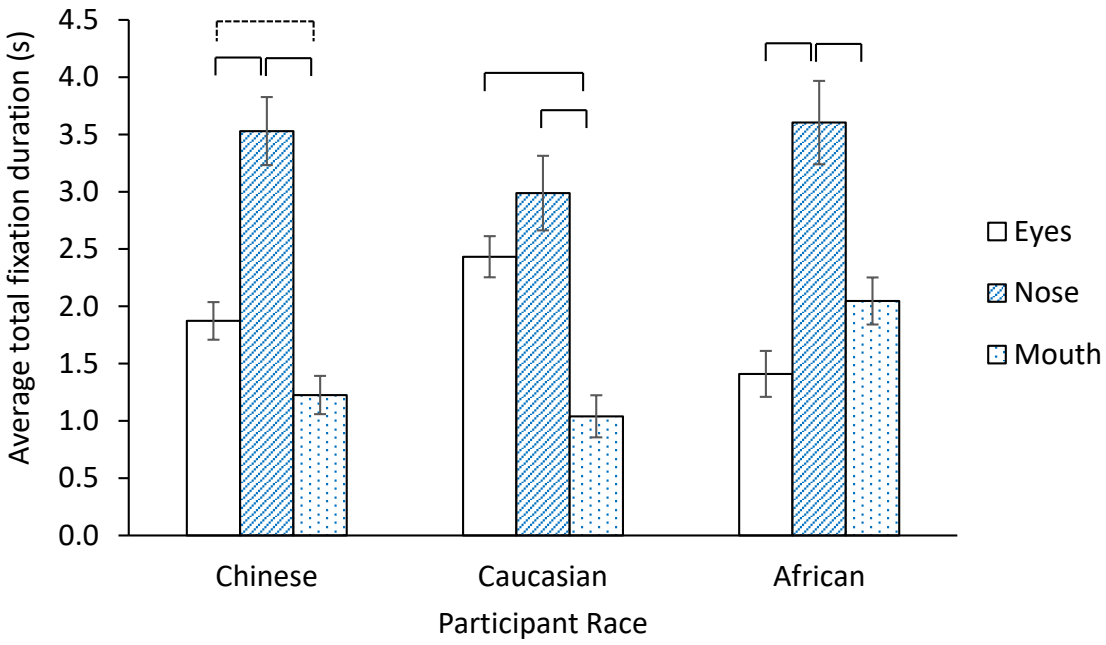


Figure 7.6. Average total fixation duration (area-normalised) on each AOI for Chinese, Caucasian and African participants. Error bars represent standard error.

There was a significant four-way interaction between phase, face race, cued feature, and AOI, F (5.39, 307.31) = 4.00, p=.001, η_p^2 = .07. Split analyses by experimental phase revealed the three-way face race × cued feature × AOI interaction was significant only in the *learning* phase, F(5.81, 330.89) = 5.27, p<.001, η_p^2 =.09, but not in the recognition phase, F

(4.81, 274.24) = 1.33, p=.25. For the learning phase, further simple main effect analyses performed separately for each AOI showed that the face race × cued feature interaction was significant only for the eye fixations, F (4, 236) = 8.47, p<.001, η_p^2 =.13, and nose fixations, F (4, 236) = p<.001, η_p^2 =.10, but not for mouth fixations, F(3.22, 190.08) = .94, p=.45. This indicates that, when encoding facial information, the location of the first fixation influenced how long participants looked at the eye and nose regions, and this effect interacts with the perceived race of face.

When the eyes were cued, Chinese and Caucasian faces both received higher average total fixation durations on the eyes than African faces (both p<.001) whereas African faces received higher average total fixation durations on the nose than Chinese (p<.001) and Caucasian faces (p=.02). When the nose was cued, Caucasian eyes received higher average total fixation durations than African eyes (p=.002). When the mouth was cued, Caucasian eyes were fixated longer than Chinese (p=.008) and African eyes (p<.001), and Chinese eyes were fixated longer than African eyes (p=.04); however, African noses were fixated longer than Chinese (p=.003) and Caucasian noses (p<.001). Overall, these results indicate that the nose region is more diagnostic for identifying African faces whereas the eye region has more diagnostic cues for identifying Chinese and Caucasian faces.

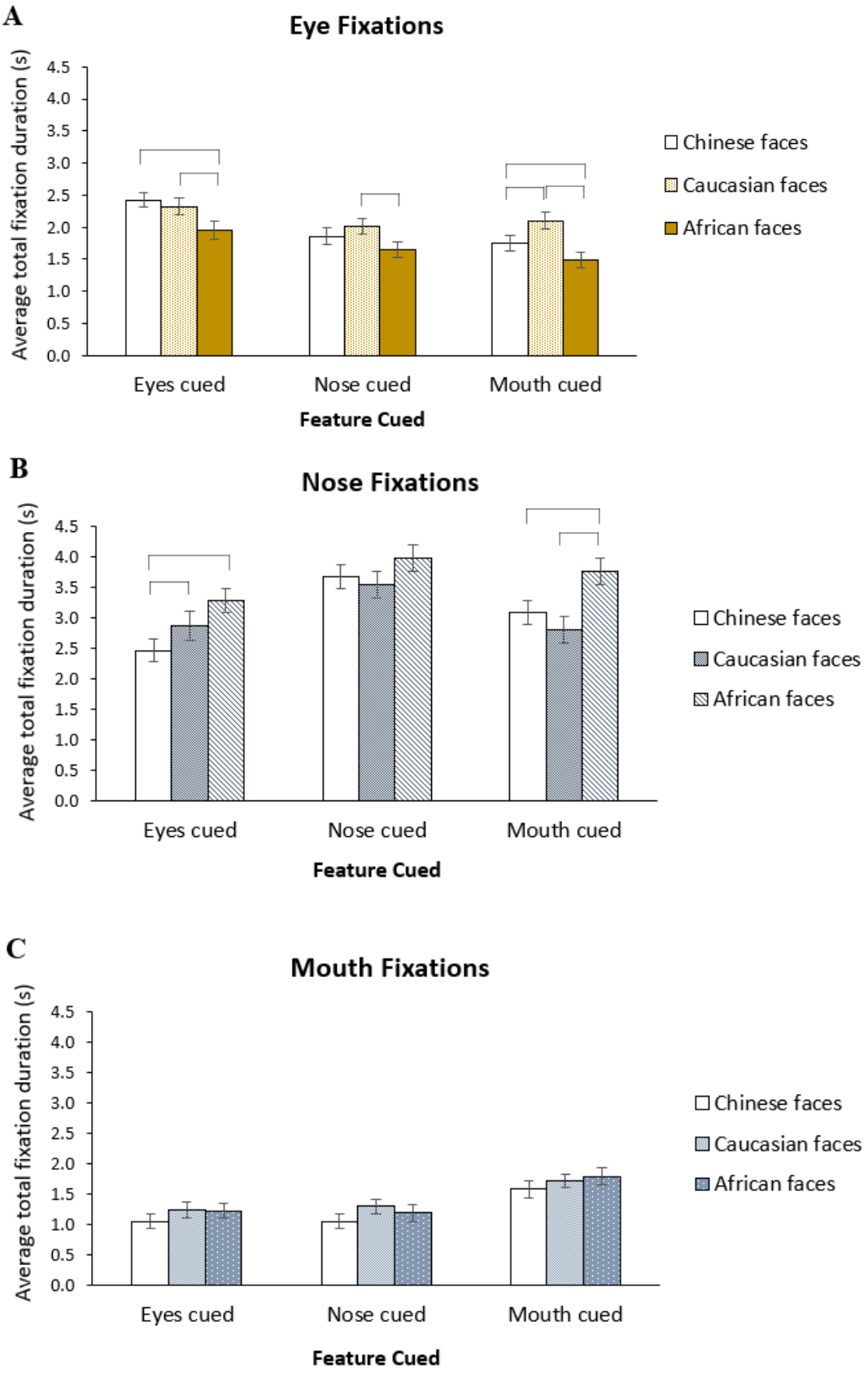


Figure 7.7. Average total fixation duration (area-normalised) on the eyes (A), nose (B), and mouth (C) for Chinese, Caucasian and African faces. Error bars represent standard error.

7.2.3.2 Average total fixation count.

An ANOVA performed on average total number of fixations showed that the main effect of participant race was not significant, F (2, 57) = 2.13, p=.13. However, there was a significant main effect of phase, F (1, 57) = 11.41, p=.001, η_p^2 = .17. Participants made more fixations during recognition phase than learning phase (p=.001). There was a significant main effect of face race, F (2, 114) =10.67, p<.001, η_p^2 = .16, showing that Chinese faces received fewer fixations than Caucasian (p=.001) and African faces (p<.001). The main effect of feature cued was significant, F (1.53, 87.36) = 66.50, p<.001, η_p^2 =.54, in which participants made more fixations when the nose or the mouth was cued than when the eyes was cued (both p<.001). The main effect of AOI was also significant, F (1.61, 91.96) = 46.69, p<.001, η_p^2 =.45. Bonferroni corrected pairwise comparisons demonstrated that the nose was more likely to be fixated on than the eyes (p<.001) and mouth (p<.001), and the eyes received marginally greater number fixations than the mouth (p=.06). There was a significant two-way interaction between AOI and race of participant, F (4, 114)=3.90, p=.005, η_p^2 =.12 (see *Figure 7*.8). Both Chinese and African participants looked more frequently at the nose than the eyes and mouth (all p<.001) while no significant difference was found between the eyes and mouth (Chinese observer: p =.14; Indian observer: p=.24). In contrast, Caucasian participants made more fixations on the eyes (p<.001) and nose (p<.001) than on the mouth while there was no significant difference between the eyes and nose (p=.52).

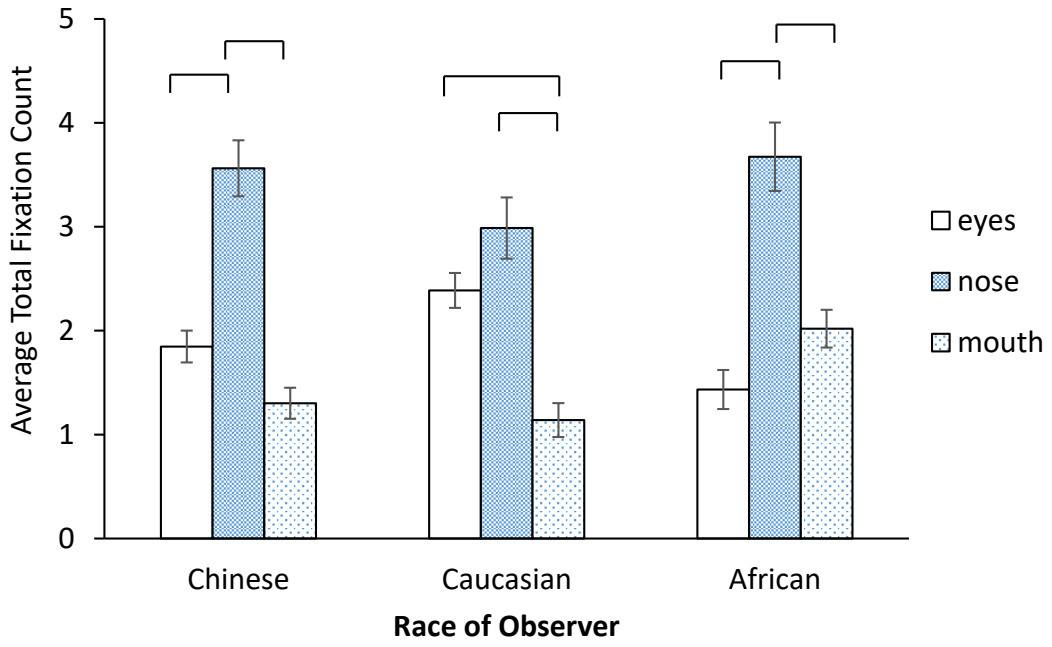


Figure 7.8. Average total number of fixations (area-normalised) on each AOI (facial feature) for Chinese, Caucasian and African participants. Error bars represent standard error.

Interestingly, there was a significant interaction between AOI and cued feature, $F(2.39, 136.39) = 130.98$, $p < .001$, $\eta_p^2 = .70$, accompanied by a four-way interaction between phase, face race, cued feature, and AOI, $F(5.51, 314.21) = 3.74$, $p = .002$, $\eta_p^2 = .06$. Split analyses by phase revealed the three-way face race × cued feature × AOI interaction was significant only in the *learning* phase, $F(5.97, 340.27) = 5.81$, $p < .001$, $\eta_p^2 = .09$, but not in the recognition phase, $F(4.91, 279.75) = 1.22$, $p = .29$. Further simple main effect analyses performed separately for each AOI showed that the face race × cued feature interaction was significant for the eye region, $F(4,236) = 7.21$, $p < .001$, $\eta_p^2 = .11$, and the nose region, $F(4,236) = 7.52$, $p < .001$, $\eta_p^2 = .11$, but not for the mouth region, $F(3.38, 199.30) = 1.60$, $p = .18$. This indicates that the location of cued fixation at encoding influenced how frequently participants looked at the eyes and noses of different face races. When the eyes were cued, Chinese and Caucasian faces received more eye fixations than African faces (both $p < .001$)

while African faces received more nose fixations than Chinese (p<.001) and Caucasian faces (p=.05). When the nose was cued, Caucasian eyes were fixated more frequently than African eyes (p=.03) whereas African noses were fixated more than Caucasian noses (p=.06). When the mouth was cued, African eyes received lower number of fixations than Chinese (p=.04) and Caucasian faces (p<.001); however, the number of nose fixations was greater on African faces than on Chinese (p=.02) and Caucasian faces (p=<.001).

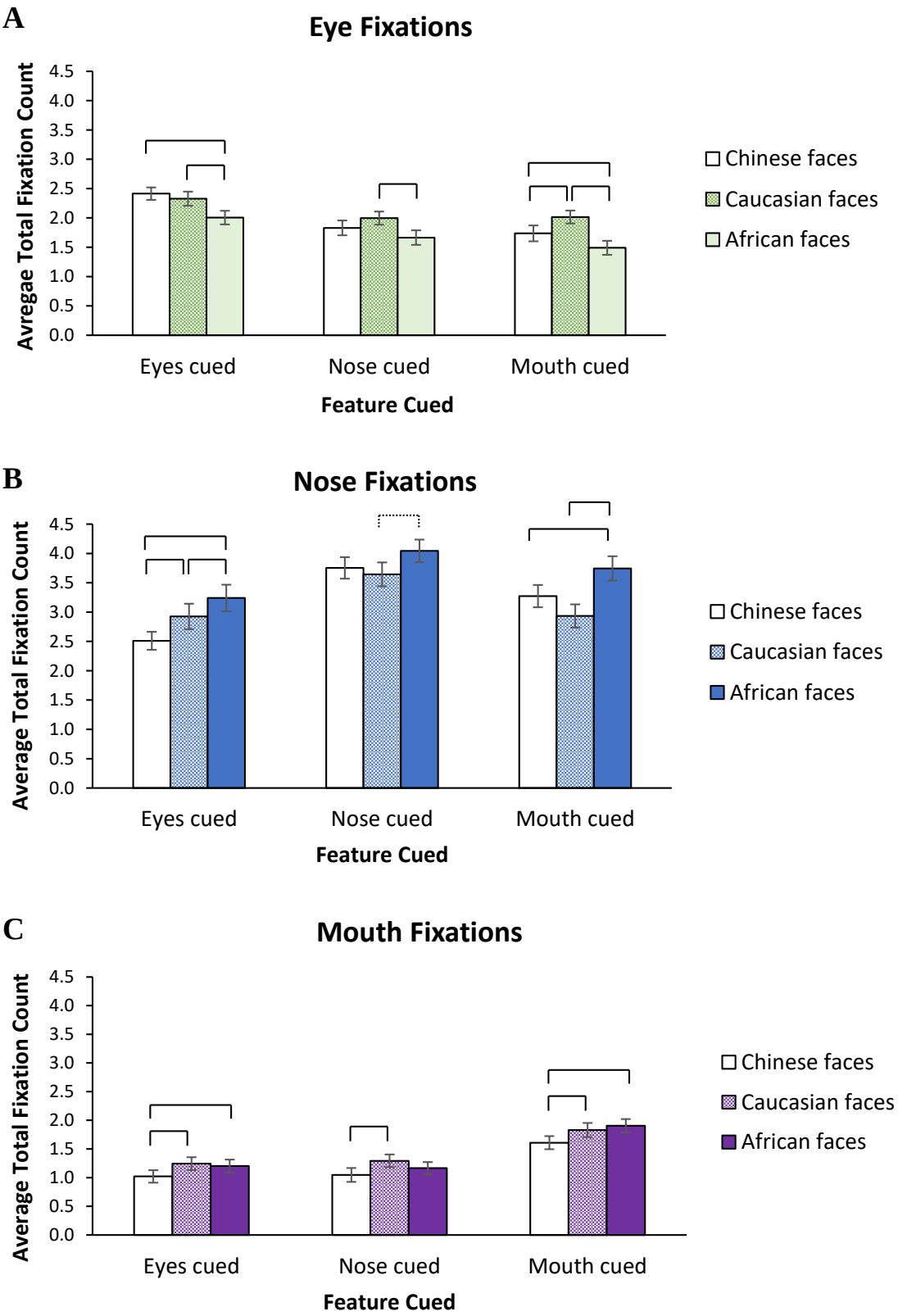


Figure 7.9. Average total number of fixations (area-normalised) on the eyes (A), nose (B), and mouth (C) for Chinese, Caucasian, and African faces split by cued feature. Error bars represent standard error.

7.2.4 Discussion

This cross-cultural experiment demonstrated that shifting initial attention to different facial regions affects recognition performance as well as subsequent fixation patterns across different race groups. In the classic yes-no recognition task, Malaysian-Chinese, Australian-Caucasian, and African participants were presented with a series of Chinese, Caucasian, and African faces that had facial regions (i.e., eyes, nose, mouth) cued with fixation crosses. Results revealed a weak ORB in Chinese and Caucasian participants whereas no significant ORB was detected in African participants.

In this experiment, Malaysian-Chinese recognised Caucasian faces equally well as Chinese faces, but were less good at recognising African faces. This supports the notion that the ORB arises from both direct and indirect experience as suggested by Tan et al. (2012). Malaysian Chinese showed the ORB only for African faces likely because such faces are not typically encountered in Malaysia either directly or indirectly through media. In contrast, the ability to recognise Caucasian faces may arise from indirect experience through media (e.g. watching Western television). However, m previous experiments (as reported in Chapter 3, 5, and 6) did observe an own-race recognition advantage for Chinese faces over Caucasian faces in Malaysian Chinese participants. One possible explanation for these discrepant findings is that the manipulation of fixation crosses might have benefited their recognition performance for Caucasian faces but not for African faces. Perhaps Caucasian faces are better processed featurally by attending to individual features (e.g. eye colour). This view is supported by the current data that Caucasian faces are generally recognised with higher accuracy than Chinese and African faces.

While participants were generally showing less of an ORB (in terms of d' and percentage correct), the location of the first fixation did influence recognition accuracy of

Chinese and Caucasian participants. Results showed that when the first fixation was to the nose, Malaysian-Chinese participants' recognition accuracy was higher than when the first fixation was to the mouth. On the other hand, Caucasian participants' recognition accuracy was higher when the eyes or the nose was cued than when the mouth was cued, as reported by Hills et al. (2011). There is a great deal of experimental evidence that shows the primary importance of the eyes in face processing, at least for Western-Caucasian participants (Blais et al., 2008; Stacey et al., 2005; Uono & Hietanen, 2015). One explanation for this cueing effect is that the first fixations guided to the upper facial regions somewhat encourage holistic face processing and/or decrease the engagement of featural processing (Hills & Lewis, 2011; Wang et al., 2018), and may enhance the encoding of individuating diagnostic information for recognition.

However, the present results fail to replicate Hills and Lewis (2011) findings that cueing Caucasian participants to the lower half of the face removed the ORB by improving the recognition performance for African faces and lowering the recognition performance for Caucasian faces. Instead, it was found that directing their first fixation to the eyes or nose led to better recognition performance than when the first fixation was on the mouth. The ORB did not seem to be abolished by presenting a fixation cross preceding the eyes, nose or mouth. Hence, my results are consistent with an expertise account of the ORB, whereby the ORB could arise as a consequence of a difference in one's perceptual expertise between faces of different races (Lebrecht et al., 2009; Meissner & Brigham, 2001; Tanaka & Pierce, 2009).

Interestingly, African participants did not manifest the ORB and the location of fixation crosses did not seem to affect their recognition performance. My data supports the idea that African participants tend to use a wider range of features to describe faces (Ellis et al., 1975), which may explain the absence of ORB in African participants. Shepherd & Deregowski (1981) found that African participants use all dimensions to recognise faces as

compared to Caucasian participants, causing them to be generally better at face recognition tasks than are Caucasian participants. If East Asian, Caucasian and African faces differ in physiognomy, they would be stored along different dimensions in Valentine's (1991) face-space. It is possible that using this kind of feature-cueing manipulation activates different dimensions of the face-space in African participants.

Hills and Lewis (2011) found a larger magnitude of cueing effect at learning than at test, indicating that first fixations are relatively important for accurate face recognition at early encoding. Although the current study did not directly test whether this cueing effect occurs at learning or at test, I explored eye movements as the potential mechanism for this cueing effect. The effect of the fixation cross on subsequent fixations was more evident in the learning phase than in the recognition phase, highlighting the importance of the location of the first fixation for accurate face encoding and processing (Hsiao & Cottrell, 2008). More specifically, the location of fixations at encoding did influence how frequently participants looked at the eyes and nose of different face races.

The present data provide evidence to suggest different diagnostic features relevant to Chinese, Caucasian, and African faces. These data are compatible with Valentine's (1991) models of face-space, by suggesting that the lower part of the face contains diagnostic features (e.g. nose, mouth, cheeks, and chin) for distinguishing between African faces. These features are relatively less diagnostic when discriminating between Chinese and Caucasian faces. Evidence from the current eye-tracking data also suggests that features are differentially diagnostic depending on the race of observer. By comparing the three races of participants, I observed that Malaysian-Chinese participants attended more to the nose region, Caucasians participants attended more to the eyes, and African attended more to the mouth (see *Figure 7.6* and *Figure 7.8*). Such differences in fixation patterns between the racial

groups are likely to be attributed to differential experience of the physiognomic characteristics.

7.3 Experiment 5B

Although Experiment 5A provides evidence that the specific position of first fixation on diagnostic features plays a role in face processing, it is unclear whether the weak cueing effect observed in Malaysian-Chinese was because of their lack of direct experience with Caucasian and African faces. It may well be that these participants would still manifest a cueing effect if tested within the range of faces they encounter more frequently in a multiracial country. Several studies have shown that the increased exposure to other-race individuals can ameliorate the ORB. For instance, real-world exposure to other-race faces in multiracial neighbourhoods (Chiroro & Valentine, 1995; Meissner & Brigham, 2001; Ng & Lindsay, 1994; Sangrigoli et al., 2005) or on sports television (MacLin et al., 2004) has been shown to reduce differences in the processing of own- and other-race faces. However, a meta-analysis of the ORB performed by Meissner & Brigham (2001) concluded that self-report assessments of other-race contact explain less than 3% of the total variance in the ORB, suggesting that factors other than mere exposure to other-race faces may influence the magnitude of the ORB.

Unlike the samples used by Hills et al. (2013) and Hills & Lewis (2006), Malaysian-Chinese participants who took part in Experiment 5A had relatively low amounts of direct contact with Caucasian and African individuals. Given that interracial contact may remove characteristics that do not discriminate between the race of faces that are most frequently encountered, it would be interesting to see if the cueing effect acts more strongly on face races that are more directly experienced through daily exposure. In this second experiment, I included Chinese, Malay and Indian individuals who lived in a multiracial country (i.e.

Malaysia). Given the importance of first fixation at encoding in determining subsequent fixation patterns (Arizpe, Kravitz, Yovel, & Baker, 2012), a no-cueing condition was added to the experimental design to see how individuals direct their first fixation to different race of faces when unguided by fixation crosses. Because Malaysians generally have been exposed to and had extensive contact with people of the three major races (Chinese, Malay and Indian) on a daily basis, they may develop a broadly tuned representation for making distinctions between faces of another, frequently encountered, race. If such a multiracial experience allows them to use dimensions of face space that are more diagnostic for other-race face recognition, then guiding their attention to process faces using diagnostic dimensions would lead to comparable recognition performance with both own-race faces and face races that are typically encountered in the country.

7.3.1 Methods

7.3.1.1 Design

A 3 × 4 × 4 mixed-subject design was employed, involving the race of observer (Malay, Chinese, or Indian) as the between-subjects variable and the race of face (Malay, Chinese, Indian, or Caucasian) and the cued feature (the eyes, nose, mouth, or no cueing) as the within-subjects variables. The dependent variables were *d'*, response bias, and the percent correct for each cueing condition (eyes, nose, mouth or no fixation).

7.3.1.2 Participants

A total of 79 undergraduate students from the University of Nottingham, Malaysia Campus participated in this experiment. Participants consisted of 27 Chinese (12 males; M_{age}=20.65, SD=1.32), 26 Malay (11 males; M_{age}=20.72, SD=1.40), and 26 Indian (11 males; M_{age}=20.36, SD=1.44) who were born and raised in Malaysia. All had normal or corrected-to-normal vision and were given either course credits or candy for their participation.

7.3.1.3 Stimuli

A total of 128 face images collected at the University of Nottingham Malaysia Campus were used. Face stimuli consisted of 32 Malay (16 male, 16 female), 32 Chinese, 32 Indian and 32 Caucasian faces. Examples of the face stimuli are presented in *Figure 7.10*.

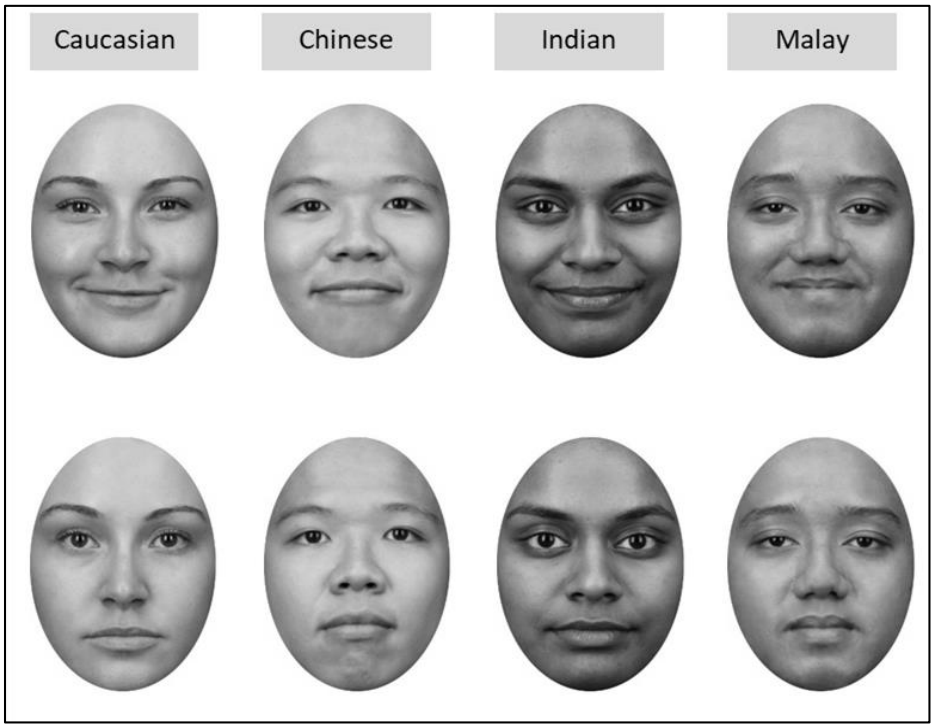


Figure 7.10. Examples of face stimuli of four different race groups with two different expressions (smiling and neutral)

7.3.1.4 Procedure

Similar to Experiment 5A, this experiment employed a standard old-new recognition paradigm except that participants performed four race blocks (128 faces in total). Each block contained 32 face stimuli (16 male and 16 female faces; half target and half distractors). Observers were cued to either of the following facial features: eyes (bridge of the nose), nose (tip of the nose), mouth (at the centre), or no fixation. In the cueing conditions, a fixation cross was presented either at the middle left or middle right position on the screen for 1 second before a face stimulus was presented. As shown in *Figure 7.11*, each face stimulus

appeared randomly at one of the six possible locations (top left, top right, middle left, middle right, bottom left or bottom right) for 5 seconds so that the general position of the face was unpredictable, preventing participants from planning any eye movements until the face had actually appeared on the screen. In the non-cued condition, the white background was set to a longer duration of 1.6 seconds before the faces were presented.

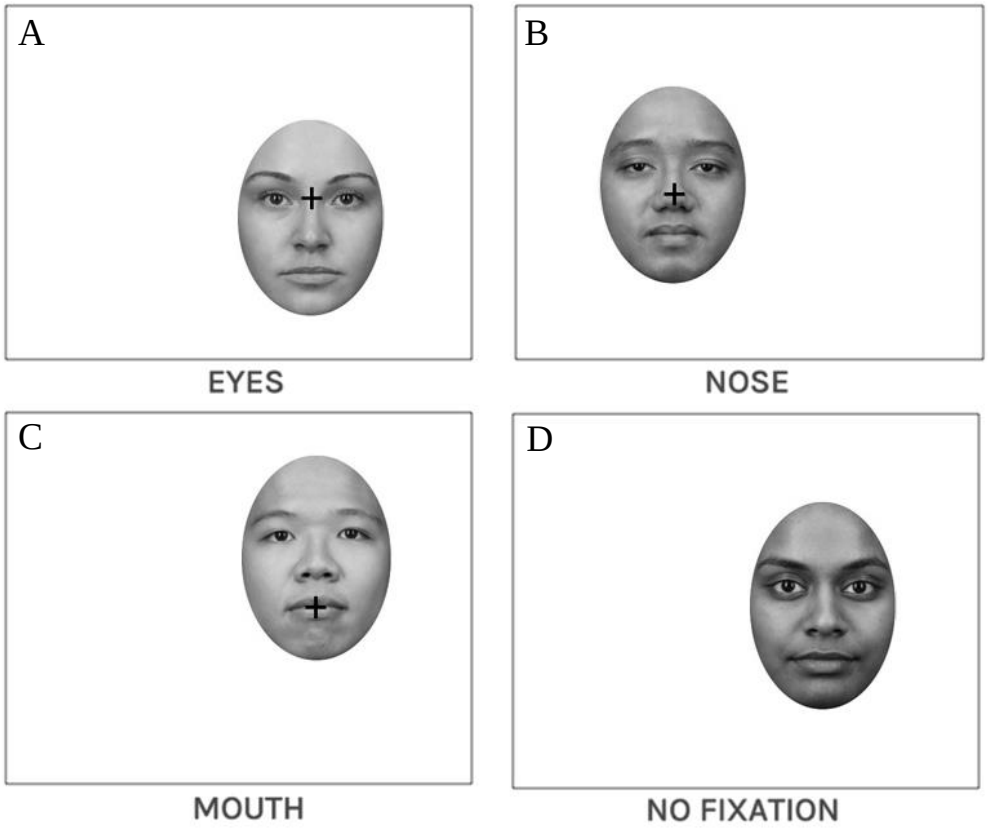


Figure 7.11. Examples of egg-shaped faces of Caucasian (A), Malay (B), Chinese (C), and Indian (D) with the spatial position of the fixation cross superimposed on eyes, nose, mouth or no fixation. The fixation cross appeared for one second prior to each face.

7.3.2 Behavioural results

Prior to the analysis, recognition accuracy was checked for outliers (values greater than 2.5 standard deviations from the mean on recognition accuracy). This results in 10

participants being removed from further analysis, leaving a final dataset of 69 observers (24 Chinse, 22 Malay and 23 Indian).

7.3.2.1 Recognition sensitivity *d'*.

A 3 (race of observer) × 4 (face race) mixed factorial ANOVA was performed on recognition sensitivity *d'*. The main effect of race of observers did not reach significance, $F(2,66)=1.35$, $p=.27$. However, the analysis revealed a significant main effect of face race, $F(3,198)=15.12$, $p=.01$, $\eta_p^2=.09$, with Indian faces being recognised better than Chinese faces ($p=.04$). Most importantly, there was a significant interaction between face race and race of observer, $F(6, 198)=2.96$, $p=.009$, $\eta_p^2=.08$. Chinese participants recognised Chinese faces significantly better than Indian faces ($p=.04$). Malay participants recognised Malay faces better than Chinese ($p=.05$) and Caucasian faces ($p<.001$). Indian participants recognised Indian faces better than Chinese ($p<.001$), Malay ($p=.02$) and Caucasian faces ($p=.008$).

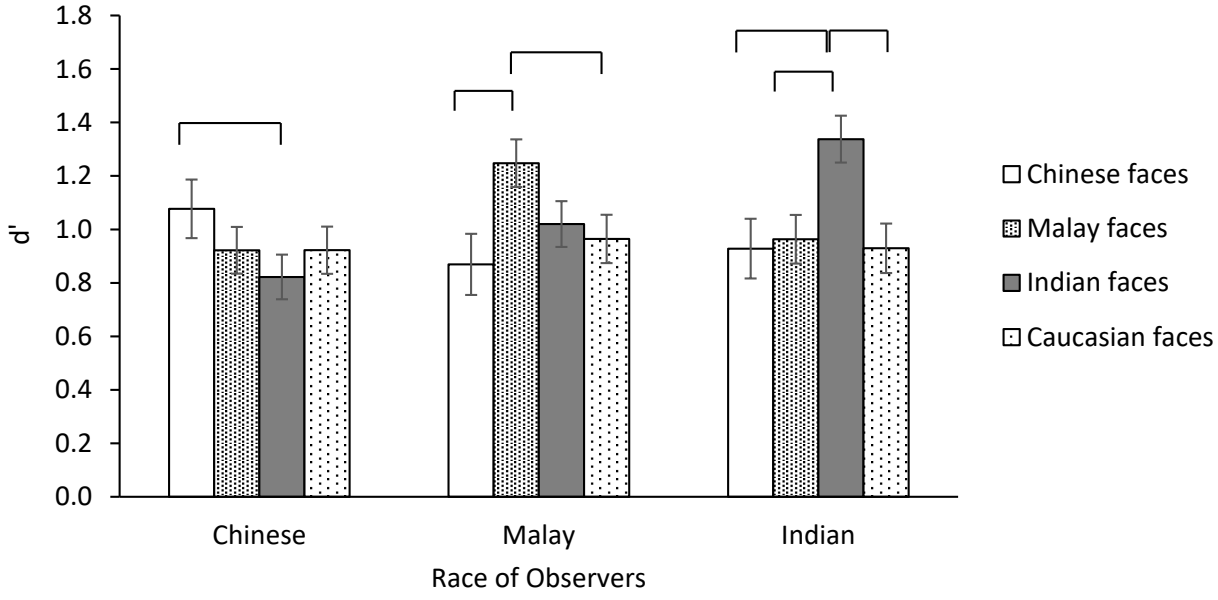


Figure 7.12. Mean recognition sensitivity (*d'*) for Chinese, Malay, Indian, and Caucasian faces split by participant race group for Experiment 5B. Error bars represent standard error.

7.3.2.2 Response bias *c*.

Neither the main effect of face race, F (3, 198) = 13.91, p=.18, nor the main effect of race of participant, F (2, 66) = .50, p=.61, was significant. Consistent with Experiment 5A, the interaction did not approach significance, F (6, 198) = 1.13, p=.35, suggesting that participants did not respond more conservatively to one particular race of face.

7.3.2.3 Percent correct.

The mean percentage correct scores were subjected to a 3 (race of participant) × 4 (face race) × 4 (cued feature) mixed-subjects ANOVA which revealed a significant main effect of cued feature, F (3, 198) = 10.38, p<.001, η_p^2 =.14. Recognition accuracy was higher when the eyes were cued relative to when the mouth was cued (p=<.001) or when there was no cueing (p=.001). The main effect of face race, F (3, 198) =19.18, p<.001, η_p^2 =.23 was also significant, showing that Caucasian faces (M=71.5%, SD =8.30) were recognised better than Chinese faces (M=68.6%, SD= 9.96) (p<.001). However, no significant main effect of race of participant was found, F (2,66)=2.24, p=.11. Crucially, there was an interaction between face race and feature cued, F (9, 594) =14.08, p<.001, η_p^2 =.18 (see *Figure 7.13*). Simple main effect analyses revealed that, for both Chinese and Malay faces, cueing the eyes or nose produced better recognition performance relative to cueing the mouth and no cueing (all p<.01). For Indian faces, recognition accuracy was higher when the eyes were cued than when the nose was cued (p=.005). Most interestingly, recognition accuracy was greater when Indian mouth was cued than when the Indian nose was cued (p<.001). Furthermore, cueing to either one of the three features (eyes, nose or mouth) led to higher recognition accuracy relative to no cueing (all p<.05). For Caucasian faces, recognition accuracy was higher when the eyes were cued than when the nose (p=.005) or mouth (p=.06) was cued.

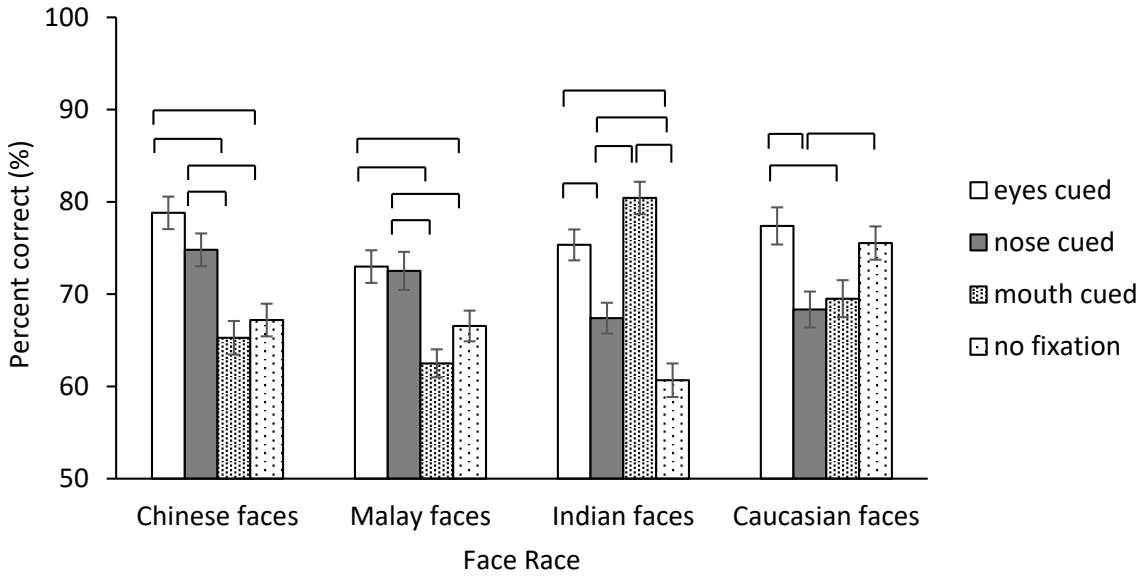


Figure 7.13. Mean percentage of correct responses on four cueing conditions (eyes, nose, mouth and no fixation) split by race of face (Chinese, Malay, Indian and Caucasian faces). Error bars represent standard error.

7.3.3 Eye-tracking data

7.3.3.1 Average fixation total duration.

A four-way mixed factorial ANOVA performed on participants' average fixation duration revealed a significant main effect of experimental phase, F (1, 77) = 59.64, p<.001, η_p^2 = .47, such that participants made longer fixation in the recognition phase than in the learning phase (p<.001).There was also a significant main effect of Face Race, F (3, 231) = 23.06, p<.001, η_p^2 = .26, where Caucasian faces received shorter fixations than Chinese, Malay and Indian faces (all p<.001). As expected, the main effect of Feature Cued was significant, F (2.52, 194.13) = 116.57, p<.001, η_p^2 =.64. Pairwise comparisons showed that participants spent more time viewing the face when the nose was cued, followed by when the mouth (p<.001) was cued, when there was no fixation cross (p<.001) and when the eyes were cued (p <.001). A main effect of AOI was revealed, F (1.45, 111.53) = 58.63, p<.001, η_p^2 =.47, where participants spent longer viewing the nose than the eyes (p<.001) and the mouth

(p<.001), and longer viewing the eyes than the mouth (p<.001). These results suggest a nose-centric scanning strategy that has been commonly reported in face recognition studies using Asian samples.

The three-way Phase × Face Race x Feature Cued interaction, F (5.66, 218.03) = 2.06, p=.03, η_p^2 =.03, and Face race × Feature Cued × AOI interaction were both significant, $F(9.81, 755.10) = 4.62$, $p<.001$, $\eta_p^2 = .06$, accompanied by a marginally significant four-way Phase × Face Race × Feature Cued × AOI interaction, F (9.19, 707.87) = 1.51, p=.08. Split analyses by Phase revealed that the Face Race × Feature Cued × AOI interaction was significant in the learning phase, F (9.90, 663.25) = 2.58, $p<.001$, η_p^2 =.04, but not in the recognition phase, F (8.75, 586.37) = 3.59, p=.07. Three ANOVAs split by AOI revealed a significant Face Race × Feature Cued interaction for the eye fixations, F (5.99, 413.15) = 3.15, p=.005, η_p^2 =.04, and mouth fixations, F (9, 621) = 4.71, $p<.001$, η_p^2 = .06, but only marginally significant for nose fixations, F (7.16, 494.27) = 1.96, p=.06, η_p^2 = .03. When being cued to the eyes, participants made longer fixations on Caucasian eyes than on Indian eyes (p=.03); when being cued to the nose, Caucasian eyes were fixated for longer than Malay (p=<.001) and Indian eyes (p=.03). When being cued to the mouth, participants made shorter fixation to the Indian eyes than Chinese (p=.02), Malay (p=.003), and Caucasian eyes (p<.001). When there was no fixation cross, Chinese and Caucasian eyes were fixated longer than Malay eyes (p=.04 and p<.001, respectively) and Indian eyes (p=.001 and p<.001, respectively).

There was a significant four-way Phase × Feature Cued × AOI × Race of Participant interaction, F (12, 462) = 2.00, p=.02, η_p^2 =.06. Split analyses by Phase revealed the significant Feature Cued × AOI × Race of Participant interaction only in learning phase, F (12, 402) = 1.84, p=.04, η_p^2 =.05, but not in recognition phase, F (12,402) = .50, p=.92. I probed this three-way interaction with separate ANOVAs conducted for each AOI, showing

that the Feature × Race of Participant interaction was significant only for the eye fixations, F (6, 201) = 3.34, p=.004, η_p^2 =.09, but not for the nose fixations, F (6, 201) = 1.67, p=.13, η_p^2 = .05, and mouth fixations, F (6, 201) = 0.43, p=.86, η_p^2 = .01. Pairwise comparisons showed that Chinese participants made significantly longer fixations to the eyes when the eyes were cued than when the nose (p<.001) or mouth (p<.001) was cued and when there was no fixation cross (p=.002). Although Malay and Indian participants also spent most time fixating the eyes when the eyes were cued, they showed no significant difference between the nose and mouth conditions (both p=1), between nose and no-cueing conditions (p_{malay}=.33; p_{indian}=1), and between mouth and no-cueing conditions (p_{malay}=.26; p_{indian}=.65).

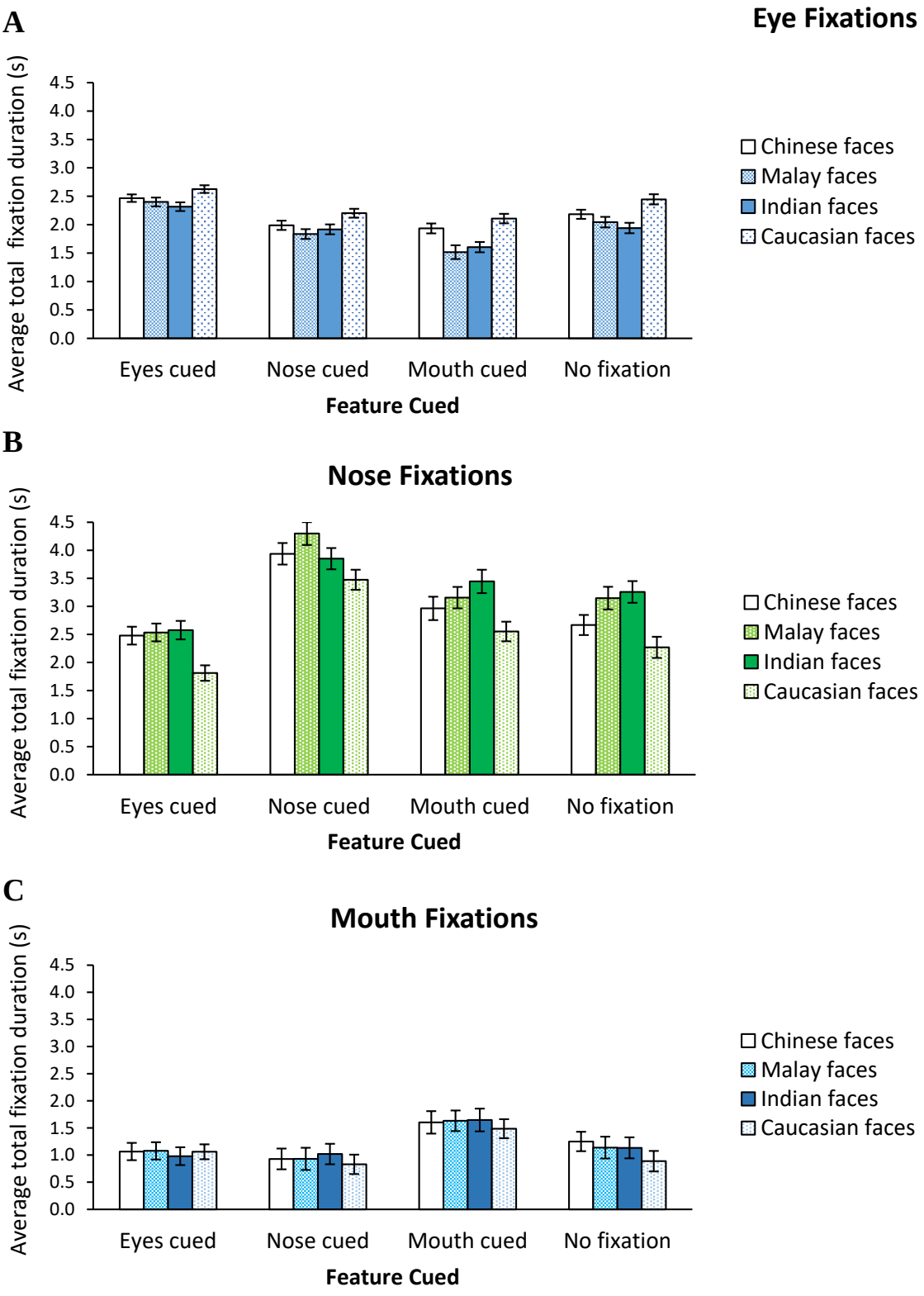


*Figure 7.14. A*verage total fixation duration on the eyes (A), nose (B), and mouth (C) for Chinese, Malay, Indian and Caucasian faces split by cued feature. Error bars represent standard error.

7.3.3.2 Average fixation total count.

A four-way mixed factorial ANOVA was performed on participants' average number of fixations. The main effect of participant race was not significant, F (2,77) = 0.29, p=.75. There was a main effect of phase, F (1, 77)=62.07, p<.001, η_p^2 =.45, with more fixations made during recognition phase than learning phase (p<.001). There was a significant main effect of Face Race, F (3, 231) = 27.33, p<.001, η_p^2 = .26, such that Caucasian faces received fewer fixation than Chinese, Malay, and Indian faces (all p <.001). The main effect of Feature Cued was significant, F(2.62, 201.96) = 144.64, p<.001, η_p^2 = .65, showing that participants made greater number of fixations when the nose was cued than when the mouth or the eyes were cued, and when there was no fixation (all p<.001). The main effect of AOI was also significant, F (1.44, 110.51) = 66.29, p<.001, η_p^2 =.46. Overall, the nose was the most likely to be fixated upon, followed by the eyes (p<.001) and then the mouth (p<.001).

Interestingly, there was a highly significant three-way Face Race × Feature Cued × AOI interaction, F(10.43, 802.97) = 7.57, p<.001, η_p^2 = .09, accompanied by a significant four-way Phase × Face Race × Feature Cued × AOI interaction, F (9.49, 730.37) = 1.53, p=.05, η_p^2 = .02. Split analyses by Phase revealed that the Face Race × Feature Cued × AOI interaction was significant in the learning phase, F (9.90, 663.25) = 2.58, p<.001, η_p^2 =.04, but not in the recognition phase, F (8.75, 586.37) = 3.59, p=.07. Three ANOVAs split by AOI revealed a significant Face Race × Feature Cued interaction for the eye fixations, F (5.99, 413.15) = 3.15, p=.005, η_p^2 =.04, and mouth fixations, F (9, 621) = 4.71, p<.001, η_p^2 = .06, but only marginally significant for nose fixations, F (7.16, 494.27) = 1.96, p=.06, η_p^2 = .03. When being cued to the eyes, participants made more fixations on Caucasian eyes than on Indian eyes (p=.01). When being cued to the nose, they made more fixations on the eyes of Caucasian faces than those on

Malay (p=<.001) and Indian faces (p=.03). When being cued to the mouth, they made fewer fixations to the Indian eyes than Chinese (p=.02), Malay (p=.01), and Caucasian eyes (p<.001). When there was no fixation cross, Chinese and Caucasian eyes were fixated more frequently than Malay eyes (p=.02 and p<.001, respectively) and Indian eyes (both p<.001).

Furthermore, there was a significant four-way interaction between Phase, Feature Cued, AOI, and Participant Race, F (12, 462) = 2.03, p=.02, η_p^2 = .05. For learning phase, the Feature Cued × AOI × Participant Race interaction was significant, F (12, 402) = 1.76, p = .05, η_p^2 = .05; for recognition phase, this three-way interaction did not reach significance, F (12, 402) = 0.42, p=.96. Simple effects revealed a significant Feature Cued × Participant Race interaction only for the eye fixations, F (6, 201) = 2.12, p = .05, η_p^2 = .06, and a marginally significant interaction for the nose fixations, F (6, 201) = 1.86, p=.09, η_p^2 = .05, but no significant interaction was found for the mouth fixations, F (6, 201) = 0.20, p=.98. This indicates that the location of first fixation affected how frequently participants look at the top part of the face, especially the eye region, and this cueing effect was mediated by the participant race. Chinese participants looked more at the eyes when the eyes were cued than when the nose (p<.001) or the mouth (p<.001) was cued, and more than when there was no cueing (p=.001). A similar pattern was observed in Malay and Indian participants where they fixated more on the eyes when the eyes were cued than when there was no fixation cross (p=.007), nose cued (p<.001), mouth cued (p=.001), and when there was no fixation cross than when the mouth was cued (p=.04). However, they did not show any significant difference of average total number of fixations on the eyes between the nose-cued and mouth-cued conditions (p=1), and between the nose-cued and no-cueing conditions. (p=.11).

7.3.4 Discussion

Past research on the ORB has mostly been conducted with Western-Caucasian, East-Asian, and Black-African faces (e.g. Blais et al., 2008; Caldara et al., 2010; Hills & Lewis, 2006, 2011). Only a few recognition studies have used Southeast Asian faces such as Malay and Indian faces. This experiment examined the effects of fixation crosses on face recognition in Malaysian-Chinese, Malaysian-Malays, and Malaysian-Indians when looking at different races of faces (Chinese, Malay, Indian, and Caucasian faces). Here I demonstrated that the recognition performance can be improved by directing participants to first fixate on the most diagnostic feature for discriminating between faces of that particular race. Results indicated that different races of faces have certain diagnostic features that are critical for identification of faces within the same race; for example, eyes and nose for Chinese faces, eyes and mouth for Malay faces, mouth for Indian faces, and eyes for Caucasian faces. Overall, cueing to the eyes and mouth improves recognition performance for Chinese, Malay, and Caucasian faces. However, for Indian faces, cueing to the mouth leads to better recognition performance compared to cueing to the eyes and nose.

Interestingly, the ORB persists despite the occurrence of cueing effect, indicating that first fixations during encoding may be important for extracting diagnostic facial information but may not be sufficient to modulate the ORB effect. This finding converges with the results of an early study, in which giving special instructions for differentiating one particular face from another face at encoding did not reduce the ORB (Bornstein et al., 2013). Similar null effects of training have been reported by Woodhead, Baddeley, & Simmonds (1979), who assessed a training programme for unfamiliar face identification that encouraged participants to attend to individual facial features. Perhaps the ORB is not merely due to attentional factors but taps more

on the underlying perceptual mechanisms shaped by experience (Hills & Pake, 2013; Tanaka, Heptonstall, & Hagen, 2013). That is, the ORB is not merely due to a failure to direct attention to the race-specific diagnostic features.

Based on the face-space account of the ORB, although participants may use the dimensions that are most diagnostic in discriminating between faces that are most frequently encountered (e.g., own-race faces; MacLin & Malpass, 2001), the ability to use the dimensions that are diagnostic for discriminating between faces of another less familiar race depends on their perceptual experience. A fixation cross that precedes the eyes, nose, or mouth may lead participants to process and encode features that they would not normally attend to provided they know what features are best to differentiate other-race faces. Indeed, during the current experiment, different fixation patterns were observed between face races: the eyes on Caucasian faces were looked at more frequently and longer than Chinese, Malay and Indian faces. While cueing to the eyes did not improve participants' recognition performance as compared to the control condition, cueing to the nose and mouth impaired recognition performance, implying that that the ORB may be partly related whether the most diagnostic facial features are encoded first or not.

7.4 General Discussion

The present study examined the effect of cued fixations on recognition performance for own- versus other-race faces and tested whether faces of different races are perceived in the same manner by attending to similar features. Cueing first fixation to different facial features did not seem to remove the ORB. Therefore, it cannot be assumed that training with cued fixations is effective for reducing ORB as results showed opposite of predicted hypothesis. More understanding is needed on how the environment and individual experiences can influence the

visual processing mechanisms used in face recognition. Despite the occurrence of cueing effect, the ORB remains robust (except for African participants), indicating that the ORB cannot be fully accounted by attentional mechanisms. This also means that directing attention to the diagnostic features may not be enough to overcome long-term, default processing strategies. Another possible reason why fixation cross training might not have been successful in the current study could be due to the timing of presentation of face stimuli after every cued fixation. In the current study, face stimuli were presented for five seconds so that the data are directly comparable with my previous old-new recognition experiments reported in Chapter 3, 4, and 5. Hills and Lewis (2011) performed a similar experiment where they manipulated the timing of the faces presented. It was found that the cueing effect exists only if faces presented remain on the screen for less than four seconds. Any longer than that, cued fixation crosses are unlikely to influence recognition performance.

The current findings have significant implications for research in face recognition and eye-tracking research. In terms of eye-tracking research, any study that employs a fixation cross may be affecting the first fixation, the subsequent encoding, and performance. For example, fixation crosses are typically presented in the centre of the screen where the centre region of the face will be presented subsequently at the same location. In this case, the fixation crosses always precede the nose region, which could elicit cueing effects. Two methods can be employed to avoid this unintentional effect: placing fixation crosses outside the face image to ensure that the first fixation does not cue any facial features (e.g., Bindemann et al., 2009) or guiding fixation using boxes/images (e.g., Wu et al., 2012).

One interesting implication of the present work is the apparent conflict between the present results and face recognition studies that employ fixation crosses. In many studies that

have reported significant ORBs, fixation crosses were not employed (such as Chiroro et al., 2008; Cross et al., 1971; Hugenberg et al., 2007; Lavrakas, Buri, & Mayzner, 1976; Malpass & Kravitz, 1969; Michel, Caldara, & Rossion, 2006; Valentine & Endo, 1992). Instead, between the presentation of faces there was a blank intertrial interval. The use of fixation crosses is a more recent procedure employed to indicate the start of a trial in order that participants are prepared to look at a relevant part of a screen. These fixation crosses are often positioned centrally (e.g., Hahn, Jantzen, & Symons, 2012), although this is not always specified, and often result in significant ORBs being observed (but see Cooper & Kennett, 2013). Nonetheless, researchers should be careful about the location of fixation crosses that precedes facial stimuli and use external fixation crosses that do not cue initial fixations to any facial features (see Bindemann et al., 2009).

Some studies of the ORB do not test multiple races and thus the differential effects of any fixation crosses across faces of different faces would not be detected. Where fixation crosses have been used and significant ORBs have been found, the contrast to the present results may be due to the fact that fixation cross does not really attract attention unless participants are directed to look at them (and in this case, the trial would not begin unless they did). Nonetheless, researchers should be careful about how they devise experimental procedures and minimise the use of fixation crosses and use fixation images (e.g., Wu et al., 2012) or use external fixation crosses (e.g., Bindemann, Scheepers, & Burton, 2009). However, it is very unlikely that the cueing to diagnostic features will be sufficient to reverse the ORB. It adds to our understanding of how perceptual learning shapes recognition ability and how faces are represented based on different dimensions of the face-space.

In summary, the current study found that directing participants' immediate attention to the most diagnostic facial features using fixation crosses may help to improve recognition performance to a small extent, but it is not effective enough to remove the ORB. Cueing participants to fixate more on the other-race features that they would not normally fixate upon does not facilitate the extraction of individuating information. Eye-tracking data showed that the first fixation was indeed directed by the fixation cross and directing first fixations to a particular feature can potentially alter their subsequent eye-movement patterns.

Chapter 8

Putting a ‘Spotlight’ on the ORB with Gaze-contingent Technique

8.1 Introduction

8.1.1 Holistic versus Featural View

Face recognition is fundamental to our daily social behaviour. Two main views on how humans recognise faces have been proposed: the featural and the holistic view (Bruce, Doyle, Dench, & Burton, 1991; Ellis et al., 1992). Both views derived from the observation that faces are visually complex stimuli, composed of multiple features (e.g., external and internal features such as chin, hair, eyes, mouth, nose, etc.) that can be diagnostic of facial identity by varying in face shape and in their surface properties (e.g., skin tone, colour, and texture variations) (e.g., Balas & Nelson, 2010). According to the featural view (e.g., Davies, 1978), observers explore a face by scanning local features in order to extract the most diagnostic information when individuating the face. This view has been supported by eye movement recording studies, showing that human observers do indeed concentrate on localised internal facial features (i.e., eye, mouth; Yarbus, 1967), and are capable of recognising individuals based on only a limited amount of information from the eyes and eyebrows (Davies, Ellis, & Shepherd, 1977; Sadr, Jarudi, & Sinha, 2003; Shepherd & Deregowski, 1981).

On the other hand, the holistic/configural view derives from early insightful observations about face perception and reflects the idea that “a face is perceived as an undecomposed whole, at a single glance, rather than as a collection of individual features” (Galton, 1883). It is important to note that this holistic view of face recognition does not ignore or dismiss the fundamental role of local features in face recognition but is contrary to the analytical/featural

view. Empirical studies concluded that face recognition relies more strongly on holistic information than does object recognition in general (see Maurer, Le Grand, & Mondloch, 2002, for a review) due to face-specific perceptual expertise. In the context of the ORB, this holistic account posits that different perceptual processes (i.e., holistic vs. analytic) are involved to a different extent for own-race and other-race faces (Crookes, Favelle, & Hayward, 2013; Richler, Cheung, & Gauthier, 2012; Richler, Mack, Gauthier, & Palmeri, 2009; Richler, Floyd, & Gauthier, 2015; Tanaka et al., 2004), such that people are capable of perceiving own-race faces at a global scale (holistic processing) yet appear to have to rely on a smaller scale of analysis (featural processing) for the other-race faces.

It is widely believed that years of visual experience with own-race faces could have tuned the face recognition system so that it developed a global representation of a face (i.e., a template) that accommodates own-race face recognition (Crookes et al., 2013; Horry, Cheong, & Brewer, 2015; Richler et al., 2015; but see Gauthier & Bukach, 2007). The matching of this holistic template with the incoming visual stimulus would form the basis of the global percept of the face. According to this experience-based holistic account, it is the internal representation of the global structure of a face that allows observers to see an own-race face holistically and therefore recognise own-race faces better than other-race faces (see Chapter 6 for more discussion).

8.1.2 Gaze-Contingent Paradigm

Eye movements are used by the brain to gather relevant information to adapt to the visual world. Therefore, the studies of eye movements might reveal important information on the way humans process faces (Henderson et al., 2005; Peterson & Eckstein, 2013). Numerous studies have used eye-tracking techniques to assess various aspects of face perception, such as face memory (Goldinger et al., 2009; Wu et al., 2012), inverted faces (Xu & Tanaka, 2013), familiar

face recognition (van Belle et al., 2010). Recent eye-tracking studies have shown differential eye-movement patterns during face recognition as a function of the culture of the observers, with a central fixation bias for East Asian observers and an eye-mouth fixation bias for Western Caucasian observers (Blais et al., 2008). Such fixational biases seem to arise early in development, from 7 years old (Kelly, Liu, et al., 2011), and persist for inverted faces (Rodger et al., 2010), and visually homogeneous objects (Kelly et al., 2010). This cultural difference in eye movement information sampling also extends to the categorisation of facial expressions of emotions (Jack, Blais, Scheepers, Schyns, & Caldara, 2009; Kelly, Jack, et al., 2011).

Some authors have claimed that the type of processing being conducted (i.e., hypothetically holistic or featural) impacts on eye movement patterns (Bombari, Mast, & Lobmaier, 2009), and some researchers have inferred the involvement of holistic face-processing from fixation patterns (Goldinger et al., 2009; Hu et al., 2014; Tan et al., 2012). However, holistic face processing can sometimes be independent of eye movement behaviour (de Heering & Rossion, 2008). The coupling between fixated and processed information is not always perfect (Posner, Snyder, & Davidson, 1980). In other words, the location of fixations may not necessarily reflect where the diagnostic information needed for recognition resides. Hence, it would be misleading to infer hypothetical holistic/configural vs. featural processing or representations based only on fixation locations with static images.

In order to address this issue, researchers developed a novel eye-tracking technique: the gaze-contingent paradigm (e.g., Maw & Pomplun, 2004; Van Belle, De Graef, Verfaillie, Busigny, & Rossion, 2010). In eye-tracking experiments using the gaze-contingent technique, the stimulus display is continuously updated in response to the participant's current gaze position. There are two versions of the gaze-contingent paradigm: *Spotlight* (Caldara et al., 2010)

and *Blindspot*: (Miellet et al., 2012). In the *Spotlight* paradigm, a window is centred at the participant's gaze position and follows it wherever the participant looks. Within the window, all stimulus information is visible, while the information outside of the window is masked. This technique obscures the observer's peripheral view so that any information outside that range is occluded. Only a small region of the stimulus being searched is displayed clearly during any fixation. In contrast, the *Blindspot* technique is the reversal of the *Spotlight* technique, where the foveal view is blocked by a mask, leaving only the peripheral visual information visible. Under such visual constraints, the observer could not rely on the fixated feature in central vision but was able to benefit from the remaining whole of the face. Although the observer could still process the element next to the mask border, the most adaptive strategy in this latter condition is to rely on the whole of the face, visible around the mask (Van Belle, De Graef, Verfaillie, Rossion, & Lefèvre, 2010).

This gaze-contingent technique provides powerful experimental control and has been used extensively in scene perception, reading, and more recently in visual search studies (e.g., Bertera & Rayner, 2000; Pomplun, Reingold, & Shen, 2001). Recent research has shown preliminary success in using the gaze-contingency paradigm as a non-invasive and low-cost tool to train autistic schoolchildren in sustaining gaze and attention (Evers, Van Belle, Steyaert, Noens, & Wagemans, 2018). Because of its potential for uncovering underlying face representation formats, this gaze-contingent technique has been recently applied in face recognition research to investigate the holistic and featural face processing not only in normal observers (Caldara, Zhou, & Miellet, 2010; Miellet & Caldara, 2010; Miellet, Caldara, & Schyns, 2011; Murphy & Cook, 2017; Van Belle, De Graef, Verfaillie, Busigny, & Rossion, 2010; Van Belle, De Graef, Verfaillie, Rossion, & Lefèvre, 2010), but also in congenital

prosopagnosic patients (Verfaillie et al., 2014). Van Belle, De Graef, Verfaillie, Busigny, et al. (2010) make the implicit assumption that extrafoveal information sampling (promoted by a gaze-contingent central mask) is equivalent to holistic processing, whereas foveal sampling (promoted via a gaze-contingent central window) corresponds to featural processing. In the ORB context, such technique that allows more restricted viewing could be used to complement free-viewing data in exploring the changes in information sampling strategies as well as determining what visual information is important for own- and other-race recognition.

8.1.3 Cultural Differences in Face Processing

By using gaze-contingent techniques, Caldara et al. (2010) and Miellet et al. (2012) further demonstrated that despite using diverse gaze scan paths, observers from both cultures rely on the same diagnostic features (i.e., the eyes and the mouth) to perform face recognition and to reach comparable levels of performance. Importantly, Miellet et al. (2011) developed a novel gaze-contingent technique – the iHybrid – and recently reported that Western Caucasian observers identify famous faces based on both foveally (local) and extrafoveally (global) sampled information, depending on the first fixation landing position (Miellet et al., 2011). The author argued that different visual strategies can be used to recognise faces and culture affects the preferred information sampling strategy during face recognition. That is, East Asian observers are more inclined to sample facial diagnostic information from extrafoveal vision (i.e. holistic processing), whereas Western Caucasian observers preferentially use foveal information (i.e. featural processing). These observations suggest that the facial information used to accurately individuate faces is invariant across individuals, but the strategies used to extract this information are likely to be flexible and might be modulated by culture (Miellet, Vizioli, He, Zhou, & Caldara, 2013). To my knowledge, only three gaze-contingent studies have tested face

recognition on East Asian and Western Caucasian observers using different races of faces (Caldara et al., 2010; Miellet et al., 2012; Miellet et al., 2013). However, in these studies, data for the East Asian and Western Caucasian face stimuli were collapsed in the analysis given the lack of effect of the race of the face stimuli on recognition accuracy or on as correct reaction times. Upon closer inspection, it was speculated that the lack of ORB in these experiments could be because identical facial images of the same identity were presented during encoding and retrieval, producing low-level image cues for the face tasks.

8.1.4 The Present Study

Here I utilised facial images of different expressions between study and test to test the ORB by means of a gaze-contingent stimulus presentation. In an individual face matching task, I used a moving window (*Spotlight*) or a moving mask (*Blindspot)* to investigate the effect of the gaze-contingent manipulation on recognition performance for own-race versus other-race faces. I also compared a control condition in which a full face was displayed in each of the two manipulated viewing conditions (window and mask) in which access to information was restricted systematically. In the window condition, the available visual information in the centre of vision was constrained by means of a gaze-contingent window. This forces observers to process the face stimulus analytically feature-by-feature. In the mask condition, the fixated feature was occluded by means of a gaze-contingent mask, forcing observers to rely on information from the unfixated region. By adopting a sequential face matching task, I first tested Malaysian-Chinese young adults' performance on upright and inverted facial images of Malaysian-Malay, Malaysian-Chinese, Malaysian-Indian, and Western-Caucasian (pilot study), and compared their behavioural performance with Malaysian-Malay, Malaysian-Indian and Western-Caucasian participants (Experiment 6).

8.2 Pilot Study

By adopting a sequential face matching task, I first tested Malaysian-Chinese young adults' performance on upright and inverted facial images of Malaysian-Malay, Malaysian-Chinese, Malaysian-Indian, and Western-Caucasian. In order to provide a more direct evaluation of featural versus holistic face processing, this pilot study was designed to (1) determine the optimal stimulus presentation duration that keeps young adults' performance free from floor and ceiling effects (2) to check if the gaze-contingent manipulation of the amount of simultaneously available information by means of a moving mask and window is effective. Both upright and inverted faces were used in this pilot study because an observation of inversion effect could provide preliminary evidence that the face stimuli engage face-specific processing mechanisms (e.g., holistic processing). I anticipated that the preliminary data would inform us whether, and if so, to what extent restricting extra- or intra-foveal vision modulates the effect of face inversion on matching own-race and other-race faces. Based on the holistic account of the face inversion effect, I hypothesised if participants perceive faces holistically, the face recognition accuracy should be relatively less affected by face inversion in the mask condition where there is a mask covering the facial feature they fixate on (mask condition), compared to the situation where their perception is limited to that single feature (window condition). Based on the results of this pilot study, I further investigated the ORB using a complete cross-over design in Experiment 6.

8.2.1 Methods

8.2.1.1 Design

This experiment employed a 4 (Race of Face: Chinese, Malay, Indian and Caucasian) × 3 (Viewing condition: control, window and mask) within-subjects design. The dependent variables were percentage correct and correct reaction time (RT).

8.2.1.2 Participants

24 Malaysian-Chinese young adults (11 males, 13 females; M_{age} = 20.83, SD = 2.93) from the University of Nottingham Malaysia Campus participated in this experiment. All participants had normal or corrected-to-normal vision, gave written informed consent, and received RM10 for their participation.

8.2.1.3 Materials

All stimuli used in the face tasks were frontal images of young adult faces (both male and female). Facial images of Chinese, Malay and Indian were collected from a student population at the University of Nottingham Malaysia Campus whereas Caucasian faces were obtained from the Macquarie University, Australia. Stimuli consisted of 264 face images of Malaysian-Malay, Malaysian-Chinese, Malaysian-Indian, and Western-Caucasian. For each race, there were 22 target faces (11 male, 11 female) with two different expressions (neutral versus smiling) and 22 distracter faces with a neutral expression. All images were converted to grayscale to minimise skin colour cues, were cropped to remove hair cues, and were devoid of distinctive features (e.g., pimples, moles, and facial hair). The size of the face was 7.5° in width by 10.5° in height and the size of the window and mask was 2.2° by 1.7°. A blurred average face was generated by morphing all face images using PsychoMorph software to be used as a face template during stimulus presentation.

8.2.1.4 Apparatus

Participants' eye movements were recorded at a sampling rate of 500Hz with the SR-Research Desktop-Mount Eyelink 100 Plus eye tracker, which has an accuracy range of 0.25° to 0.50° and a spatial resolution of 0.01°. Although viewing was binocular, only the left eye was tracked. The experiment was implemented in Experimental Builder software. Stimuli were

displayed on a 24-inch BenQ LCD monitor at a viewing distance of 60cm with a size of 1600 by 900 pixels and a refresh rate of 60Hz. The head movement of participants was restricted by a head and chin rest during the experiment.

8.2.1.5 Procedure

Participants sat 60cm away from the display monitor. A standard 9-point calibration was performed prior to the experimental task. Calibrations were then validated with the EyeLink software and repeated when necessary until the optimal calibration criterion (< 1° of visual angle) was reached. Each participant completed 6 blocks of 88 trials (528 in total), half of which contained upright, the other half inverted faces. 176 trials of each viewing condition were presented in a random order. The course of a trial is presented in *Figure 8.1*. Each trial started with a drift correction with a dot, followed by the presentation a fixation cross on the left centre of the screen. Participants were instructed to fixate the fixation cross. Upon accurate fixation, the cross disappeared. A blurred face, which was the average image of all faces was then presented in the centre of the screen and was replaced by the study face as soon as the participant fixated the blurred face. Participants were instructed to remember the study face, which was presented for 3 second, followed by a 1-second blank screen. Next, two faces (one target and one distracter) were presented side-by-side. The target face in each trial was presented with a different expression from the study face to ensure this task measures face-specific processing. The participant could freely explore both faces without any time restriction but were asked to respond as accurately and quickly as possible. During the exploration of the pair of faces, the face that was not fixated was replaced by the blurred average face, in order to provide a reference template for saccade planning to the face in all viewing conditions. This face template does not provide any useful information for the recognition task. The task was to indicate which face was

the target face by pressing the left or right assigned key on the keyboard. The presentation order of the blocks was counterbalanced across participants.

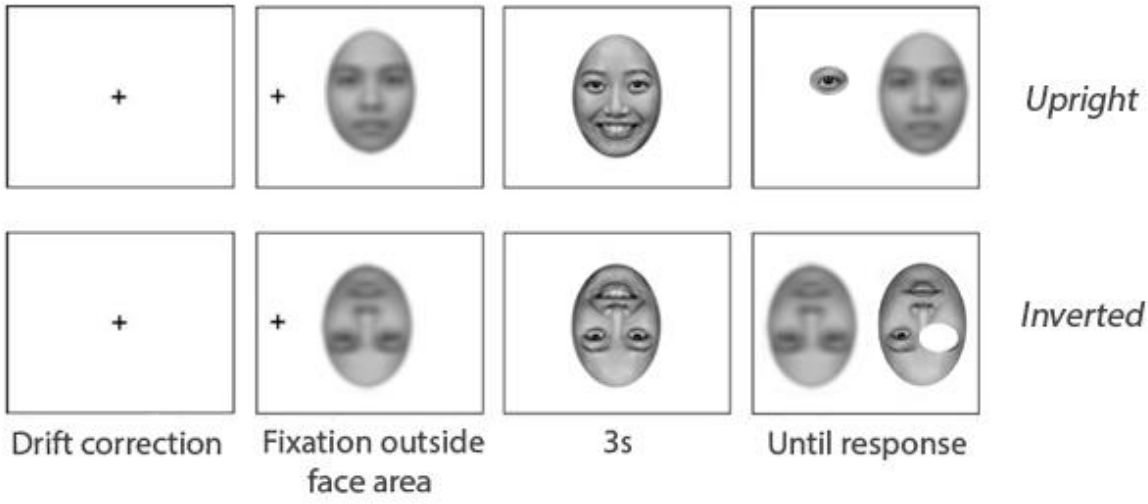


Figure 8.1. Examples of one trial for the upright and the inverted condition.

8.2.1.6 Data Analysis

Percentages of correct responses and response times (RTs) were calculated. Prior to the RT analysis, incorrect trials were excluded, and outlying RTs were discarded when they were below 200ms or more than 2.5 standard deviations above the participant's mean RT. In addition, I determined within each face race and each viewing condition outlier data by inspection of boxplots. Three extreme outliers were identified and dropped from the analysis because their accuracy and RTs deviated more than three times the interquartile range from the range borders. To account for any possibilities of speed-accuracy trade-offs, I also calculated inverse efficiency scores (see Rossion, 2013), i.e. RT divided by accuracy (proportion correct responses) for each participant and for each condition. A significance level of $p < .05$ (two-sided) was adopted, and main effects or interactions with a p value between .05 and .10 were indicated as marginally significant.

8.2.2 Results

8.2.2.1 Accuracy (%)

An ANOVA performed on percentage correct revealed a significant main effect of orientation, F (1, 20) = 17.55, p <.001, η_p^2=.47, with a higher accuracy for upright faces (M=91.46%, SD = 3.49%) than for inverted faces (M=87.03%, SD=5.36%). There was also a significant main effect of viewing condition, F (2, 40) = 48.80, p <.001, η_p^2 =.71. Pairwise comparisons showed that participants generally performed best in the control condition (M=92.33%, SD=3.12%), followed by mask condition (M=90.43%, SD = 4.59%), and then window condition (M=84.98%, SD=5.06%). Neither the main effect of face race, F(3,40) =0.40, p=.75, nor the interactions associated with face race reached significance (all p>.05). Most interestingly, there was an interaction between orientation and condition, F (2, 40) = 5.86, p =.006, η_p^2 =.23 (see *Figure 8.2*). When the faces were presented upright, accuracy did not differ in the control and the mask condition (p=1), and both the control and the mask conditions received better performance than the window condition (both p<.001). In contrast, when the faces were inverted, participants performed better in the control condition than in the mask (p=.008) and window conditions (p<.001). They also performed better in the mask condition than in the window condition (p=.03), suggesting a larger effect of inversion for processing configural than featural information, as previously reported in Van Belle, De Graef, Verfaillie, Rossion, et al. (2010).

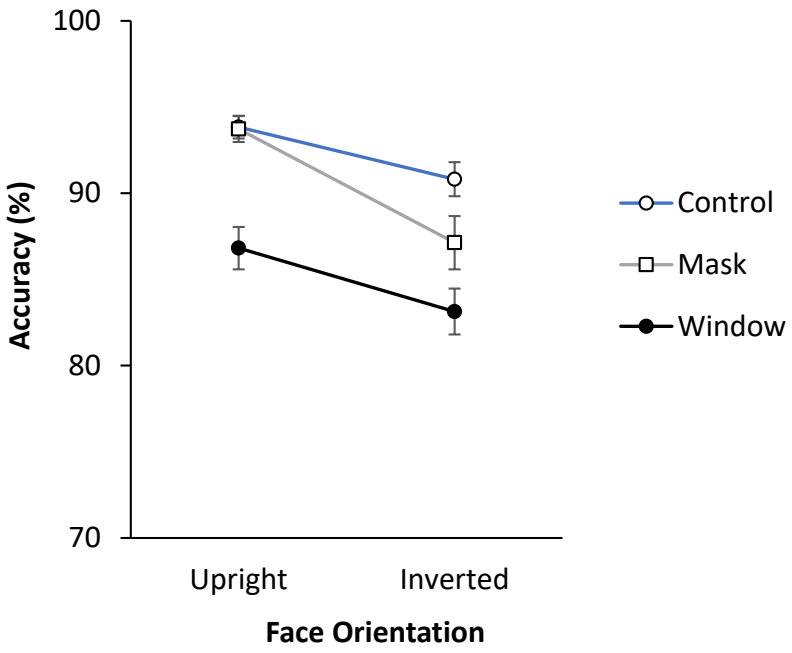


Figure 8.2. Accuracy in percentage correct scores for each combination of viewing condition and orientation. Compared to the control condition, the drop in accuracy with inversion was greater in the mask condition and was smaller in the window condition. The error bars represent standard errors of the means.

8.2.2.2 Reaction time (ms)

An ANOVA on correct response times revealed a significant main effect of orientation, F (1, 20) = 21.30, p <.001, η_p^2 =.52. Participants made slower responses to inverted faces (M=2450.62ms, SD =178.08ms) than upright faces (M=2228.33ms, SD =146.46ms). There was a significant main effect of viewing condition, F (2,40) = 47.94, p <.001, η_p^2 =.71, such that participants required more time to match the faces in the window condition (M=3175.32ms, SD =264.64ms), followed by the mask condition (M=2062.30ms, SD =140.15ms), then the control condition (M=1780.80ms, SD =104.93ms). The two-way interaction between orientation and viewing condition was also significant, F (2,40) = 7.06, p =.002, η_p^2 =.26. Post hoc analysis

showed that participants responded significantly faster for upright faces than inverted faces in the control and mask conditions (both p <.001), but not in the window condition (p=.52).

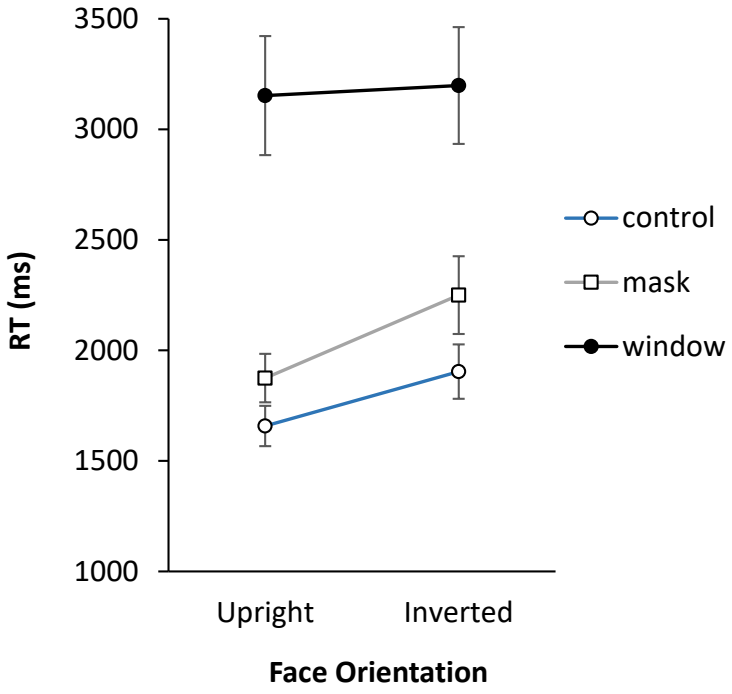


Figure 8.3. Correct response times in milliseconds for each combination of viewing condition and orientation. The error bars represent standard errors.

In addition, there was a significant three-way interaction between orientation, face race and viewing condition, F (6,120) = 2.44, p =.03, η_p^2 =.11 (see *Figure 8.4*). Analyses split by race of face revealed that the interaction between orientation and viewing condition was highly significant for Chinese faces, F (2, 44) = 9.27, p <.001, η_p^2 =.3, and was marginally significant for Malay faces, F (2, 44) = 3.59, p =.06, η_p^2 =.14. However, this interaction did not reach significance for Indian, F (2, 44) = 1.85, p =.17, and Caucasian faces, F (2, 44) = 2.34, p =.11. Pairwise comparisons showed that, for Chinese (own-race) faces, Malaysian-Chinese

participants responded faster for upright faces than for inverted faces in the control and mask conditions (p=.02 and p=.03, respectively) but not in the window condition (p=.57).

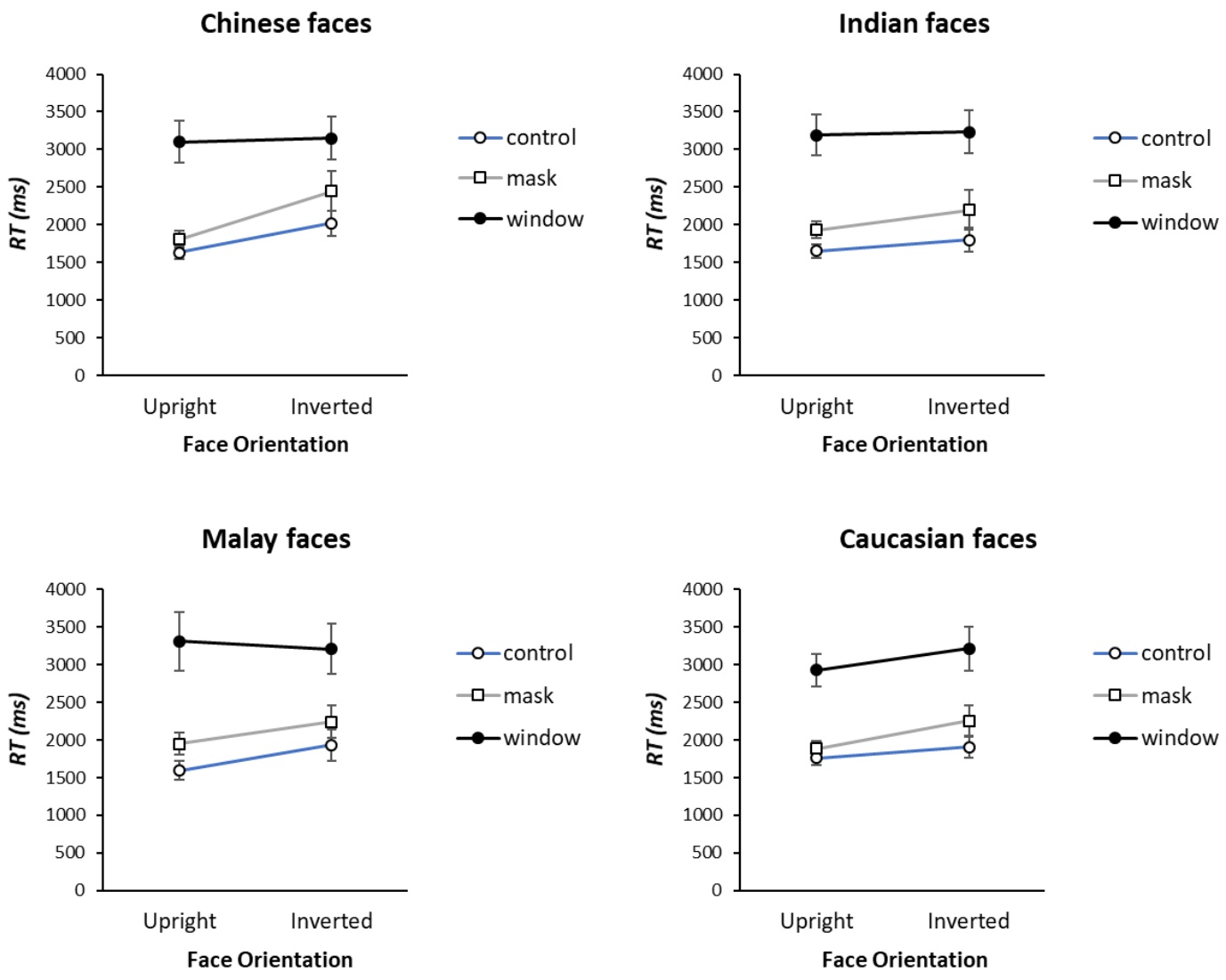


Figure 8.4. Correct reaction times in milliseconds for each combination of viewing condition and race of face. The error bars represent standard errors.

8.2.2.3 Inverse efficiency scores

A repeated-measures ANOVA performed on the inverse efficiency scores yielded main effects of orientation, F (1,20) = 21.18, p <.001, η_p^2 =.51, and viewing condition, F (2,40) = 50.46, p <.001, η_p^2 =.72. However, these main effects were qualified by a significant interaction, F (2,40) = 4.31, p =.02, η_p^2 =.18. Consistent with the RT measure, the inversion effect was evident in the control and mask conditions (both p<.001), but not in the window condition (p=.14). Inverse efficiency scores yield similar patterns compared to accuracy scores and therefore it is unlikely that results are systematically biased by speed-accuracy trade-offs.

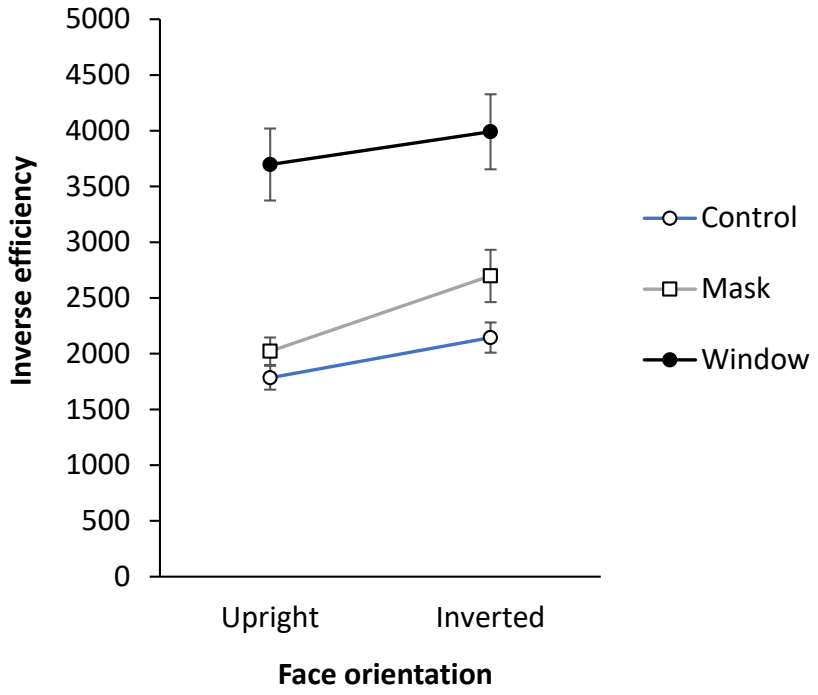


Figure 8.5. Inverse efficiency scores (reaction time divided by proportion of correct responses) for each combination of viewing condition and face orientation. Note that higher inverse efficiency scores indicate a worse performance in the sequential face matching task. Error bars represent standard errors of the mean.

8.2.3 Discussion

When faces were presented in full view, I replicated the well-known face inversion effect in the face matching task, as previously observed in several behavioural studies (Taubert, Apthorp, Aagten-Murphy, & Alais, 2011; Van Belle, De Graef, Verfaillie, Rossion, et al., 2010): better and faster performance with upright faces than with inverted faces. The performance data showed that, compared to the full view (i.e., control) condition, participants' performance for upright faces was more affected in the window condition than in the mask condition. However, the near absence of an inversion effect in the window condition supports the long-standing hypothesis that the reason why inverted face recognition is difficult is because of the inability to simultaneously extract diagnostic information at different locations on an inverted face.

Unlike previous face matching studies that employed gaze-contingent technique (Maw & Pomplun, 2004; Miellet et al., 2012; van Belle et al., 2010), the emotional expression of the target faces was changed between the study and test phase to avoid trivial image matching strategies. Although the holistic account of the face inversion effect is a high-level vision account, it is important to acknowledge that the face inversion effect may be constrained by low-level visual properties of the stimulus (e.g., colour and pigmentation cues). One way to distinguish between image- and face-specific discrimination is the face inversion effect (Rossion, 2008), where sensitivity to faces, relative to other objects, is disproportionately reduced by inversion (e.g., Bindemann & Burton, 2008; Olk & Garay-Vado, 2011). Since my data show that the inversion effect can almost be cancelled out when perception is limited to a single feature, it is very unlikely that the face matching task encouraged participants to engage image-based, rather-than face specific, processing strategies. Here I also found a significant inversion effect for both own- and other-race faces, which provides preliminary evidence that these stimuli

engage face-specific processing mechanisms. With this validated face matching task, I proceeded to investigate the ORB using a complete cross-over design in the next experiment.

8.3 Experiment 6

The experience-based holistic account of ORB posits that, due to experience, people become experts recognising faces from their own ethnic group; consequently, own-race faces would be processed more holistically rather than analytically. Yet, extensive exposure to other-race faces would also increase the amount of holistic processing, diminishing the ORB. This experiment was conducted to address two issues. First, do participants of different races use a more holistic strategy to recognise own-race faces? Second, do Chinese, Malay, and Indian individuals who were born and lived in a multiracial environment rely more on holistic information than Western-Caucasians who lived in a less racially diverse country? There is empirical evidence that own-race faces are perceived more holistically (e.g., DeGutis, Mercado, Wilmer, & Rosenblatt, 2013; Horry et al., 2015; Tanaka, Simonyi, Tanaka, & Simonyi, 2016; Zhao, Hayward, & Bülthoff, 2014; for more details, see Chapter 6). A previous study using the *Spotlight* technique (Caldara et al., 2010) showed that a gaze-contingent masking of extrafoveal information during face recognition induces a "Western-style" looking strategy (more and longer fixations on eyes and mouth) among East Asian observers. Hence, I hypothesised that the *Blindspot* technique, by restricting access to central (foveal) visual information, would lead to greater impairment in recognition performance among Western Caucasian observers than Malaysian observers. If the holistic account of the ORB is supported that own-race faces are processed more holistically than other-race faces, participants' performance for own-race faces should be relatively less affected by the presence of a mask covering the facial feature they fixate

on (mask condition) than when their perception is limited to that single feature (window condition).

8.3.1 Methods

8.3.1.1 Design

This experiment employed a 4 (Race of Face: Chinese, Malay, Indian and Caucasian) × 4 (Race of Participant: Chinese, Malay, Indian and Caucasian) × 3 (Viewing condition: control, window and mask) mixed design, with race of face and viewing condition as within-subjects variable and race of participant as between-subjects variable. The dependent variables were percentage correct and reaction time (RT).

8.3.1.2 Participants

A total of 113 (36 males, 57 females) undergraduate students studying at the University of Nottingham Malaysia Campus took part in the study. All provided informed consent prior to taking part and received RM10 for participation. Each participant was tested individually in a quiet room. The data of one Indian participant was dropped from the analysis due to eye-tracking calibration error. As a result, 30 Malaysian-Malay (M_{age}=21.33 years, SD = 0.12), 31 Malaysian-Chinese (M_{age}= 22.32 years, SD = 0.44), 31 Malaysian-Indian (M_{age}= 21.16 years, SD = 0.32), and 30 Western-Caucasian (M_{age}= 20.47 years, SD= 0.31) formed the group of participants. Malaysian participants were all born and lived in Malaysia whereas Caucasian participants were exchange students from the UK who had been staying in Malaysia for 2 months and 4 days on average. All participants self-reported normal or corrected-to-normal vision.

8.3.1.3 Apparatus and Materials

The apparatus and materials were identical to the pilot study reported earlier.

8.3.1.4 Procedure

The procedure was identical to the pilot study except the following. Because the pilot study with the same procedure informed us that the stimulus presentation duration of 3 seconds might lead to a performance level close to ceiling for accuracy (mean accuracy: 91.2% ± 4%), in this experiment, the stimulus presentation duration was reduced from 3 seconds to 1 second (van Belle, De Graef, Verfaillie, Rossion, et al., 2010). In this experiment, participants were required to complete a two-alternative-forced-choice (2AFC) face matching task which included a total of 264 trials (without inverted trials). Trials were presented in four randomised experimental blocks, separated by short breaks. The four different races of faces were mixed and equally divided into blocks of 66 trials. Faces were presented under three conditions: (1) control (full view), (2) window, and (3) mask. The order of the viewing condition within each block was randomised. The course of a trial is presented in *Figure 8.6*.

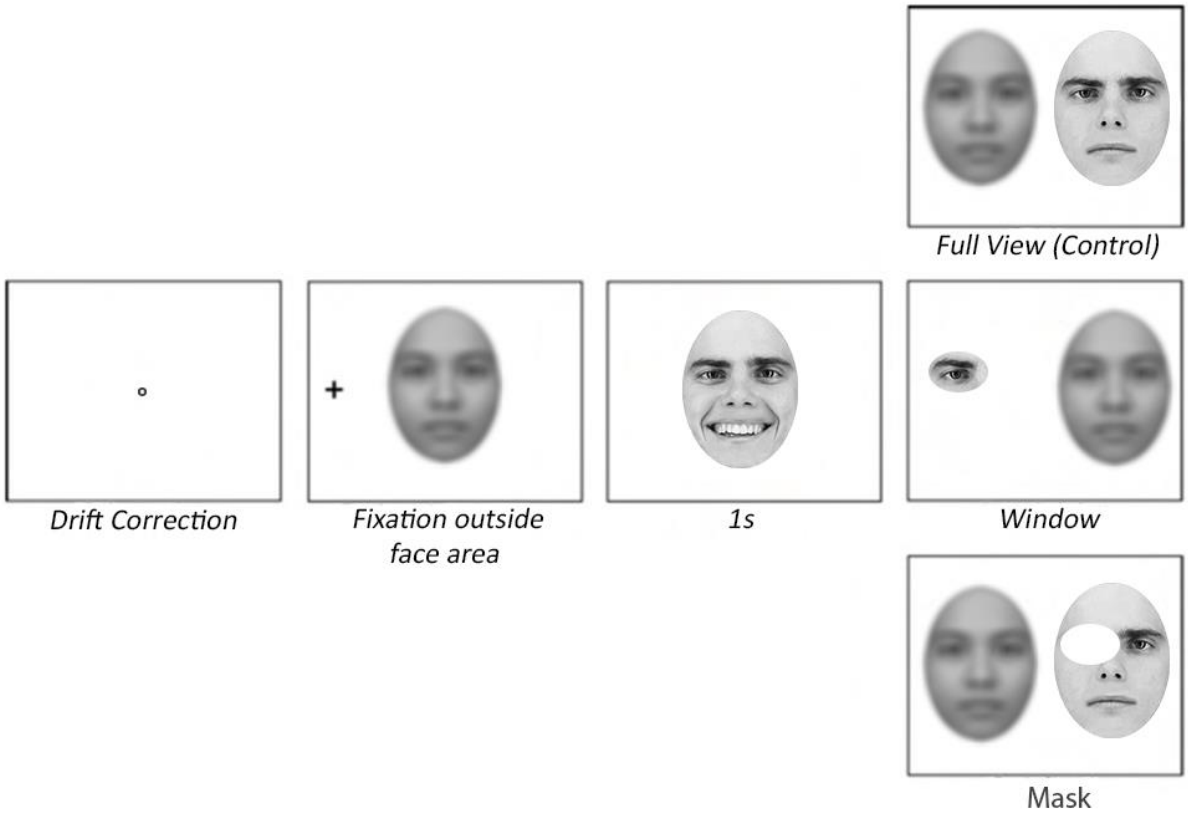


Figure 8.6. The course of a trial. After the nine-point calibration and validation, the trial started with a drift correction. A study face was presented in the centre of the screen for 1 second. Subsequently, two faces (one target and one distracter) were presented side-by-side and participants were instructed to indicate as quickly and accurately as possible which of two faces had the same identity as the study face. Three viewing conditions were included: full-view/control condition (top panel), window condition (middle panel), and mask condition (bottom panel).

8.3.1.5 Data Analysis

Participants' behavioural performance was measured by the percentage of correct recognition, correct RTs, and inverse efficiency scores. A 3 × 4 × 4 mixed factorial analysis of variance (ANOVA) was performed on each measure, with the Viewing Condition (control,

windows, and mask) and Race of Face (Malaysian-Malay, Malaysian-Chinese, Malaysian-Indian, and Western-Caucasian) as within-subjects variables and the Race of Participant (Malaysian-Malay, Malaysian-Chinese, Malaysian-Indian, and Western-Caucasian) as between-subjects variables. RT analysis included only trials with correct responses.

8.3.2 Behavioural Results

8.3.2.1 Accuracy (%).

A significant main effect of viewing condition was found, F (2, 236) = 303.24, p <.001, η_p^2 = .73, showing that participants generally performed better in the control condition (M= 91.04%), followed by the mask condition (M= 89.88%) and then the windows condition (M= 78.33%) (all p < .05). No significant main effect of race of participant was found, F (3, 118) = 1.05, p =.37, η_p^2 = .03. A highly significant interaction between race of participant and race of face was found, F (9, 354) = 3.61, p < .001, η_p^2 =.09. Pairwise comparisons showed that Chinese participants' accuracy performance for Chinese faces was significantly better than Caucasian faces (p=.05), and marginally better than Malay (p=.09) and Indian faces (p=.06). In contrast, Caucasian participants showed a higher accuracy for Caucasian faces than for Malay faces (p=.003) and Chinese faces (p=.008). No ORB was detected in Malay (all $p \geq .59$). and Indian participants (all $p \geq .13$).

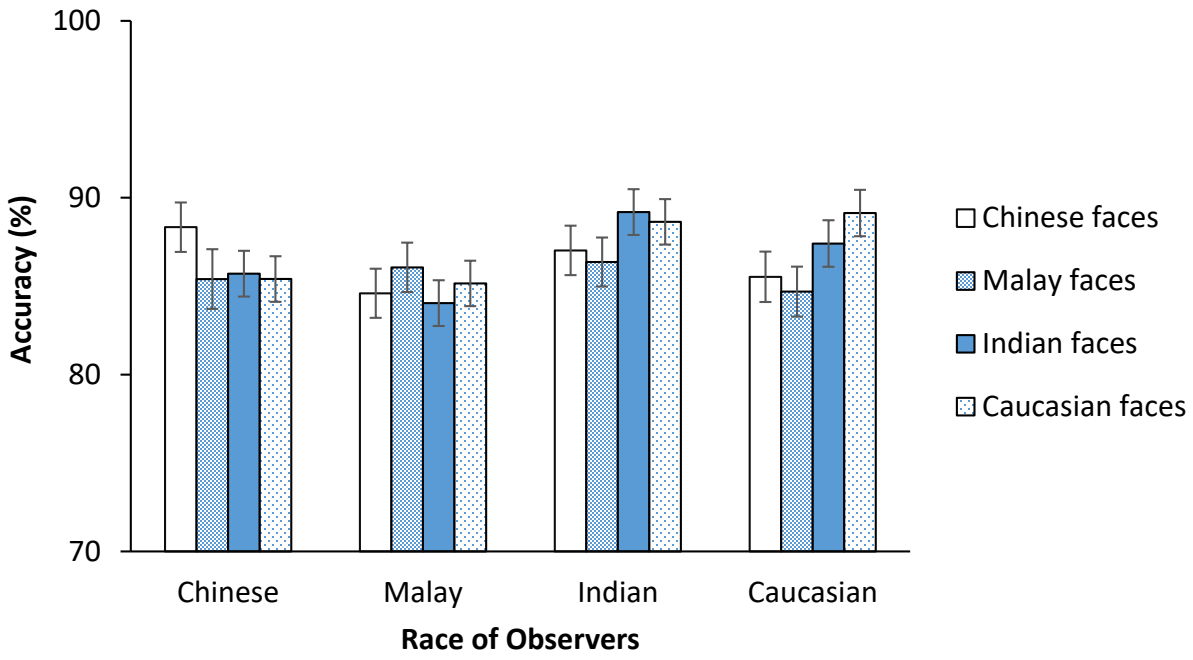


Figure 8.7. Mean accuracy in percentage correct of Chinese, Malay, Indian and Caucasian participants for each face race. The error bars represent standard errors.

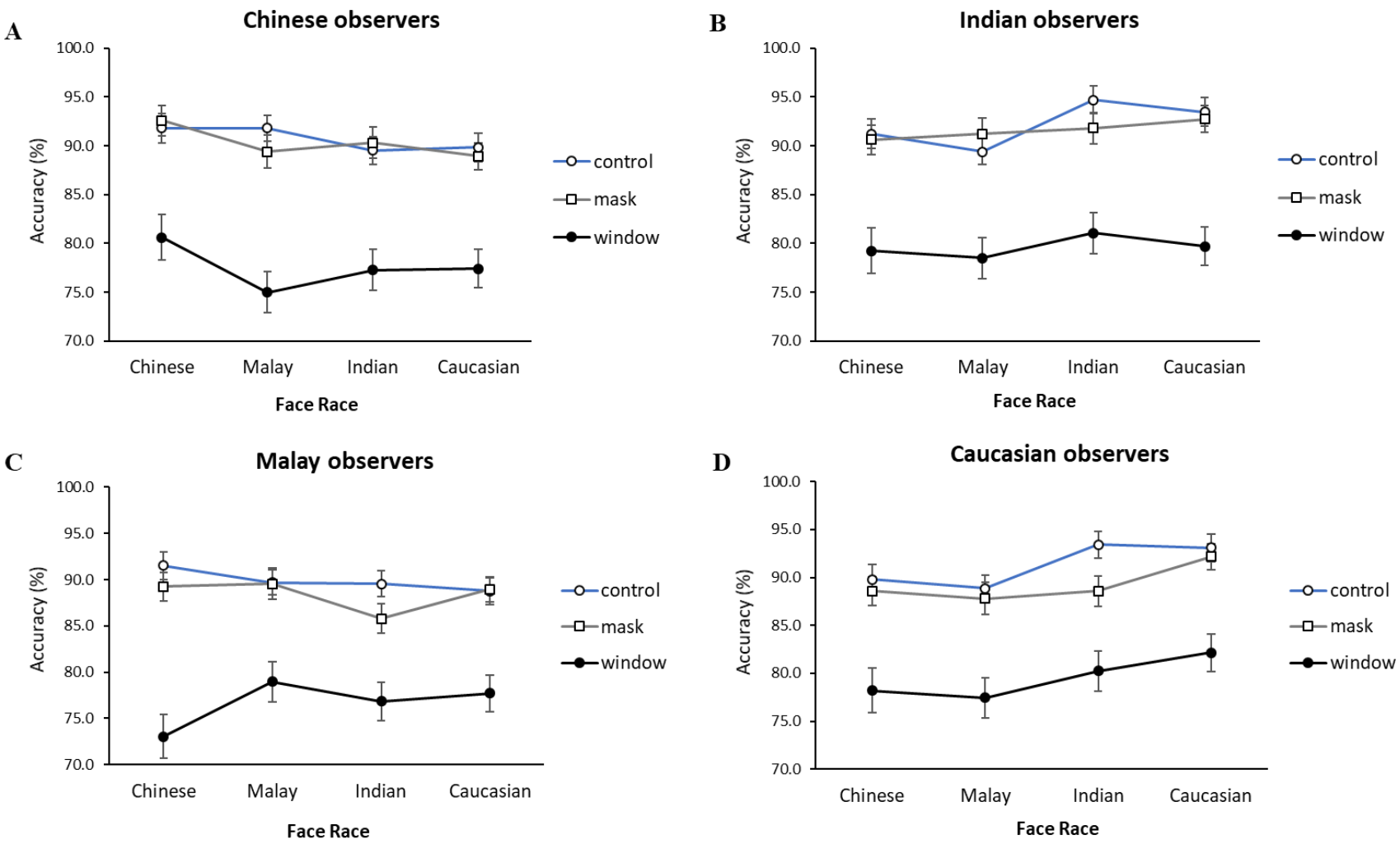


Figure 8.8. Mean recognition accuracy for the four face races by (A) Chinese, (B) Malay, (C) Indian and (D) Caucasian observers. Error bars represent standard errors.

8.3.2.2 Reaction time (ms).

There was a significant main effect of viewing condition, F (2, 236) = 162.93, p <.001, η_p^2 = .59. Participants generally responded faster in the control condition (M=1658.89ms, SD = 453.14ms), followed by mask condition (M=1859.38ms, SD = 645.03ms), and then window condition (M=2844.73ms, SD = 1264.54ms). There was a main effect of Race of Face, F (3, 354) = 7.32, p<.001, η_p^2 = .06, revealing a shorter mean RT for Caucasian faces (M=2052.04ms, SD = 692.07ms) than for Chinese (M=2151.51ms, SD = 734.43ms), Malay (M=2156.22ms, SD = 802.32ms) and Indian (M=2124.22ms, SD = 795.26ms) faces. Both two-way interactions between race of participant and race of face, F (9, 354) = 2.60, p = .007, η_p^2 = .06, and between Race of Face and Viewing condition, F (6, 708) = 2.60, p = .001, η_p^2 = .03, were significant, accompanied by a significant three-way interaction between race of observer, condition and race of face, F (18, 708) = 2.36, p = .001, η_p^2 = .06. Split analyses by race of participant revealed a significant interaction face race and viewing condition only in Chinese, F (6, 180) = 3.59, p=.002, η_p^2 = .11, and Malay participants, F (6, 162) = 5.48, p<.001, η_p^2 = .17, but not in Indian, F (6, 180) = 0.53, p=.78, η_p^2 = .02, and Caucasian participants, F (6, 162) = 0.54, p=.78, η_p^2 = .02. Pairwise comparisons revealed that, in the mask condition, Chinese participants responded faster to Chinese faces than Malay faces (p=.02); however, in the window condition, their RTs for Caucasian faces were significantly shorter than for Indian faces, and marginally faster than for Chinese and Malay faces (p=.06 and p=.08, respectively). For Malay participants, in the window condition, their RTs were significantly longer on Malay faces than on Indian (p=.005) and Caucasian faces (p=.01); however, no significant RT difference was found between face races in the control and mask conditions (all p >.05).

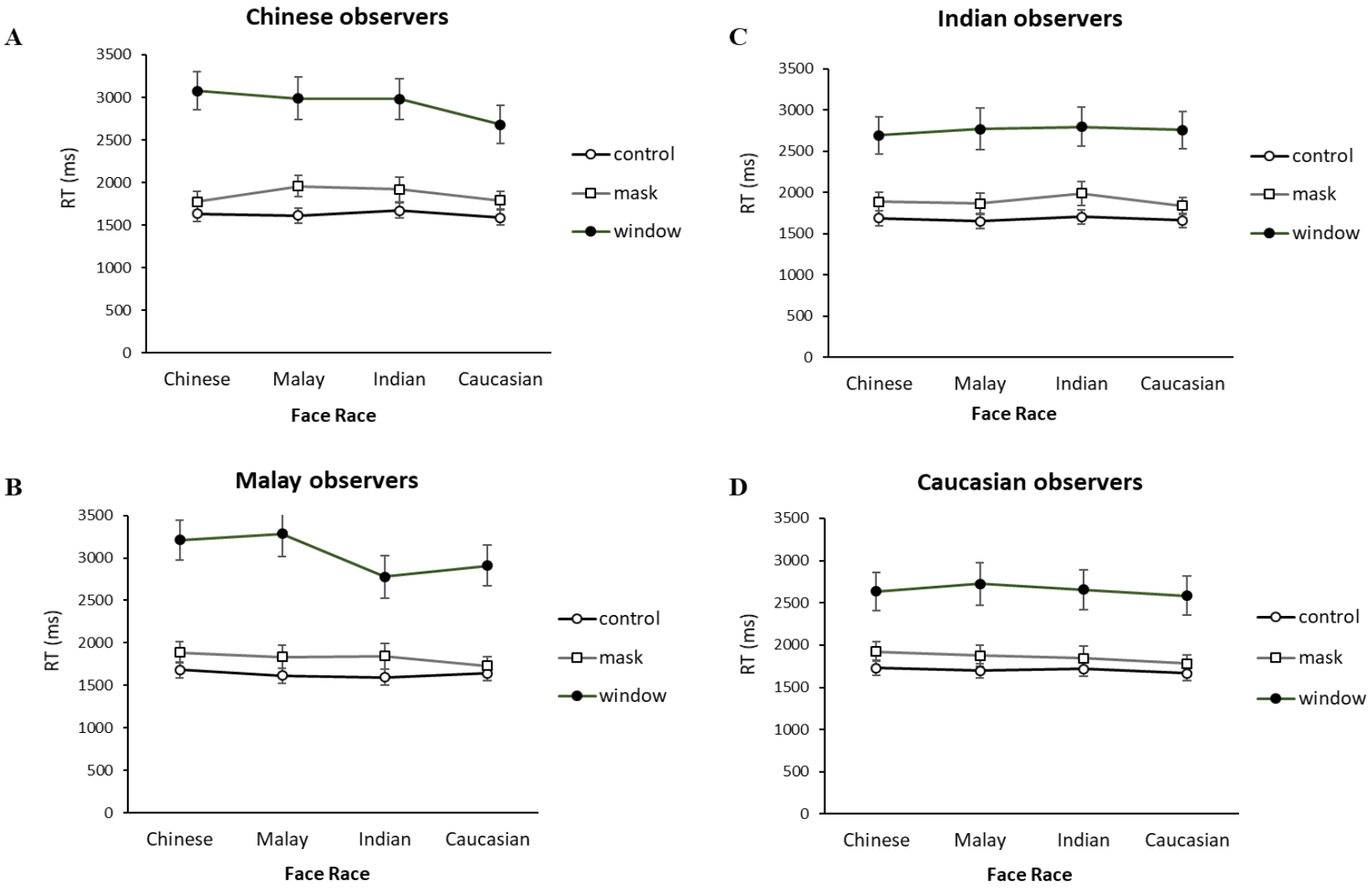


Figure 8.9. Reaction times in milliseconds for each combination of viewing condition and race of face in (A) Chinese, (B) Malay, (C) Indian and (D) Caucasian observers. Error bars represent standard errors.

8.3.2.3 Inverse efficiency scores

A mixed ANOVA on inverse efficiency with Race of Observer as between-subjects variable and Race of Face and Viewing Condition as within-subjects variable revealed a significant main effect of Race of Face, F (3, 345) = 9.79, p <.001, η_p^2 =.08, such that Caucasian faces (M= 2419.84ms, SD =381.82ms) were performed significantly better than Chinese (M=2614.11ms, SD = 482.15ms) and Malay faces (M=2600.59ms, SD = 476.68ms) (both p<.001), and marginally better than Indian faces (M=2510.22ms, SD = 433.03ms; p=.07). There was a highly significant main effect of Viewing Condition, F (2, 230) = 270.71, p <.001, η_p^2 =.70, such that participants generally performed best in the control condition (M=1843.70ms, SD=514.24ms), followed by the mask condition (M=2097.05ms, SD=752.70ms) and then the window condition (M=3667.81, SD =1480.09ms). No main effect of Race of Observer was found, F (3, 115) = 1.82, p =.15, η_p^2 =.05.

A three-way interaction between race of face, viewing condition and race of participant was also significant, F (18, 606) = 50.09, p =.006, η_p^2 =.06 (see *Figure 8.10*). To gain further insight in this interaction, I conducted separate repeated measures ANOVA for each participant race group. As a result, the Race of Face by Viewing Condition interaction was significant in Chinese, F (6, 168) = 2.73, p =.02, η_p^2 =.09, and Malay participants, F (6, 174) = 7.84, p <.001, η_p^2 =.21, but not in Indian, F (6, 174) = 0.42, p =.87, η_p^2 =.01, and Caucasian participants, F (6, 174) = 0.77, p =.59, η_p^2 =.03. Chinese participants showed no difference of inverse efficiency scores between different races of faces in the control and window conditions (all p≥.64); however, in the mask condition, they performed better for Chinese faces than Malay faces. In contrast, Malay participants showed no difference of performance between races of faces in the

control and mask condition (all $p \geq .17$). However, in the window condition, they performed significantly better for Indian faces than for Malay ($p=0.2$) and Chinese faces ($p=.001$).

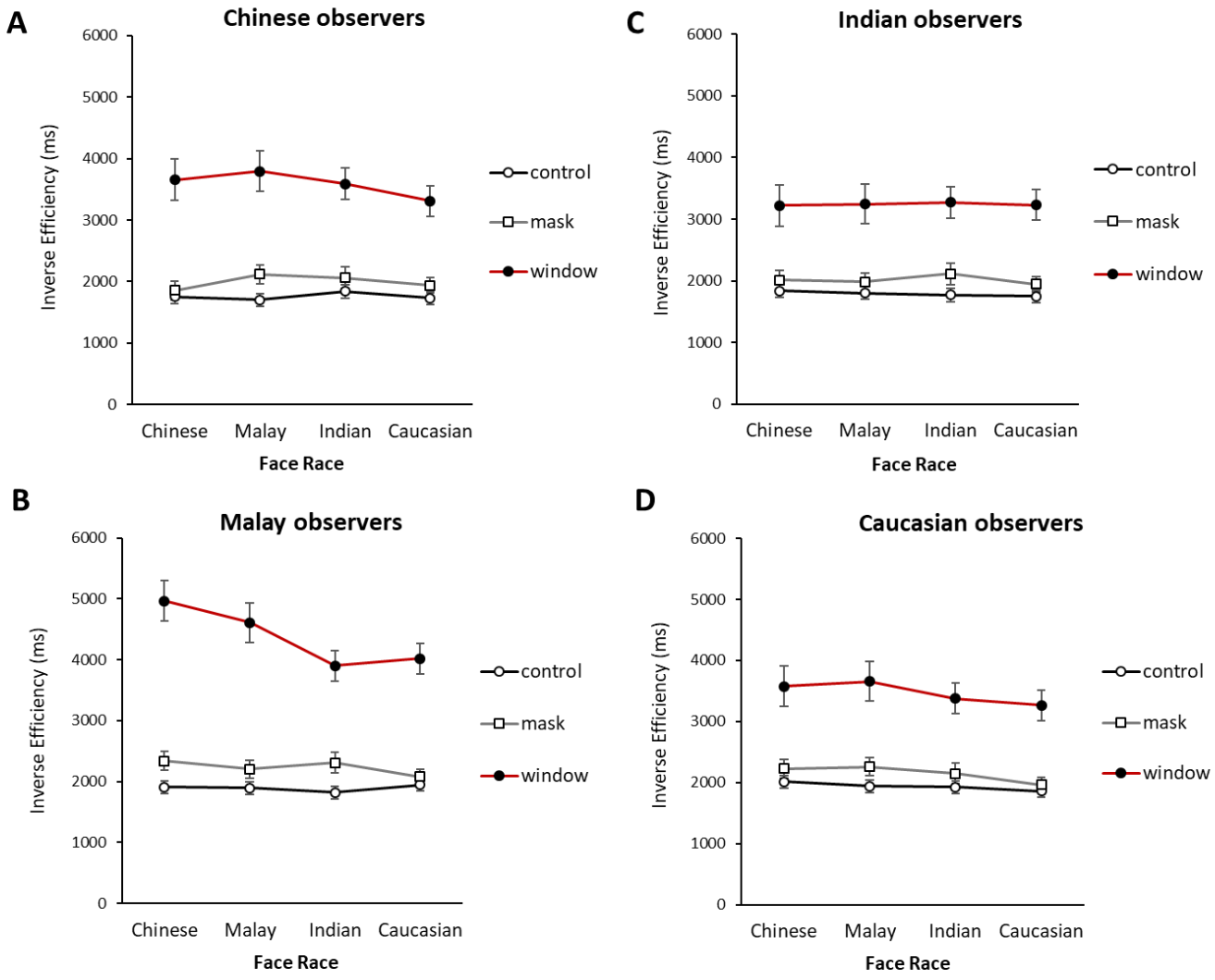


Figure 8.10. Inverse efficiency scores for each combination of viewing condition and race of face in (A) Chinese, (B) Malay, (C) Indian and (D) Caucasian observers. Note that higher inverse efficiency scores indicate a worse performance in the sequential face matching task. Error bars represent standard errors of the mean.

8.3.3 Discussion

This experiment employed the gaze-contingent technique to investigate whether restricting facial information outside/inside central vision affects face recognition accuracy for own- and other-race faces in Malaysian-Chinese, Malaysian-Malay, Malaysian-Indian and Western Caucasian observers. Regardless of the race of observers, observers responded faster and more accurately when they saw full faces than when there was a mask or window. This performance difference between viewing conditions was observed even though the task was quite simple. Clearly, the simultaneous availability of the entire face information is crucial for efficient face recognition, supporting the view that face recognition involves holistic processing that heavily relies on parafoveal and peripheral input, not only for own-race faces, but also for other-race faces (Caldara et al., 2010; Maw & Pomplun, 2004; Miellet & Caldara, 2010; Van Belle, De Graef, Verfaillie, Busigny, et al., 2010)

In the window condition, the observer can extract information from one feature at a time but is unable to see two or more features simultaneously. Participants showed greater impairment in the delayed face matching task when they could only use a single feature that was fixated compared to when this feature was masked. This observation implies that a forced feature-by-feature processing through a limited spatial window is not at all optimal for face recognition, supporting previous reports that a limited spatial window impairs recognition performance (Caldara et al., 2010; Van Belle, De Graef, Verfaillie, Busigny, et al., 2010). Despite a small effect, there was a general trend towards an ORB across participant race groups when observers had their vision constrained in such a way that they could see only through small central window. This observation indicates that the ORB effect is not caused primarily by reduced holistic processing. Rather, the difficulty in perceiving local detailed facial features on other-race faces may also play a part. An alternative explanation for the observation of own-race recognition advantage only in the window

condition is that the ORB was masked by high performance accuracy in the control (mean accuracy = 90.38%) and mask conditions (mean accuracy = 89.27%) relative to the window condition (mean accuracy = 77.75%).

When the central vision was masked, there was also a performance decrease, although this drop in accuracy rates was significantly less pronounced than that in the window condition. This indicates that the fixated local features (featural processing) certainly contribute to face recognition and perhaps it is more critical to be able to see the remainder of the entire face for optimal face recognition. In the mask condition where the observer's central vision is masked, the optimal strategy is to extract information visible outside the mask, simultaneously from the remaining area of the face. It is possible that observers still relied on a single feature at the border of the mask in this condition; however, the data suggest that observers did not do so because such a piecemeal strategy in the mask condition would make them perform at the level of the window condition at best, but not better. That is, if participants relied only on one feature at a time in the mask condition, their performance should have been lower than in the window condition, given that the information was presented outside of their foveal vision. Rather, the higher performance in the mask than in the window condition implies that, observers extracted information extrafoveally from several features available simultaneously over the whole face in the mask condition (Van Belle, De Graef, Verfaillie, Busigny, et al., 2010).

8.4 General Discussion

The gaze contingent method used here and my findings with it have wider implications for a better understanding of the nature of ORB. It has been long proposed that individuals who suffer from difficulty in recognising other-race faces, employ less holistic face processing (e.g., Crookes, Favelle, & Hayward, 2013; Hayward, Crookes, & Rhodes, 2013; Horry et al., 2015; Michel, Rossion, Han, Chung, & Caldara, 2006; Michel, Caldara, &

Rossion, 2006; Tanaka et al., 2004; Zhao, Hayward, & Bülthoff, 2014). However, mixed evidence has been reported as a series of recent experiments did not observe such a relationship (e.g., Horry et al., 2015; McKone et al., 2012; Nakabayashi & Liu, 2014; Zhao et al., 2016). If the holistic view of the ORB is true, participants' performance for own-race faces should be particularly impaired in a central window condition, but relatively unaffected when their central vision is masked. The current results clearly did not support this view. It is likely that the process of perceiving faces holistically may be a critical stage of the initial face matching or detection but does not necessary lead to accurate identification at the individual level.

My data are counter to the prediction derived from the experience-based holistic account of ORB (Tanaka, Kiefer, & Bukach, 2004; see Chapter 6 for more discussion) that own-race faces are processed more holistically than other-race faces due to perceptual expertise. If this is true, the overall performance for own-race faces would have been lower than for other-race faces in the window condition. Clearly, this is not the case. Despite the observation of the weak ORB, in most cases, the recognition accuracy for own- and other-race faces was comparable when the perceptual field was constricted to one facial feature at a time when attempting to recognise a face. Results from the mask condition also suggest that ability to extract diagnostic information from outside the central window of vision did not differ between own- and other-race faces. These findings complement more indirect evidence of a lack of difference in holistic processing between own-race and other-race faces during face identification (Horry et al., 2015; McKone, Stokes, et al., 2012; Nakabayashi & Liu, 2014; Schwarzer & Zauner, 2003; M. Zhao et al., 2016a), indicating that the ORB cannot be merely due to differences in holistic processing (see also Chapter 6).

It has been recently suggested that both configural and featural coding were better for own-race than for other-race faces (Rhodes et al., 2006). In addition, cross-cultural studies

have shown that Western Caucasian observers favour local eye movement strategies to process faces, whereas East Asian observers favour a global strategy (Blais, Jack, Scheepers, Fiset, & Caldara, 2008; Caldara et al., 2010; Miellet & Caldara, 2010; Miellet et al., 2013). For example, Blais et al. (2008) reported that Westerners predominantly fixate the eyes during face recognition, whereas Easterners more the nose region, yet recognition accuracy is comparable. However, these culture-specific looking strategies are not compulsory but extremely flexible (Miellet & Caldara, 2010).

By using a gaze-contingent technique masking central vision, Miellet & Caldara (2010) also found consistent cultural bias on fixation patterns during face recognition: Easterners preferentially sample information extrafoveally for faces whereas Western Caucasians preferentially sample the diagnostic features foveally. More interestingly, there was a shift between the distributions of foveal versus extrafoveal information sampling strategies for Western Caucasian versus East Asian participants depending on the size of the gaze-contingent mask. Specifically, East Asian observers can shift from their favourite strategy (central-nose bias) to the Western Caucasian observers' strategy (eyes-mouth bias) without any cost in terms of performance (Caldara et al., 2010). My results provide a behavioural parallel to their observation that the same observer might use one or the other (local/foveal versus global/extrafoveal) on different trials, depending on the viewing condition (Miellet, Caldara, & Schyns, 2011). Compared to other-race faces, recognition of own-race faces seemed to be less affected in the window condition but not in the mask condition, indicating that analytical/featural mode of processing can be applied to own-race faces if needed (Hayward et al., 2008).

In conclusion, the observations made in the current study challenge the holistic account of ORB. Regardless of the race of input face, participants' performance at an individual face discrimination task decreased when they were forced to extract the facial

information feature-by-feature than when they could process all features at once holistically. Given the high-performance level across viewing conditions, I favour a view that facial information can be flexibly gathered from own-race and other-race faces through diverse looking strategies (holistically and/or featurally). In other words, the ORB cannot be purely accounted for by the inability to perceive other-race faces as a whole. My data support the idea of the existence of diverse strategies dedicated to face processing which adjust to the task at hand and the ability to extract detailed information from particularly diagnostic local features might be useful for both own- and other-race faces in a face matching task. While restricting one's central/peripheral visual input could provide us with insight into which essential information was needed to be processed, future eye-tracking studies should consider using the gaze-contingent stimulus presentation method as an alternative tool for elucidating the perceptual mechanisms underlying face processing, for which the nature of ORB and different processing styles between races remain unclear at this stage.

Chapter 9

General Discussion and Conclusions

9.1 Overview of Research

The own-race bias (ORB) is a reliable phenomenon across cultural and racial groups (Meissner & Brigham, 2001). A meta-analysis, by Meissner & Brigham (2001), reports that the majority (about 88%) of research on ORB employed Caucasian or African populations, with only a few studies employing other races. In the past two decades, a growing body of research has also addressed the ORB in East Asian populations (Goldinger et al., 2009; Kelly et al., 2005; Wu et al., 2012). However, these findings may not necessarily apply to individuals from a multi-racial country because the social environment can be more complex and vary drastically in comparison to that of individuals from a mono-racial background. Therefore, more specific research on the ORB with Southeast Asians (e.g. Malaysians) living in a racially diverse environment would be beneficial for understanding the mechanisms underlying cross-race face processing. By employing a series of face memory and face perceptual tasks, this thesis set out to examine the role of multi-racial experience (Chapter 3 and 5) as well as potential perceptual/attentional mechanisms (Chapter 6 – 8) in modulating own- and other-race face processing. In this final chapter I will address the main findings of each study and propose further directions for research.

Chapter Three (1) investigated the contact hypothesis that Malaysian individuals (i.e. Malay, Chinese, and Indian) with more interracial experience in a multicultural society would exhibit a diminished ORB in comparison to Western-Caucasian individuals with less interracial experience; (2) tested the enculturation hypothesis by observing how the eye movement patterns produced by Caucasians differ from those of the three different racial

groups in Malaysia when performing a classic old/new face recognition task involving own- and other-race faces.

It is well known that distinctive faces (i.e. those that deviate from the face norm or "average") are remembered particularly well (e.g., Chiroro & Valentine, 1995; Valentine & Bruce, 1986) and associated with greater processing efficiency (Semmler & Brewer, 2006), such that more accurate memory for own-race faces in the previous ORB studies may have been partly influenced by differences in distinctiveness in the respective sets of faces. Therefore, distinctiveness is an important factor to consider in ORB research. To test this possibility, Chapter 4 investigated (1) whether the consistently better performance for Indian faces than for other-race faces across race groups in Chapter Three could be due in part to a larger amount of variability in distinctiveness within Indian faces than within the sets of faces of other races and (2) how facial distinctiveness affects the recognition of own- and other-race faces. In this eye-tracking study, I collected facial similarity ratings from four race groups: Chinese, Malay, Indian and British-Caucasian participants using Malaysian (Chinese, Malay, Indian). In the facial similarity rating task, participants were asked to rate how strongly an original face deviates from an average face generated from faces used in the former old-new face recognition experiment. The link between the mean distinctiveness rating scores and recognition accuracy was then examined using correlational analyses.

Many ORB studies have used static face stimuli without hair (e.g., McKone, Brewer, MacPherson, Rhodes, & Hayward, 2007) and only focused on the recognition of internal features, perhaps because the internal features (i.e. eyes, nose and mouth) have been shown to be the most significant features for face recognition. Given that external features are useful for recognising and matching unfamiliar faces (Ellis et al., 1979; O'Donnell & Bruce, 2001; Young et al., 1985; but see Toseeb, Keeble, & Bryant, 2012), Chapter 5 further examined whether and, if so, to what extent the presence of external features reduces the ORB in face

memory. I replicated the experiment reported in Chapter Three using an identical procedure but a different stimulus type. Rather than egg-shaped faces, face images including the external features were presented.

Holistic processing has been proposed as one important mechanism underlying the ORB. According to this view, in contrast to own-race faces, people are inefficient at integrating information from individual facial components from other races into a whole representation (Tanaka, Kiefer, & Bukach, 2004a). Thus, holistic processing would be reduced for other-race faces. Despite extensive evidence for a holistic mode of processing for faces, whether own- and other-race faces are processed holistically to the same degree is not clear (for a recent review, see Hayward, Crookes, & Rhodes, 2013). Chapter 6 aimed to investigate whether the ORB in face memory can be attributed to reduced holistic processing of unfamiliar other-race faces. In order to address this question, I adopted a cross-cultural design where Malaysian-Chinese, African, European-Caucasian and Australian-Caucasian participants performed four different tasks: (1) yes-no face recognition, (2) composite, (3) whole-part and (4) global-local tasks. Each face task was completed with unfamiliar own- and other-race faces.

Some studies indicate that the ORB may not necessarily be due to an inability of the perceptual system to encode other-race faces (Hills & Lewis, 2006; Hugenberg, Miller, & Claypool, 2007; but see Bornstein, Laub, Meissner, & Susa, 2013). Rather, it may be due to differential allocation of attentional resources to own-race and other-race faces so that own-race faces are individuated or processed expertly and other-race faces are not. While individuation training (Hussain, Sekuler, & Bennett, 2009; McGugin et al., 2011; Tanaka & Pierce, 2009) and instructions (Hugenberg et al., 2007; Megreya, 2018; Rhodes, Locke, Ewing, & Evangelista, 2009) do sometimes lead to a reduction in the ORB, Hills and Lewis (2011) extended these findings by demonstrating that extensive training was not required to

improve face identification for unfamiliar other-race faces. Given that the initial fixations are important for accurate recognition of faces (Hsiao & Cottrell, 2008), Hills and Lewis (2011) reported that directing immediate attention to diagnostic features may reduce the ORB.

Two experiments in Chapter 7 were designed to test this hypothesis that directing immediate attention to diagnostic features would reduce the ORB while taking both the race of face stimuli and observers into consideration. Both experiments employed identical procedures but included different participant race groups. Not only Caucasian and African participants, as reported in Hills et al. (2013b), were tested, but also the three major races in Malaysia (Chinese, Malay and Indian) who have frequent direct and indirect exposure to other-race races. Experiment 7A explores any effect the fixation crosses have on the recognition performance for own- and other-races faces in Malaysian-Chinese, compared with Australian-Caucasians and South Africans. Experiment 7B further investigates whether the cueing effect would be stronger for Malaysians within the range of faces typically experienced in the multiracial population.

In Chapter 8, I further tested the experience-based holistic account of ORB by the means of a gaze-contingent stimulus presentation. In an individual face discrimination task, I used a moving window ('Spotlight', Caldara et al., 2010) or a moving mask ('Blindspot', Miellet et al., 2012) to investigate whether restricting facial information outside/inside central vision affects face recognition accuracy for own- and other-race faces in Malaysian-Chinese, Malaysian-Malay, Malaysian-Indian and Western Caucasian observers.

9.2 Summary of the Main Findings

9.2.1 Chapter 3: Face Recognition in Malaysians and Caucasians

While the vast majority of previously published ORB studies have been conducted in racially homogenous communities (e.g., USA, UK, and Germany), recognition deficits for other-race faces have often been attributed to the amount of contact with other-race and own-

race faces. Moreover, only recently have researchers questioned whether identical underlying strategies are used when observers of different races perceive faces (e.g., Blais, Jack, Scheepers, Fiset, & Caldara, 2008). By adopting a yes/no recognition paradigm, Chapter Three revealed that the ORB was pronounced not only in Western-Caucasian participants, but also in Malaysian participants (Malay, Chinese, and Indian) who grew up in a racially diverse environment, implying that growing up in a profoundly multiracial society does not eliminate the ORB. These results clearly failed to support my prediction, derived from the contact hypothesis, of equally high recognition performance for own- and other-race faces in either group of Malaysian participants. My findings therefore add to a body of evidence suggesting that the ORB in adulthood is a very robust effect and may not be as malleable as is commonly assumed. Interracial contact did not appear to predict the magnitude of the ORB. Overall, my results did not support a simplistic version of contact hypothesis. My eye-tracking results showed that participants from different ethnic groups tend to adopt broadly similar eye movement patterns although some differences were found. Compared with the other three race groups, Malaysian-Indian participants tend to have shorter fixation durations (and lower number of fixations) on the eyes but longer (or more) on the mouth. In contrast, Caucasian participants directed more and longer fixations to the eyes and mouth than Malaysian-Chinese participants did. Such an inconsistency indicates that facial cues which have higher diagnostic value for identifying faces may differ between race groups, with individuals preferentially directing attention to the features that are most diagnostic of identity in their own racial group.

The ORB may be attributed to an inability to extract information from the most diagnostic visual features on other-race faces (Michel, Rossion, Bülthoff, & Hayward, 2013). Despite many years of interracial experience, the ORB in Malaysian young adults does not seem to be attenuated or eliminated as compared to Western-Caucasian young adults who

lived in communities that are relatively less racially and ethnically heterogenous. This current finding renders previous reports that the ORB is less evident in multiracial populations (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Chiroro & Valentine, 1995; Wright, Boyd, & Tredoux, 2001), can be reversed following cross-race adoption before the age of 9 years (Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005), and can be reduced by training (Hills & Lewis, 2006), difficult to interpret. An open question raised by my data is whether, in addition to interracial contact *per se* affecting the size of ORB, the ability to recognise other-race faces might also be affected by the age at which that contact is obtained (Mckone et al., 2019). This idea draws parallels with an analogous effect in another recognition memory biases, such as the own-age bias (Cassia et al, 2014; see also Harrison and Hole). Cassia et al. (2014) showed infants' discrimination abilities narrow to adult human faces within the same time frame when narrowing to own-race faces occurs. More specifically, their newborn-face discrimination ability decreases between 3 and 9 months of age, whereas adult-face discrimination is maintained. Altogether these results highlight the importance of early perceptual experience in shaping face representation.

Although the current study was not specifically designed to address this question as the period of contact was not directly measured, my results raise the intriguing possibility that Malaysian individuals living in a racially heterogeneous context might still lack childhood experience in individuating other-race individuals due to prototypical perceptual environmental in the early developmental stages of face recognition ability. To my knowledge, this hypothesis has not been directly investigated.

Despite a long history of interaction among the Malays, Chinese and Indians, a common culture did not emerge and each group more or less holds to their own religion, culture, language, and tradition (Embong, 2002). Low levels of interracial contact during infancy and childhood in Malaysians is commonly reflected through the same-race primary

caregivers (Su et al., 2018) and the racially segregated educational systems in primary and secondary schools (Kawangit et al., 2012). For instance, the Chinese usually send their children to the Chinese schools with their syllabus adopted from mainland China; Malays send their children to *Madrasa* (religious school) and Indians to Tamil schools. Therefore, opportunities for Malaysians (Malays, Chinese and Indian) to integrate and interact with other-race individuals as a community in early childhood may not be as frequent as expected. Theoretically, the current proposal that ORB might be specifically associated with low childhood contact would imply that the effectiveness of multiracial experience on tuning the adult face recognition system would differ depending on individuals' early other-race experience.

Developmental studies have demonstrated a critical period for plasticity of ORB (Chien et al., 2016; Fioravanti-bastos et al., 2014; Su et al., 2017) and such recognition bias can be reduced by contact with the faces of another race during childhood, pointing towards the importance of early individuating experience in developing mechanisms of remembering and distinguishing other-race faces. Perhaps such early-formed recognition bias for own-race faces cannot be readily altered by increased exposure to other-race faces in adulthood, even in a highly multiracial context. Future research that is longitudinal is needed to investigate the relative contributions of early and late interracial experiences to the reduction of ORB.

9.2.2 Chapter 4: The Distinctiveness Effect on the ORB

Chapter Four examined how distinctiveness influences memory for own- and other-race faces, with the particular aim of determining whether the recognition advantage observed for Indian faces in Chapter Three could be merely due to a distinctiveness effect. Facial distinctiveness rating scores obtained from four participant race groups (Chinese, Malay, Indian, and Caucasian) showed that Indian faces contained in the stimulus set were rated more distinctive as compared to other race face sets. In addition, a correlational analysis

showed that memory for target faces improved with distinctiveness; most importantly, own-race faces benefited more from this distinctiveness effect than other-race faces in most participant race groups. The distinctiveness effect was discussed in relation to the multidimensional space framework proposed by Valentine (1991). This framework offers an explanation of distinctiveness effect in cross-race memory biases: own-race distinctive faces are distributed more widely in the face space than other-race distinctive faces due to an individual's limited experience with other-race groups. Perhaps face-space dimensions are appropriately tuned to describe the facial configuration and featural characteristics of own-race faces; on the other hand, other-race faces which are less experienced may be processed less efficiently due to a lack of flexibility in face processing (Richler et al., 2008). Eye-tracking results demonstrated the subtle differences in the way different race groups process facial information during the facial distinctiveness rating task, implying a perceptual processing difference between own- and other-race faces. Chinese, Malay, and Indian participants made most and longest fixations on the nose, followed by the eyes and then mouth region. However, Caucasian participants showed no difference of time spent fixating the eyes and mouth. This reflects the use of different attributes to make facial similarity judgement in different cultures (East Asians vs. Western Caucasians).

9.2.3 Chapter 5: The Significance of External Features for Other-Race Face Recognition

Recognition of unfamiliar faces heavily relies on external features (Henderson, Williams, & Falk, 2005; Sporer & Horry, 2011; but see Toseeb, Keeble, & Bryant, 2012). However, most studies on own-race bias (ORB) have focused on the recognition of internal features, and relatively little is known about to what extent external features affect the ORB. Chapter Five built on the results from Chapter Three to investigate how the inclusion of the external features affects the magnitude of ORB. Results demonstrated that the ORB

disappeared when faces were presented with external features. Furthermore, the absence of external features was disruptive to recognition of other-race faces but not own-race faces, suggesting that external features play a larger role in the recognition of other- than own-race faces (Sporer & Horry, 2011). This clear finding is compatible with the perceptual expertise account of the ORB, which suggests that own- race faces are distinguished and recognised based on precise individuating information, whereas other-race faces are processed shallowly based on categorical information. In the same vein, Levin (2000) advocates for an explanation for the ORB in which own-race face processing involves the most diagnostic individuating information, whereas other-race face processing relies more on categorical information (e.g. race-specific features). Sporer (2001) proposed an in-group/out-group model, suggesting that perception of own- race faces automatically initiates a finer level of perceptual encoding processing that emphasizes the internal features of a face that help distinguish the target from similar faces in memory. In contrast, other-race face perception promotes a categorisation process that accentuates race-specific features (Fiset, Blais, Gosselin, Bub, & Tanaka, 2008) at the expense of individuating information. Here I suggest that recognition differences between own-race and other-race faces may be related to some qualitative differences in own-race and other-race face processing, with internal features of own-race faces being processed more efficiently while external features dominate representations of other-race faces.

9.2.4 Chapter 6: Holistic Processing of Own- versus Other-Race Faces

Despite a long-standing controversy over the role of holistic processing in cross-race face recognition, the ORB has often been attributed to the fact that other-race faces are processed less holistically than own-race faces. Chapter Six revealed that the holistic effects, as indexed by composite-face effect and whole-part effect, for other-race faces were similar in size to that observed for own-race faces. In other words, participants processed all face

stimuli holistically independent of stimulus race. Although I detected the robust nature of ORB in recognition accuracy, the occurrence of holistic processing for other-race faces did not lead to a smaller ORB in any of the four race groups. These observations run counter to my prediction derived from the experience-based holistic account of ORB in face recognition. Notably, however, this empirical evidence supports recent findings suggesting that holistic processing is not directly linked with face recognition ability (Richler, Wong, & Gauthier, 2011; Richler, Floyd, & Gauthier, 2015) and can sometimes be elicited by both own- and other-race faces without extensive individuating experience (e.g., Harrison et al., 2014). Taken together, these observations disagree with the assertion that the ORB in face recognition is purely a consequence of reduced holistic processing for other-race faces. Here I suggest that holistic processing may play a significant role in the early stages of face recognition, possibly at the level of face detection or face matching that place lower cognitive demands on memory; yet, it is not sufficient for reducing the ORB. This rather varied evidence also suggests that the degree of holistic processing applied to a face stimulus may not be as strongly modulated by its perceived race identity as commonly believed; instead, it seemed to be somewhat dependent on the facial physiognomy, stimulus characteristics and tasks performed on them.

9.2.5 Chapter 7: The Effect of Attentional Shift towards Diagnostic Features on the ORB

In this chapter, I found that directing participants' immediate attention to the most diagnostic facial features using fixation crosses may help to improve recognition performance but not it is effective enough to remove the ORB. In other words, cueing participants to fixate more on the other-race features that they would not normally fixate upon does not improve other-race recognition performance. The fixation training task employed in this experiment did not appear to be efficient in alleviating the ORB, possibly because it was less intensive

than those training tasks used previously (Cavazos, Noyes, & Toole, 2018; Hills & Lewis, 2006; Hugenberg et al., 2007; McGugin et al., 2011). Although past work has shown that training can eliminate (e.g., Malpass et al., 1973) or even reverse this effect (Sangrigoli et al., 2005), directing immediate attention to diagnostic features may be difficult to implement as a solution to the ORB, even for Malaysian individuals who have a considerable amount of interracial experience. Eye-tracking data showed that the first fixation was indeed directed by the fixation cross and directing first fixations to a particular feature can potentially alter their subsequent eye-movement pattern, such as fixation duration and number of fixations. My data suggests that there may be racial differences in the way participants view faces, providing support for the perceptual expertise account of the ORB. A cross-cultural study examining participants' verbal descriptions of faces have found that participants from different racial groups tended to use different facial features to describe faces (Ellis et al., 1975). More specifically, Caucasians were more likely to describe features like eye colour, while Africans focused on the lower facial features such as lips and noses. In conjunction with this finding, a previous study has found that training participants to focus on the diagnostic features associated with a specific race of face subsequently increased participants' recognition accuracy, thereby reducing the ORB (Hills & Lewis, 2006). This finding indicates that the ORB may be attributable to the use of looking strategies, learned during development, that are optimized for recognising familiar own-race faces, but which are suboptimal when applied to unfamiliar other-race faces. This provides evidence that the face processing style and associated looking strategy that observers employ may be determined by the diagnostic features of the faces encountered during development, and that the looking strategy adopted may reflect the variance in facial appearance in the local population. Overall, these observations suggest that the ORB is not solely attributable to

general lack of attention towards diagnostic features but may be rooted at the level of facial information use.

9.2.6 Chapter 8: Putting a 'Spotlight' on the ORB with Gaze-Contingent Technique

In this chapter, I applied a gaze-contingent approach to study the ORB in Chinese, Malay, Indian, and Caucasian participants, allowing selective manipulation of processing modes and providing insights into facial information use through fixation patterns during a delayed face matching task. The face matching task was conducted in which a 1000-ms presentation of an unfamiliar young adult reference face was followed by two faces presented side by side, one of which corresponded to the target face. The participant's task was to indicate the target. In one third of the trials, the faces were completely visible (full view condition), in one third of the trials, a gaze-contingent mask covered the central part of the visual field (mask condition), and in the remaining third of the trials, only the fixated feature was visible through a window (window condition). The ORB persists in the current face matching task, in which memory contributions are minimised. Results showed that, regardless of the race of the input face, participants' performance at an individual face discrimination task decreased when they were forced to extract the facial information feature-by-feature than when they could process all features at once holistically. The lack of difference between face race strongly challenged the holistic account of ORB where own-race faces are processed more holistically than other-race faces. Given the high-performance level across viewing conditions, it appears that eye movements are flexibly used to elaborate face representations by gathering information from own-race and other-race faces through diverse strategies (holistically and/or featurally). Consistent with the findings reported in Chapter 6, the ORB cannot be purely accounted for by the inability to perceive other-race faces holistically. My data support the idea of the existence of diverse strategies dedicated to face processing which adjust to the task at hand and the ability to extract detailed information

from particularly diagnostic local features might be useful for both own-race and other-race faces in a face matching task.

9.3 Theoretical Implications

This thesis has taken into account memory and perceptual aspects of the ORB and has a number of theoretical and practical implications. The first is related to the question of ORB in multiracial populations. Chinese, Malay and Indian young adults recruited for this project came from a multiracial country (i.e. Malaysia) and were studying at a branch campus of a British university. This setting would provide abundant exposure and great familiarity with other-race individuals. Intuitively, owing to a higher level of exposure to other-race faces in the multiracial country, Malaysians should show reduced ORB. However, my results appear to reject this simple hypothesis. Indeed, the most striking aspect of my findings is the consistent observations of ORB across face recognition tasks in Malaysian participants (Chinese, Malay, and Indian). This raises an open question of why the ORB seems to be reduced in face training studies (Anzures, Quinn, Pascalis, Slater, & Lee, 2013; Heron-Delaney et al., 2011; Hills & Lewis, 2006) but not in a multiracial environment. One explanation is that more "natural" face experience may not function in the same way as these laboratory manipulations. Most laboratory training methods only increase other-race face experience quantitatively via photographic exposure in extensive, intentional face learning tasks, which differ from casual individuating experience with faces from other races in the real world. Although training studies provide an indication regarding the flexibility of the ORB and the plasticity of one's face recognition system, the enhancement effect from training studies is often transient (e.g., Hills & Lewis, 2011).

Based on the perceptual expertise hypothesis of the ORB, a lack of perceptual learning and lifetime experience with other-race faces is the basis of the ORB; however, the present findings indicate that experience is a complex factor. If experience is related to other-

race recognition, it appears to be the quality of that experience that is most important. The effect of interracial contact on the ORB was tested in Chapter 3 and 5 by submitting participants' rating scores on social contact questionnaire and relative ORB scores to correlational analyses. The results showed that all Malaysian participants from the three race groups still had considerably less social interaction (quality of contact) with other-race people in comparison with own-race people. Contrary to assumptions based on the contact hypothesis, participants' self-reported amount of interracial contact on a social contact questionnaire did not appear to predict the magnitude of the ORB, suggesting that the level of contact with other-race people accounts for only a small part of the ORB in adulthood.

While some studies have shown that higher contact with other-race faces – either through experimental manipulations or real-world experience – is associated with a smaller ORB (Chiroro & Valentine, 1995; Goldstein & Chance, 1978; Hancock & Rhodes, 2008), other studies have failed to find any significant association between contact levels with other-race people and other-race recognition accuracy (Goodman et al., 2007; Ng & Lindsay, 1994). Moreover, most studies that included minority-race members found that these participants also showed an ORB, suggesting that even a high level of contact with other-race people over a long period of time is insufficient to eliminate the ORB (e.g., MacLin & Malpass, 2001; Walker & Hewstone, 2006). This suggests that people must have meaningful contact or individuating experience with members of another race; contact is not enough.

It was first hypothesised that more interracial contact would be related to a reduced ORB. This hypothesis was not supported, as the correlations obtained from participant data failed to reach significance. Given that both quantity and quality of contact did not correlate with the ORB, I proposed that high *quantity of contact* may not necessarily reduce the other-race effect as it does not require observers to differentiate other-race faces. Instead, *meaningful contact* would allow observers to learn the diagnostic features that individuate

faces of other-races, which subsequently reduces the ORB (Hills & Lewis, 2006). It should be noted, however, that the social contact questionnaire used in the current experiments was not designed to measure the quantity and quality of both past and present interracial contact separately. Chiroro & Valentine (1995) showed that individuals with more recent other-race contact demonstrate improved recognition for other-race faces, highlighting the possibility that present *quality* and *quantity* of interracial contact could have greater influence than past contact on participants' recognition sensitivity for other-race faces. Upon closer inspection of the rating score data, there was a low variability in the report of contact levels with other groups. Because of this variability, the ability to detect some of the correlations between self-report measures and the ORB may have been lost. Future research that include more detailed questionnaires to more specifically inquire about the current and past of participants' interracial contact would provide more in-depth understanding of mechanism of the ORB.

Although the ORB is likely a phenomenon that is the result of multiple perceptual and cognitive factors, the current work showed that the recognition deficit for other-race faces was more evident at a mnemonic level (e.g., recognition) than at a perceptual level (e.g., face matching). Studies differing in their recruitment of perceptual vs mnemonic cognitive mechanisms might have drawn different conclusions regarding the magnitude of the ORB. A face memory task was likely more cognitively demanding because participants had to remember a large set of faces. For example, in the yes-no recognition task, participants were asked to recall representations of newly learned own- and other-race faces from their long-term memory, providing an examination of the precision of long-term memory for own- versus other-race faces. On the other hand, the perceptual tasks do not require high memory demands, but could be used to test observers' perceptual sensitivity to the properties of facial features. Despite the fact that targets were presented for a short time, accuracy rates during the task were very high and the size of ORB was very small across four different participant

race groups. I therefore suggest that the face matching task is not the most sensitive task to measure the ORB which can be better explained by the inability to quickly consolidate the representations of an other-race face into a stable representation in working memory (Baker, Laurence, & Mondloch, 2017).

9.3.1 Eye movements and ORB

Exposure to and familiarity with the diagnostic features of other-race faces encountered during early development may affect one's face scanning pattern. The current study is the first to compare the eye movement patterns between the three major race groups (Malay, Chinese, and Indian) in Malaysia and Western-Caucasian comparison group. Consistent with the physiognomy hypothesis, my results provide evidence that eye movement pattern is modulated by the race of the incoming face stimulus. It appears that Caucasian faces receive more fixations to the eyes, but fewer on the nose and mouth when compared to other races of faces. Participants attended most to the eyes for Caucasian faces possibly because they convey more individuating information (e.g. eye colour) of a face than for Malaysian faces, which tend to have rather uniform eye colour (Rhodes, Ewing, et al., 2009). Additionally, Malaysian (Southeast Asian) faces produced longer fixations on the nose than other face races, implying that the centre region of the face could be more informative or diagnostic for identifying Malaysian faces.

Recording of eye movements showed that, across Malaysian race groups, participants tend to fixate on the nose (i.e. central) region most rather than at the eyes and mouth region, indicating a preferential holistic style of face processing, as suggested by Blais et al. (2008) and Caldara, Zhou, & Miellet (2010). Perhaps most interesting is the result that, compared with the other three race groups, Indian participants tend to fixate more on the mouth but less frequently on the eyes. In contrast, Caucasian participants directed more and longer fixations to the eyes and mouth than Chinese participants did, as reported in the earlier cross-racial

studies (Blais et al., 2008; Kelly, Jack, et al., 2011; Kelly, Liu, et al., 2011). Taken together, my eye-tracking results indicate that the diversity of fixation patterns may be due to race-specific diagnostic cues provided by specific regions of the faces while a reliance on particular facial features could be attributable to perceptual experiences with own- and other-race faces (Hills & Lewis, 2006).

9.3.2 Methodological implications

This research also has significant methodological implications for research in face recognition. The limited ecological validity of the laboratory use of stimuli displaying only internal features has been addressed and criticised frequently because the generalizability of the obtained results is questionable (e.g., Kelly et al., 2011). Although results based on static face images free from any cropping (e.g., with hair and facial contours included) are arguably more representative of performance in real-world viewing conditions, my study suggests that using this type of stimulus may encourage reliance on external, non-facial features for other-race faces (Megreya & Bindemann, 2009; Sporer & Horry, 2011), thereby masking the genuine ORB in face memory. On the other hand, cropped face images without external features may accentuate the ability to process configural information from faces. Since the removal of external features is more detrimental to the recognition of other-race faces compared to own-race faces, a face memory task that utilises face stimuli controlled for external information could be more sensitive in picking up a potentially subtle ORB. Hence, very different conclusions could have been drawn from studies due to the selection of stimulus type, highlighting that subtle methodological differences may modulate the detection of ORB. Future replications of the ORB should take the stimulus type into account when comparing the results between studies.

Eye-tracking data showed that the first fixation was indeed directed by the fixation cross and directing first fixations to a particular feature can potentially alter their subsequent

eye-movement patterns. The current findings have significant implications for research in face recognition and eye-tracking research. In terms of eye-tracking research, any study that employs a fixation cross may be affecting the first fixation, the subsequent encoding, and performance. For example, fixation crosses are typically presented in the centre of the screen where the centre region of the face will be presented subsequently at the same location. In this case, the fixation crosses always precede the nose region, which could elicit cueing effects. Two methods can be employed to avoid this unintentional effect: placing fixation crosses outside the face image to ensure that the first fixation does not cue any facial features (e.g., Bindemann et al., 2009) or guiding fixation using boxes/images (e.g., Wu et al., 2012).

One interesting implication of the present work is the apparent conflict between the present results and face recognition studies that employ fixation crosses. In many studies that have reported significant ORBs, fixation crosses were not employed (such as Chiroro et al., 2008; Cross et al., 1971; Hugenberg et al., 2007; Lavrakas, Buri, & Mayzner, 1976; Malpass & Kravitz, 1969; Michel, Caldara, & Rossion, 2006; Valentine & Endo, 1992). Instead, between the presentation of faces there was a blank intertrial interval. The use of fixation crosses is a more recent procedure employed to indicate the start of a trial in order that participants are prepared to look at a relevant part of a screen. These fixation crosses are often positioned centrally (e.g., Hahn, Jantzen, & Symons, 2012), although this is not always specified, and often result in significant ORBs being observed (but see Cooper & Kennett, 2013). Nonetheless, researchers should be careful about the location of fixation crosses that precedes facial stimuli and use external fixation crosses that do not cue initial fixations to any facial features (see Bindemann et al., 2009).

9.4 Limitations and Future Directions

In the last few decades, the processes supporting face identification have been extensively investigated using group-based approaches where inter-individual variations were

typically regarded as uninformative noise. However, significant variations in face identification ability have been observed (Richler et al., 2015; Royer, Blais, Gosselin, Duncan, & Fiset, 2015; Wilmer et al., 2010), and many researchers now highlight the importance of individual differences to gain a better understanding of face processing mechanisms (e.g. Yovel, Wilmer, & Duchaine, 2014; see also Richler, Cheung, & Gauthier, 2011 for a discussion). In fact, considerable evidence has accumulated to show that there are significant individual differences in face recognition ability (Li et al., 2010), in the amount of holistic processing participants employ (Wang et al., 2012), and in terms of how faces are encoded (Bobak, Parris, Gregory, Bennetts, & Bate, 2017; Mehoudar, Arizpe, Baker, & Yovel, 2014). Thus, it is important to investigate the perceptual and cognitive mechanisms known to be involved in ORB using an individual-difference-based approach. Most of the current data on the ORB are clearly at a group level; not all participants will show the ORB. To fully understand the ORB, these individual differences must be understood, not only in terms of behavioural performance, but also eye movement strategies.

In none of the experiments reported in this thesis did I find evidence that interracial contact modulated the ORB. Although there is evidence to support the hypothesis that the quantity and/or quality of contact contributes to other-race face processing (Dickter, Gagnon, Gyurovski, & Brewington, 2015; Rhodes, Ewing, et al., 2009; Wright et al., 2003), similar null effects have been reported elsewhere in the literature (e.g., Malpass & Kravitz, 1969; Ng & Lindsay, 1994). Understanding when and how interracial contact relates to the ORB remains to be determined. It has long been debated whether meaningful exposure versus mere exposure to other races is important for preventing the ORB. A lifelong visual experience with other-race faces may enhance recognition of other-race faces (e.g., Walker & Hewstone, 2006b); however, the contact with other-race individuals is unlikely to translate into perceptual expertise unless the person is relatively attentive and puts effort in individuating

the faces (Walker & Hewstone, 2006). In a relatively multiracial country where there is high proportion of three main races (Malay, Chinese, and Indian), Malaysian individuals still might not have sufficient meaningful exposure to other-race faces to avoid the ORB (see Table 3.1).

Alternatively, limited experience with other-race faces in childhood may help explain why the ORB persists in the multiracial population. If experience underpins the ORB, then it is possible that the effect follows a developmental trajectory whereby face representations become increasingly more tuned to faces of the perceiver's own race. Chance, Turner, and Goldstein (1982) reported a developmental trend, suggesting that the ORB becomes more robust with increasing age. In a recent study, (Walker & Hewstone, 2006a) tested Caucasian primary school (aged 7–11 years), secondary school (aged 12–15 years) and university students to investigate the developmental time course of the ORB, using a same/different perceptual matching task (Walker & Hewstone, 2006b, Walker & Tanaka, 2003). Results revealed that that while the ORB was observed in primary school children (aged 7-11 years), secondary students (aged 12-15) and university students, the magnitude of the ORB increased with age. Collectively, this demonstrates that encoding biases in face recognition occur relatively early, and that experience drives a developmental time course whereby face representations become gradually more finely tuned for differentiating between faces of one's own race (Chance & Goldstein, 1982; Ferguson et al., 2009; Furl et al., 2002; Goodman et al., 2007; Walker & Hewstone, 2006a). Most interestingly, the amount of experience required for the ORB to reduce may change across development since there is evidence that the plasticity of ORB decreases with age (Tanaka et al., 2013; James Tanaka & Pierce, 2009). An interesting direction for future research would be to examine the developmental changes in the size of ORB in infants or children born and raised in a multiracial environment.

9.5 Conclusions

In summary, the current thesis has shown that the ORB in face recognition remains evident in Malaysian individuals who live in a highly multiracial population. It appears that Malaysians' substantial everyday mere exposure to different races does not generally lead to a broadly-tuned representation that accommodates multiple other-race faces. My results converge with existing literature to suggest that there is relatively little plasticity in face recognition in adulthood (e.g., Tree, Horry, Riley, & Wilmer, 2017). Considerable evidence from developmental studies suggests that the plasticity of the ORB is determined largely by experiences with own- and other-race faces in early infant and childhood (Fioravanti-bastos et al., 2014; Pascalis et al., 2005; Tanaka et al., 2013; Tanaka & Pierce, 2009). Changes in perceptual experience during the critical period of the development of the ORB may play a crucial role in reorganising the face representation to adapt to changes in multiracial experience in adulthood. Additionally, the magnitude of the ORB was modulated by the presence/absence of external features, such that other-race faces with limited external facial information were recognised poorly. This sheds further light on the face representations and mechanisms that governs own- versus other-race face recognition. People may encode and/or retrieve own- and other-race faces from memory in qualitatively different ways, with internal features of own-race faces being processed more effectively whereas external features dominate representations of other-race faces. Based on the findings derived from the holistic tasks (Chapter 6), fixation-cross cueing task (Chapter 7), and gaze-contingent paradigm (Chapter 8), it is concluded that neither the inability to perceive other-race faces holistically nor the difficulty in directing attention to diagnostic features can fully account for the ORB. While it is clear that perceptual experience and development could interact to determine the ORB in face recognition (Anzures et al., 2012, 2013; Chien, Wang, & Huang, 2016; Heron-Delaney et al., 2011; Xiao, Quinn, Pascalis, & Lee, 2014; but see McKone, Crookes, Jeffery,

& Dilks, 2012), future research is required to directly address whether and how early perceptual experience modulates the plasticity of ORB in adulthood. Another open question is whether people possess the necessary perceptual abilities to recognise other-race faces at the level of the individual, but only lack the social motivation to do so (Hugenberg, Miller, & Claypool, 2007). According to the social-cognitive position, the source of the ORB is not perceptual, but a resistance to individuate other-race faces due to their out- group status. Hence, the emergence of the ORB may be due to motivational factors rather changes in perceptual expertise. Alternatively, ORB could be a product of converging factors involving social categorization, motivated individuation, and perceptual experience; for example, neither raw perceptual exposure nor the motivation to individuate is sufficient to attenuate the ORB but requires both the proper motivation and practice to individuate other-race faces. Further research is required to confirm these hypotheses.

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Appendices

APPENDIX A

Social Contact Questionnaire

Gender: Male / Female **Race**: **Age:** **Participant Number:**

For each of the statements listed below please identify to what extent you agree for each of the three groups of people.

	Malay People					Chinese People					Indian People					White People				
I often work closely (voluntary/paid work/studied) with	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Within my circle of friends I regularly socialise with	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
My closest friends are	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
In my family I have many	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
When having problems with my work I usually ask for help from	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
On a regular basis I interact with	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
For a prolonged period of time I have lived in the same house as	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
I regularly spend time at the homes of	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
I have often comforted/have been comforted by	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
I frequently give/receive personal advice to/from	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
I know lots of	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
For a prolonged period of time I have lived on the same street as	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
In the media I regularly see	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
In my current occupation I come across many	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Whilst socialising I come across many	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5

APPENDIX B

Non-Area-Normalised Results for Total Number of First Fixation in Experiment 1

A 4 (Race of Observer: Malay, Chinese, Indian, Caucasian) × 4 (Race of Face: Malay, Chinese, Indian, Caucasian) × 4 (AOI: eyes, nose, mouth, and other facial areas) mixed factorial ANOVA was conducted on the total number of first fixations during learning phase. Neither the main effect of Race of Face nor the main effect of Race of Observer was significant, both $p>.05$. A main effect of AOI was found to be significant, with Bonferroni corrected pairwise comparisons revealing that participants directed their first fixations to the nose more than the eyes ($p<0.001$) and mouth ($p<0.001$), and the eyes significantly more than the mouth ($p<0.001$). There was also a significant interaction between AOI and Race of Observer (see *Figure B1*), F (6.28,178.01) = 4.05, $p=.001$, in which Indian participants first fixated on the mouth significantly more than did Malay ($p=.002$) and Chinese ($p=.003$) participants. In contrast, Indian participants made significantly fewer first fixations to the eyes than did Malay ($p=.03$) and Chinese ($p=.002$) participants. However, no significant difference of the total number of initial fixations on the nose was found between race groups (all $p>.05$). The interaction between AOI and Race of Face was also found to be significant (see *Figure B2*), F (5.28, 448.39) = 2.58, $p=.02$. Follow-up simple main effect analysis revealed that Malay faces received more first fixations to the mouth compared to Caucasian faces ($p=.02$) while initial fixations directed to the eyes of Indian faces were fewer compared to Chinese ($p=.05$) and Caucasian faces ($p=.02$).

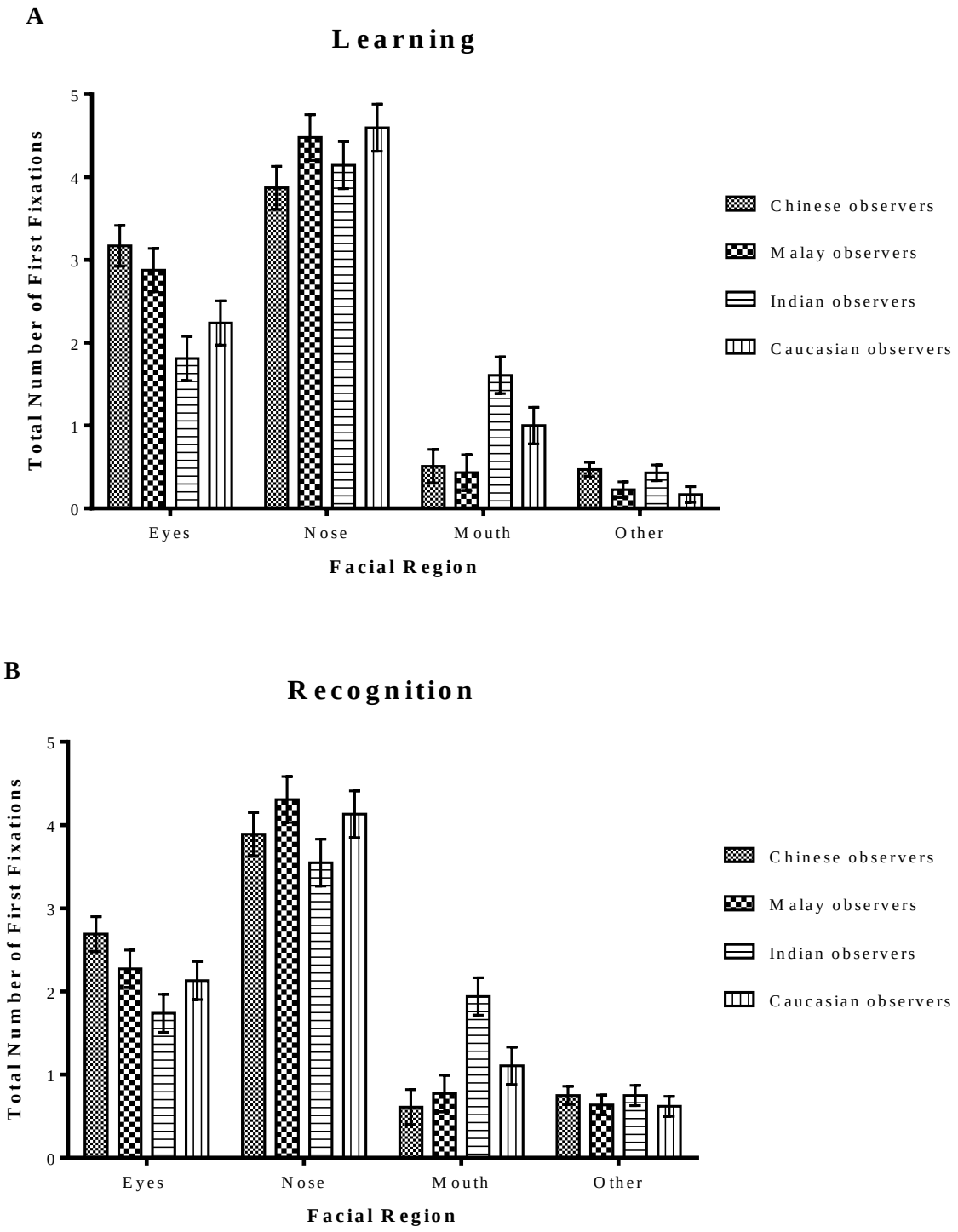


Figure B.1. Total number of first fixations on the eyes, mouth, nose, and other facial regions for different *races of observers* during the (A) learning and (B) recognition tasks. Error bars represent standard error of mean.

In the recognition phase, the main effects of Race of Face and Race of Observer did not reach significance, both p>0.5. There was a significant main effect of AOI, F (2.24, 189.94) = 137.84, p<.001, with participants making more initial fixations on the nose than the eyes (p=0.002) and mouth (p<0.001), and the eyes significantly more than the mouth (p<0.001). Total number of first fixations on other facial regions (e.g. cheeks, forehead, chin) were significantly fewer compared to those landed on each key AOI (eyes, nose, mouth; all p<0.001). A significant interaction effect between AOI and Race of Observer was also found (see *Figure B1*), F (6.70, 189.94) = 3.31, p =.003. Simple main effect analysis revealed that Indian participants first fixated on the mouth significantly more than Malay (p=.002) and Chinese (p<.001) participants while there was a trend towards a greater number of first fixations landed on the nose by Malay participants than Caucasian participants did (p=.062). Compared to Indian participants, Chinese participants made significantly more first fixations on the eyes (p=.02). There was also a significant AOI by Race of Face interaction (see Figure B.2), F (6.61, 562.08) = 5.30, p<.001. Malay faces received significantly more initial fixations on the nose region compared to Chinese (p=.047), Indian (p=.001) and Caucasian faces, but the difference between Malay and Caucasian faces was marginal (p = 0.092). However, Malay faces received significantly fewer initial fixations on the eyes than Chinese (p=.003) and Indian faces (p<.001). Greater number of first fixations was directed to the eyes region of Indian faces compared to Caucasian faces (p=.02).

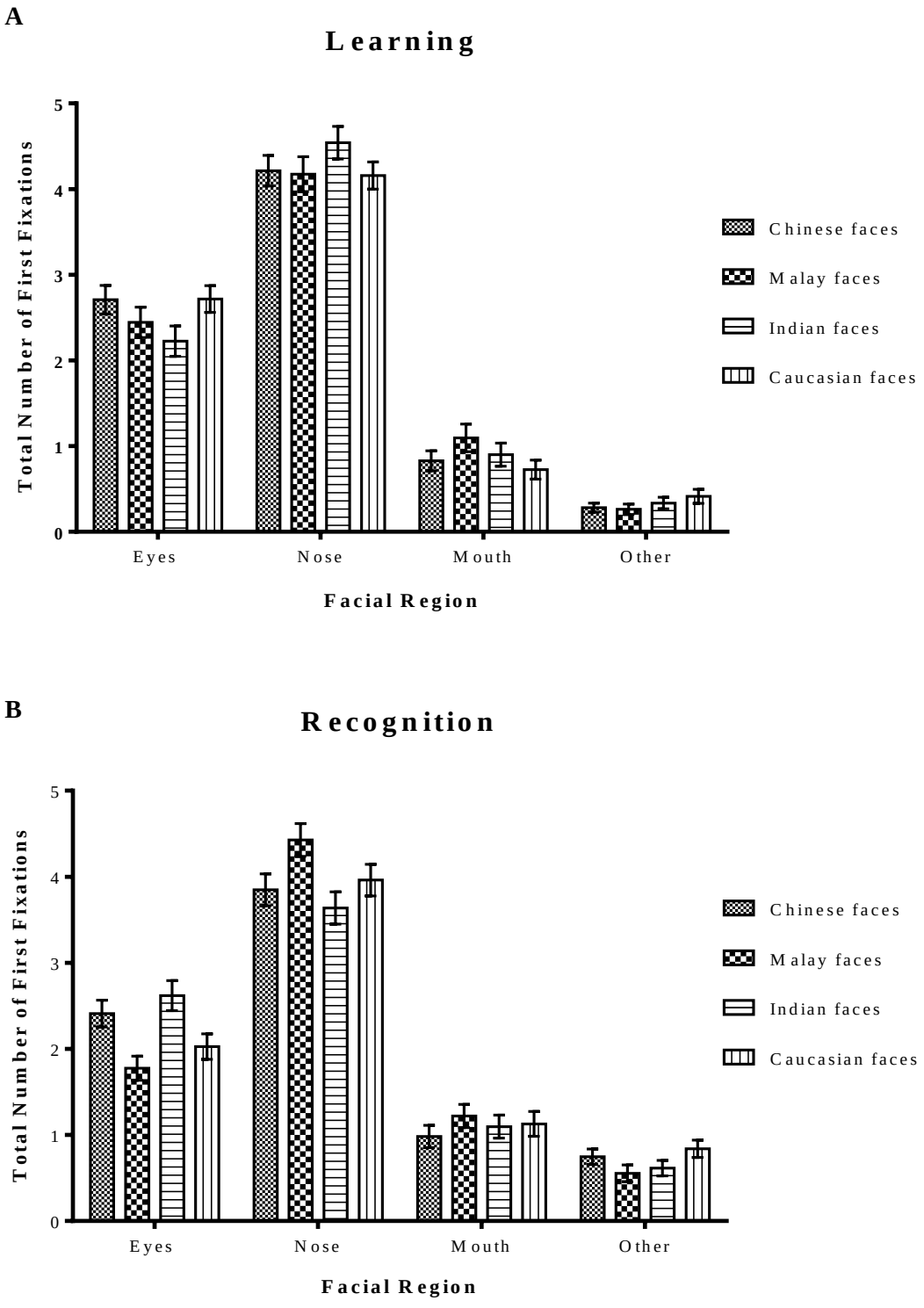


Figure B.2. Total number of first fixation on the eyes, mouth, nose, and other facial regions for different *races of observers* during the (A) learning and (B) recognition tasks. Error bars represent standard error of mean.

APPENDIX C

Non-Area-Normalised Results for Average Total Fixation Duration in Experiment 1

An ANOVA with Race of Face (Malay, Chinese, Indian, and Caucasian) as a within-subject factor and Race of Observer (Malay, Chinese, Indian, and Caucasian) as a between-subjects factor was conducted on average total fixation duration on each AOI (eyes, nose, mouth, and other facial areas, separately) during learning phase. In the learning phase, there was no significant interaction between Race of Face and Race of Observer, F (9, 255) = 1.28, p = 0.248. A main effect of AOI was highly significant, F (1.86, 158.14) = 240.93, p < 0.001, with Bonferroni-corrected pairwise comparisons revealing that participants made longer fixations on the eyes, followed by the nose (p<.001) and mouth (p<.001), and a significant difference between the nose and the mouth was found (p < .001). A main effect of Race of Observer was also significant, F (3, 85) = 5.80, p = 0.00, with Bonferroni post hoc test revealing that Caucasian participants' average total fixation duration on the whole face (across all AOIs) was significantly higher than that of Chinese (p=.021) and Indian participants (p=.002). Compared with Chinese participants, there was also a considerable trend towards a longer duration of fixations made by Malay participants on the whole face (p=0.067). A main effect of Race of Face was highly significant, F (3, 255) = 6.84, p < 0.001, which reflected that fixations of shorter duration for Chinese faces than Malay and Indian faces (both p=0.001) whereas there was a trend towards longer fixation duration for Caucasian faces than Chinese faces (p=0.095).

A significant Race of Observer by AOI interaction was found (see *Figure C.1*), F (9, 255) = 3.97, p < 0.001. Simple main effect analysis revealed that Chinese participants made fixations of significantly shorter duration on the mouth region than that of Indian (p = 0.002) and Caucasian participants (p = 0.008). In addition, Malay and Caucasian participants fixated significantly longer at the eye region compared to Indian participants did (p = 0.03 and p <

0.001, respectively). For the nose region, however, no significant difference was found between race groups (all p=1). Another interaction between Race of Face and AOI was also significant (see *Figure C.2*), F (5.94, 504.54) = 22.91, p < 0.001. Simple main effect analysis revealed that participants' average total fixation durations on Caucasian nose and mouth were significantly lower than those on the Malay, Chinese and Indian nose and mouth (all p < 0.001). Fixation durations on Caucasian eyes, however, were significantly higher than those on Malay, Chinese, and Indian eyes, all p < 0.001. In addition, participants' average total fixation durations on the Chinese nose were significantly lower than those on the Malay (p = 0.014) and Indian nose (p = 0.039).

In the recognition phase, a main effect of AOI was also found to be significant, F (1.81, 153.58) = 10.63, p < 0.001. Participants fixated longer on the eyes, followed by the nose and then mouth (all p<0.001). A main effect of Race of Observer was significant, F (3, 85) = 3.01, p = 0.035, with Bonferroni post hoc test revealing that Caucasian participants' average total fixation duration on the whole face was significantly higher than that of Chinese (p=0.03) and Indian participants (p=0.001). The interaction between Race of Observer and AOI was significant, F (6, 170) = 2.80, p = 0.013. Simple main effect analysis revealed that Caucasian participants tended to spend more time fixating on the mouth and significantly more on the eyes than Chinese participants did (p = 0.05 and p = 0.04, respectively). Besides, the average total fixation duration on the eyes was significantly longer in Caucasian participants than in Indian participants (p<0.001) and a similar trend was also observed between Caucasian and Malay participants (p= 0.071). For the nose region, no significant difference was found between race groups (all p=1). There was also a significant interaction between Race of Face and AOI (see Figure C.2), F (4.95, 421.04) = 13.92, p < 0.001. Simple main effect analysis revealed that the average total fixation duration on the nose region was significantly longer for Malay faces than for Chinese (p=0.003), Indian (p< 0.001), and

Caucasian faces ($p<0.001$), and longer fixations were directed to the nose for Chinese faces than Indian faces ($p=0.04$). Fixations to the mouth on Chinese faces were relatively brief compared to those on Malay ($p=0.05$) and Indian faces ($p=0.01$). In addition, Caucasian faces received shorter fixations to the mouth but longer fixations to the eyes compared to those on Malay, Chinese, and Indian faces (all $p<0.001$)

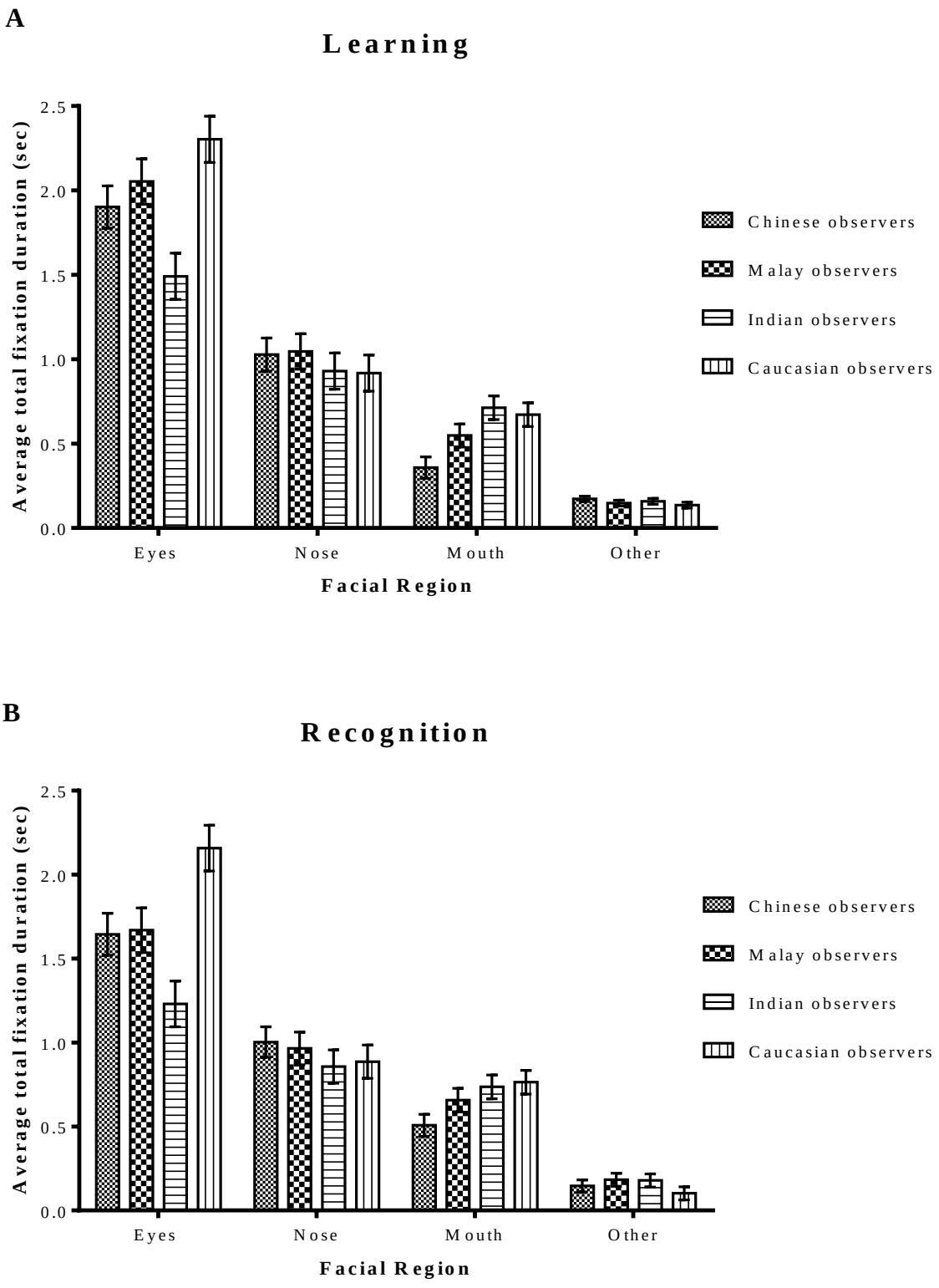


Figure C.1. Average total fixation duration on the predefined AOIs for different *observer races* during the (a) learning and (b) recognition tasks. Error bars represent standard error of mean.

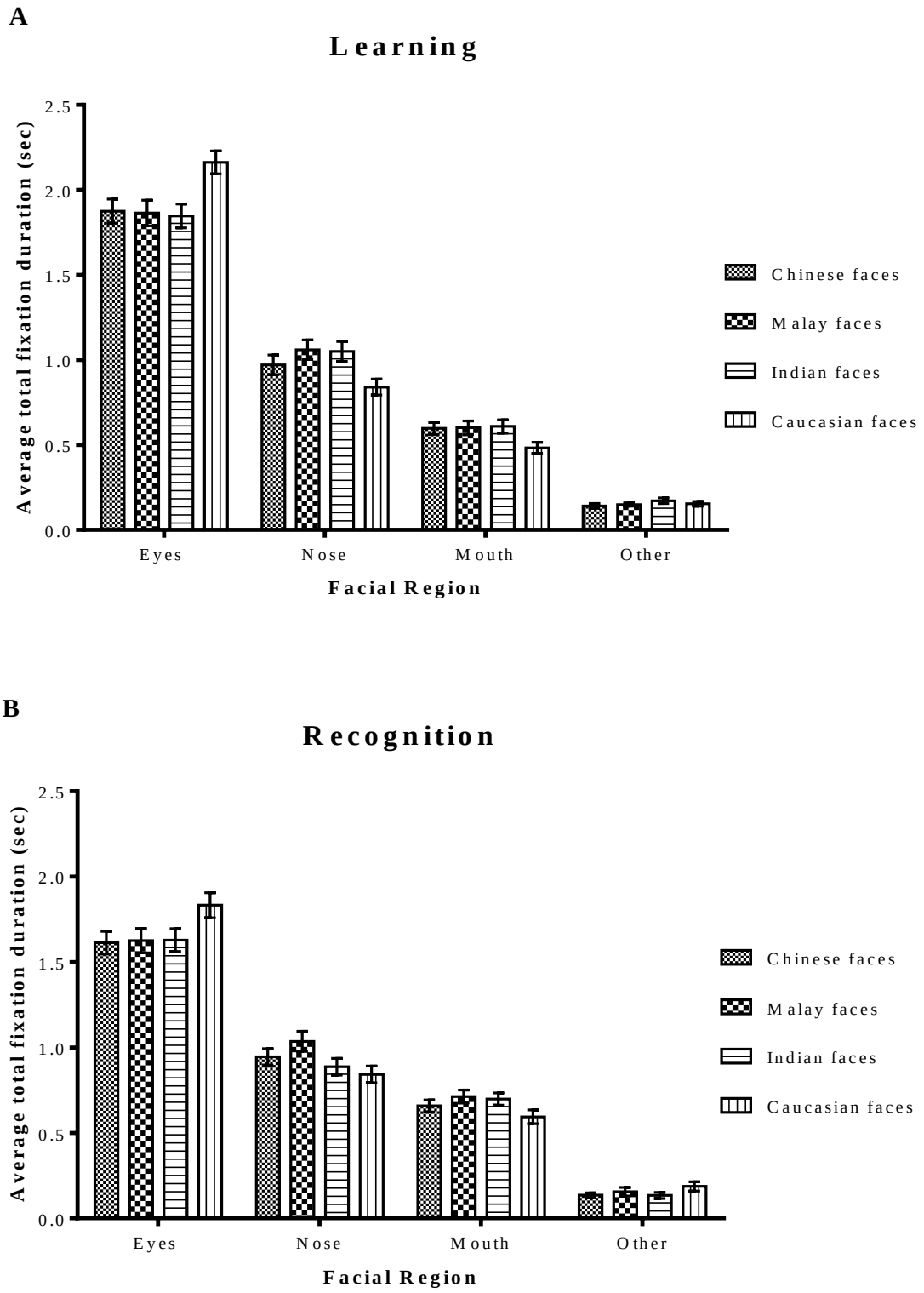


Figure C.2. Average total fixation duration on the predefined AOIs for different *face races* during the (a) learning and (b) recognition tasks. Error bars represent standard error of mean.

APPENDIX D

Non-Area-Normalised Results for Average Total Fixation Count in Experiment 1

A mixed factorial ANOVA with AOI (eyes, nose, mouth, and other facial areas) and Race of Face as within-subject factors, and Race of Observer as a between-subjects factor, was conducted on the average total number of fixations deployed on each AOI during the learning phase. A main effect of Race of Face did not reach significance, F (3,255) = 0.64, p = 0.593. However, there was a significant main effect of AOI, F (1.89,160.84) =312.55, p < 0.001 (Greenhouse-Geisser corrected), with the eyes attracting the greatest number of fixations, followed by the nose and then the mouth (all p<.001). A significant main effect was also found for Race of Observer, F (3, 85) =3.54, p=.02, with Bonferroni post hoc test revealing that Malay participants' average total number of fixations on the whole face was significantly higher than that of Chinese participants (p=0.011). A significant interaction between Race of Face and Race of Observer was found, F (9, 255) = 2.47, p=.01. In the encoding phase, Indian participants' mean number of fixations on own-race faces was significantly higher than that of Chinese (p =.02) and Malay faces (p =.02) whereas no significant difference was found between Caucasian and own-race faces (p=0.57). For Chinese, Malay, and Caucasian participants, however, no significant difference between face categories was observed (all p>.05).

There was a significant interaction between Race of Observer and AOI (see Figure 1a), F (9, 255) = 3.25, p = .001. Simple main effect analysis revealed that Chinese participants fixated significantly less on the mouth region than did Indian (p =.001) and Caucasian participants (p =.04) while Malay participants looked more frequently at the eyes compared to Indian participants (p = .04). The interaction between Race of Face and AOI was also found to be significant (see Figure D.1), F (5.92, 503.51) = 22.65, p < 0.001 (Greenhouse-Geisser corrected). For the nose region, there were significantly fewer fixations

landing on Caucasian faces than Malay (p<.001), Chinese (p=.003), and Indian faces (p<.001). Number of fixations on the mouth region of Caucasian faces was significantly lower than that of Malay, Chinese and Indian faces (all p < .001) whereas fixations landed on the eye region was significantly higher for Caucasian faces compared to faces of the other three races (all p <.001).

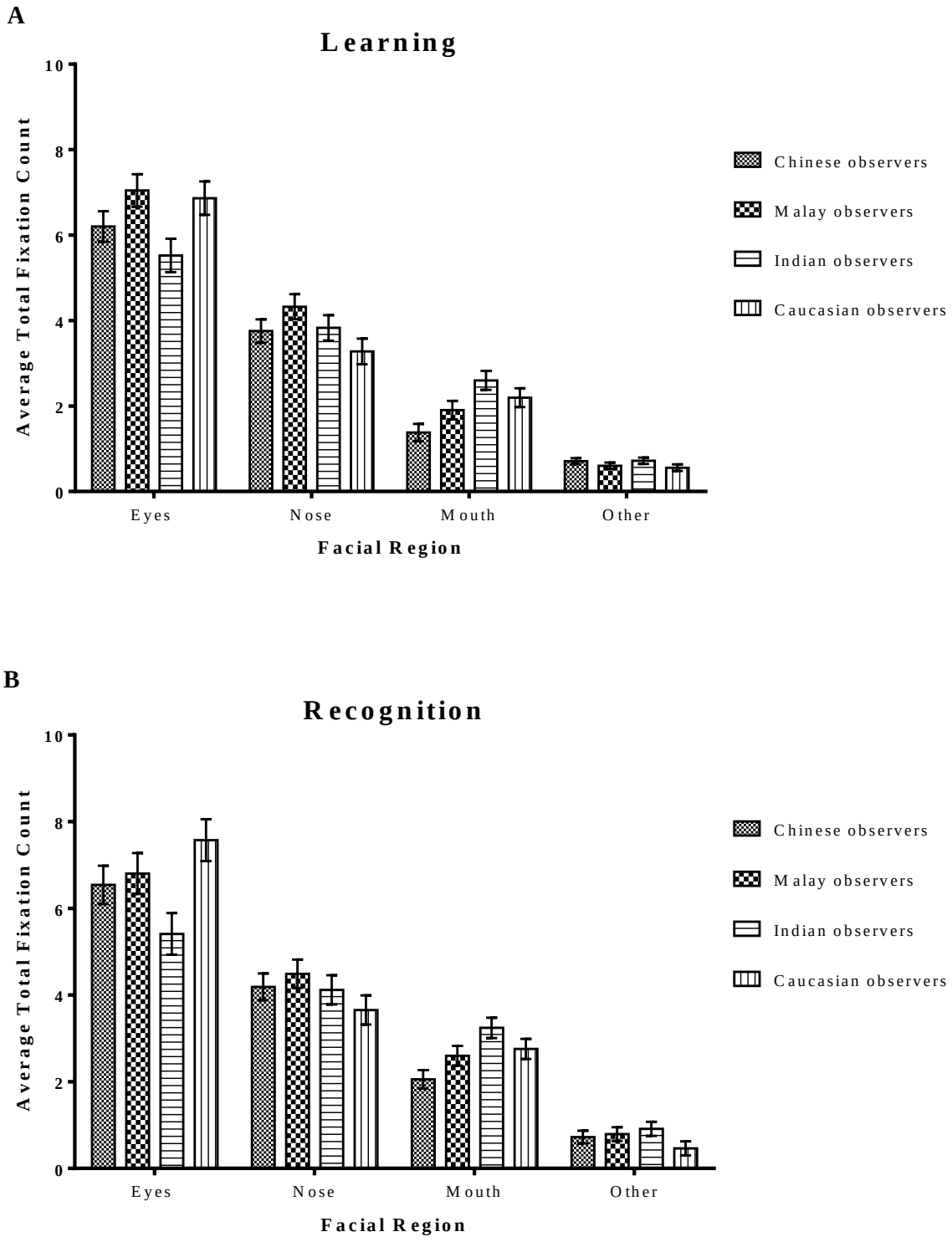


Figure D.1. Average total number of fixations on the predefined AOIs for different *observer races* during the (a) learning and (b) recognition tasks. Error bars represent standard error of mean.

Another ANOVA with Race of Face as within-subject factor and Race of Observer as between-subjects factor was conducted on the average total fixation count on each AOI (eyes, mouth, nose, and other facial areas) for *recognition* phase. Neither a significant main effect of Race of Observer nor a significant interaction between Race of Face and Race of Observer was observed, $F(3, 85) = 1.81$, $p = 0.152$ and $F(9, 255) = 1.29$, $p = 0.242$. There was a significant main effect of AOI, $F(1.98, 167.93) = 204.93$, $p < 0.001$, with Bonferroni pairwise comparisons showing that participants fixated on the eyes significantly more than the nose and mouth, and the nose more than the mouth (all $p < 0.001$). There was also a significant main effect of Race of Face, $F(3, 255) = 3.99$, $p = 0.008$. A Bonferroni post hoc test revealed that average total number of fixations on the whole face was significantly higher for Malay faces than Indian faces ($p = 0.002$).

The analysis also revealed a significant interaction between AOI and Race of Observer (see *Figure D.1*), $F(9, 255) = 3.01$, $p = 0.002$. Simple main effect analysis revealed that Indian participants directed more fixations to the mouth than did Chinese participants ($p = 0.002$) but fewer fixations on the eyes compared to Caucasian participants ($p=0.012$). Besides, a significant interaction between AOI and Race of Face was found, $F(5.60, 475.77) = 11.51$, $p < 0.001$. Simple main effect analysis showed that number of fixations landed on the nose region of Malay faces was significantly greater than those on Chinese ($p=0.038$), Indian ($p<0.001$), and Caucasian faces ($p<0.001$). For Chinese faces, there were significantly more fixations landing on the nose than those of Indian faces (0.002) and a trend towards more fixations landing on the nose compared to those of Caucasian faces ($p=0.062$). Caucasian faces received significantly fewer fixations to the mouth region but more fixations to the eye region compared to faces of other three races (all $p<0.05$) (see *Figure D.2*).

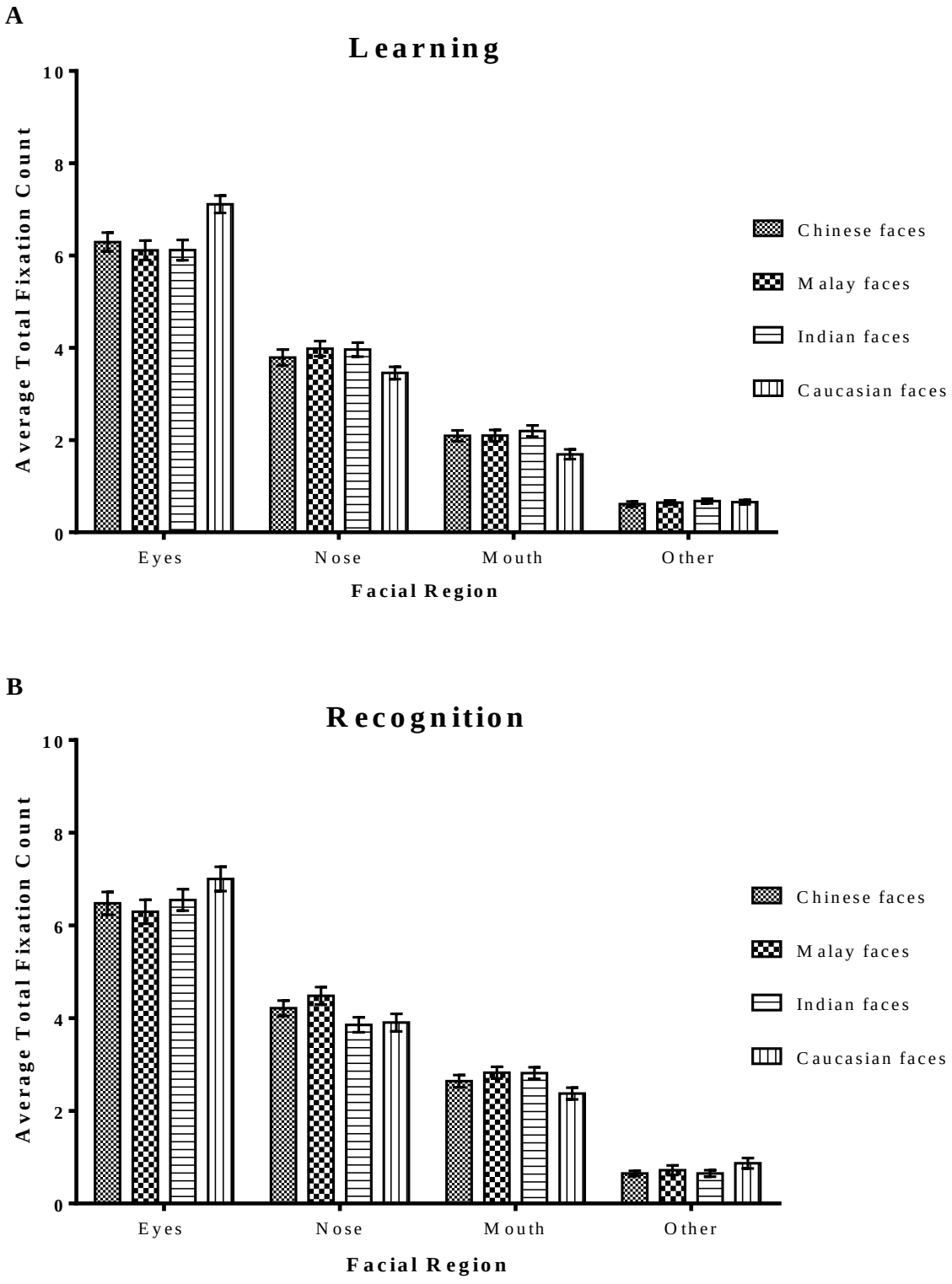


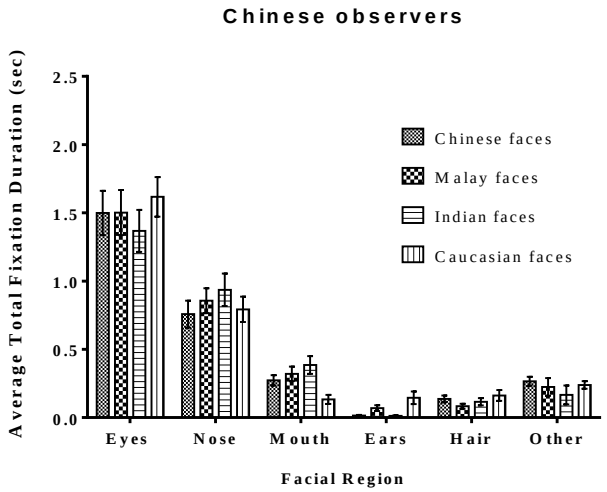
Figure D.2. Average total number of fixations on the predefined AOIs for different face races during the (a) learning and (b) recognition tasks. Error bars represent standard error of mean.

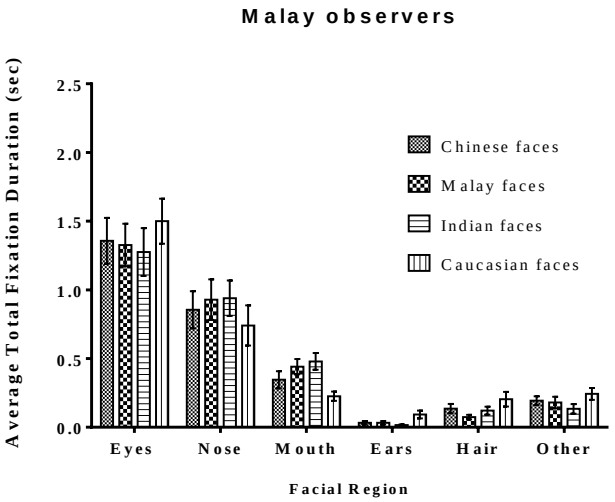
APPENDIX E

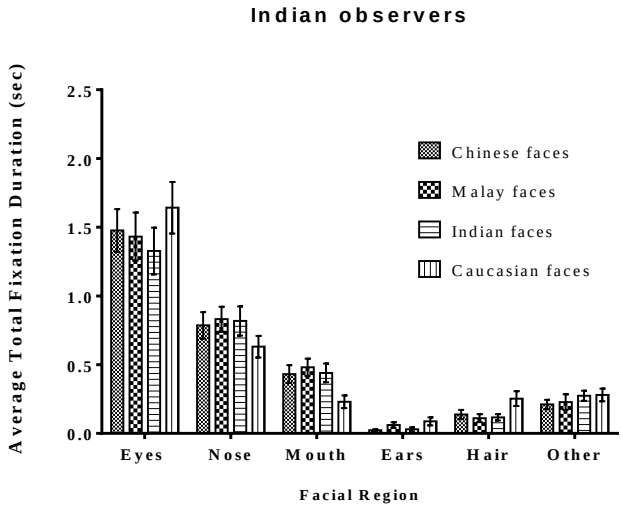
Non-Area-Normalised Results for Average Total Fixation Duration in Experiment 3

A four-way ANOVA on average total fixation duration revealed a significant main effect of experimental phase, F (1, 22) = 8.15, p=.009, η_p^2 =.27. Participants generally fixated longer at the faces during learning than during recognition phase (p=.001). The main effect of Feature was significant, F (1.84, 40.45) = 46.17, p<.001, η_p^2 =.68, showing that participants made longest fixations on the eyes, followed by nose, mouth, other, hair and ears (all *p*<.001). The four-way interaction between Phase, Face Race, Feature and Race of Observer was significant, F (45, 1290) = 1.41, p=.04, η_p^2 =.05. Split analyses by Phase revealed a significant Face Race × Feature × Race of Observer interaction only in learning phase, F (45,1290) = 1.72, p=.002, η_p^2 =.06, but not in recognition phase, F (45, 1290) = 1.13, p=.26, η_p^2 =.04. This indicates that fixation patterns differ among the participant groups, particularly when studying faces of different races. Further split analyses by Race of Observer showed that Face Race × Feature interaction was highly significant in Chinese, F(5.68, 124.96) = 3.52, p=.004, η_p^2 =.14, Malay, F(6.23, 137.04) = 4.42, p<.001, η_p^2 =.17, and Indian observers, F(5.66, 130.25) = 5.89, p<.001, η_p^2 =.20, but only marginally significant in Caucasian observers, F(5.36, 101.82) = 1.89, p=.07, η_p^2 =.09. Chinese observers fixated longer at Caucasian eyes than Indian eyes but shorter to Caucasian mouth than Chinese (p<.001), Malay (p=.03) and Indian mouth (p=.002). Yet, no significant difference of nose fixation duration was found between face race. Malay observers looked longer at the nose (p=.02) and mouth (p<.001) of own-race faces than that of Caucasian faces; however, they tended to fixate longer on Caucasian eyes than own-race eyes (p=.08). Additionally, they fixated significantly longer on Indian mouth than Caucasian mouth (p=.001) but looked longer at Caucasian hair than own-race and Indian hair (p=.05; p=.03). Indian observers looked longer at Caucasian eyes than Malay (p=.05) and Indian eyes (p=.006) but shorter at Caucasian

noses than Chinese (p=.04) and Malay noses (p=.002). They also looked longer at Chinese, Malay and Indian mouths than Caucasian mouths (all $p \leq .001$) and longer at Caucasian hair than other three races (all $p<.05$). For Caucasian observers, no difference in average fixation duration on internal features (nose, mouth, eyes) was found among different face races. However, they looked significantly longer at the external features (hair and ears) on own-race faces than those on Chinese, Malay and Indian faces (all $p<.01$). Overall, there was a trend that participants looked at the eyes more often in Caucasian faces than in Asian faces, and there were significantly more fixations to the nose for Asian compared to Caucasian faces.


Chinese observers
Average Total Fixation Duration (sec)
2.5
2.0
1.5
1.0
0.5
0.0
Chinese faces
Malay faces
Indian faces
Caucasian faces
Eyes
Nose
Mouth
Ears
Hair
Other
Facial Region


Malay observers
Average Total Fixation Duration (sec)
2.5
2.0
1.5
1.0
0.5
0.0
Chinese faces
Malay faces
Indian faces
Caucasian faces
Eyes
Nose
Mouth
Ears
Hair
Other
Facial Region


Indian observers
Average Total Fixation Duration (sec)
2.5
2.0
1.5
1.0
0.5
0.0
Chinese faces
Malay faces
Indian faces
Caucasian faces
Eyes
Nose
Mouth
Ears
Hair
Other
Facial Region

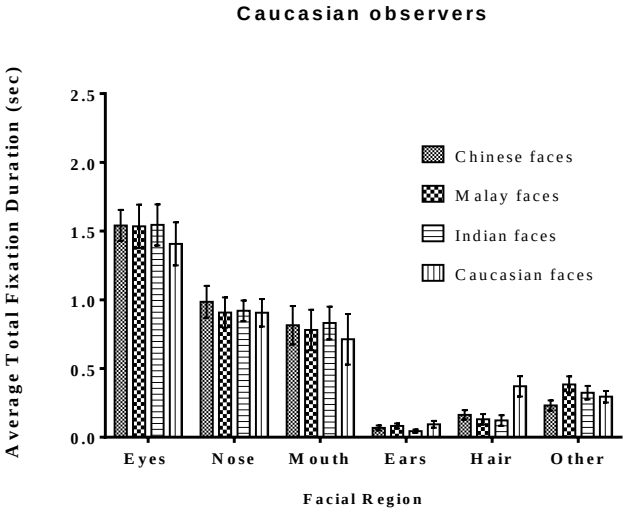

Caucasian observers
Average Total Fixation Duration (sec)
2.5
2.0
1.5
1.0
0.5
0.0
Chinese faces
Malay faces
Indian faces
Caucasian faces
Eyes
Nose
Mouth
Ears
Hair
Other
Facial Region

Figure E.1. Average total fixation duration on the predefined AOIs for different face races in Chinese, Malay, Indian and Caucasian observers. Error bars represent standard error of mean.

APPENDIX F

Non-Area-Normalised Results for Average Total Number of Fixations in Experiment 3

A four-way ANOVA on average total fixation count revealed a significant main effect of Feature, F (2.09, 179.87) =243.36, p<.001, η_p^2 =.74. Pairwise comparisons revealed that participants fixated most frequently on the eyes, followed by nose, mouth, other, hair and ears regions (all p<.001). There was a significant three-way interaction between Phase, Feature, and Race of Observer, F (15, 430) = 1.80, p=.03, η_p^2 =.06. Simple main effect analyses showed that Chinese, F (2.78, 52.81) = 5.28, p=.004, η_p^2 =.22, Indian, F (2.83, 56.66) = 3.27, p=.03, η_p^2 =.14, and Caucasian observers, F (2.54, 43.22) = 2.03, p=.03, η_p^2 =.11, fixated more on the mouth and hair during recognition than learning phase (all p<.05). However, the Phase × Feature interaction did not reach significance for Malay participants, F (2.77, 52.58) =1.31, p=.28. There was also a significant three-way interaction between Phase, Face Race and Feature, F (10.03, 862.49) = 3.44, p<.001, η_p^2 =.04. Further analyses showed that, compared to recognition phase, Chinese faces received fewer fixations to the mouth (p=.001) during learning phase, F (3.29, 256.22) = 2.60, p=0.3, η_p^2 =.03. Malay faces also received fewer fixations to the mouth and other regions (both p=.004) but more the eyes (p=.03) during learning phase, F (3.29, 256.22) = 5.52, p=0.001, η_p^2 =.07. Caucasian faces, on the other hand, received fewer fixations on the mouth (p<.001) during learning, but more on hair (p<.001) and ear (p=.05), F (3, 233.67) = 7.57, p<.001, η_p^2 =.09. However, the average number of fixations made to Indian features did not differ significantly between learning and recognition phase, F (3.23, 251.70) = 1.76, p=0.15, η_p^2 =.02.

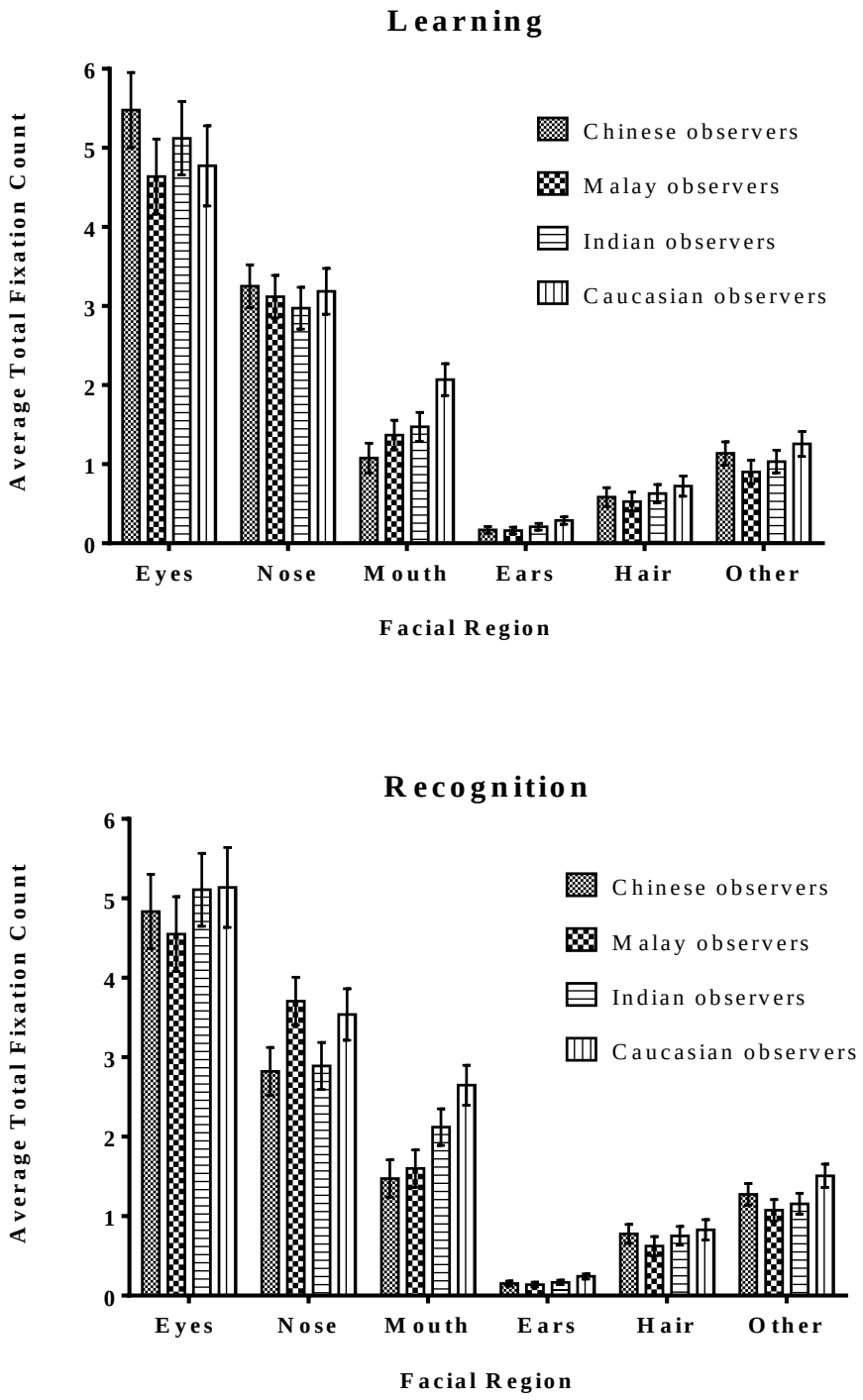


Figure F.1. Average total number of fixation count on the predefined AOIs for different races of observers during the (a) learning and (b) recognition tasks. Error bars represent standard error of mean.

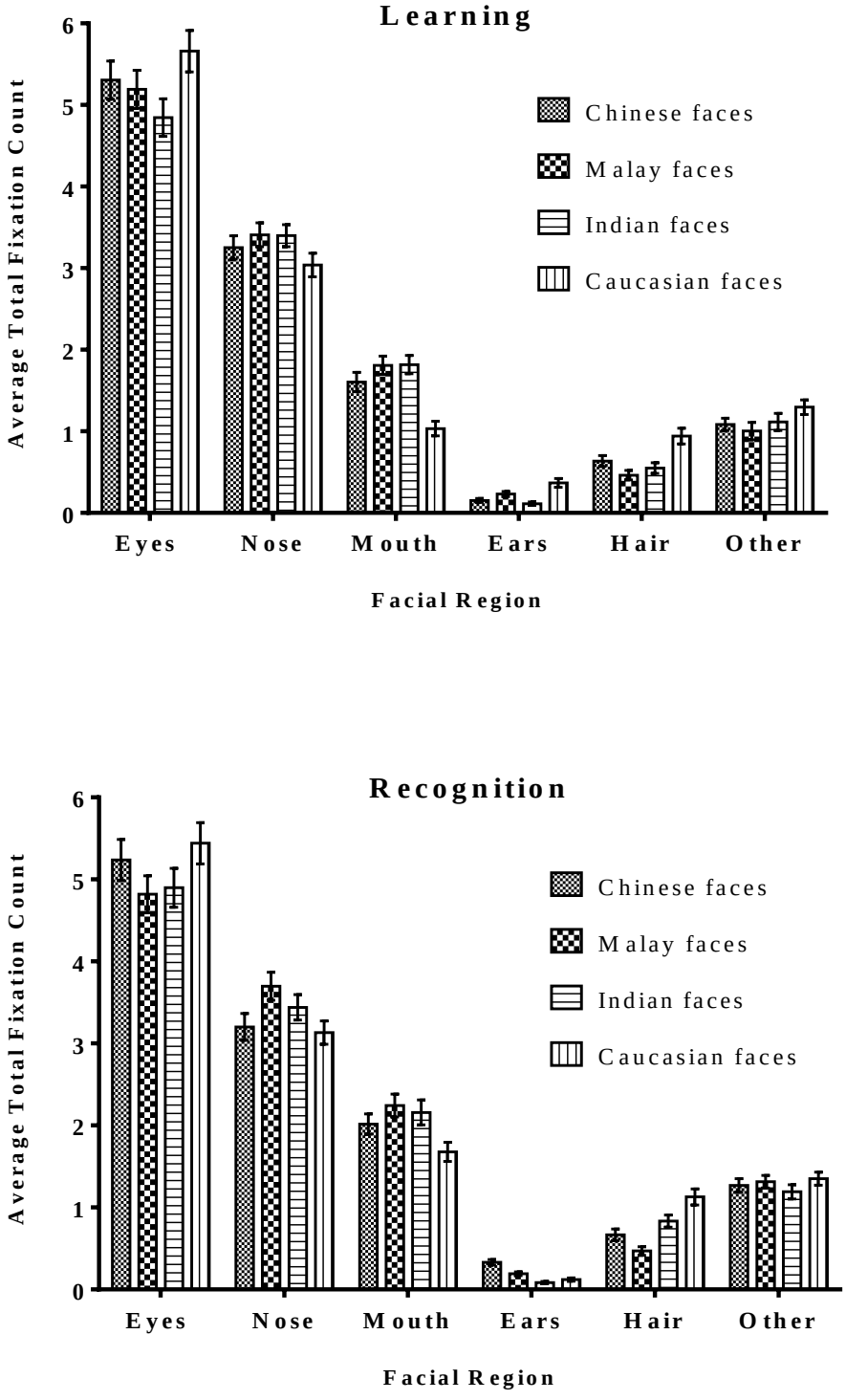


Figure F.2. Average total number of fixation count on the predefined AOIs for different races of faces during the (a) learning and (b) recognition tasks. Error bars represent standard error of mean.