

PERCEPTUAL AND NEURAL MECHANISMS OF THE OTHER-RACE EFFECT IN FACE RECOGNITION

Ao Wang

PhD

University of York

Psychology

January 2022

Abstract

The underlying cause of the other-race effect (ORE) remains controversial. A dominating social cognitive theory, suggests that group-bias causes us to process own-race and other-race faces using different cognitive processes. There are two key predictions from the social cognitive theory. Firstly, following the social categorization of faces, different cognitive processes are used to process own-race faces and other-race faces; own-race faces are individuated, whereas other-race faces are categorized. The second is that people are more engaged or attentive to own-race faces because of their in-group status. The aim of this thesis was to test these two hypotheses using behavioural and neural approaches. First, a behavioural experiment with two different tasks was developed to investigate individual differences in the ORE for face recognition. Although a clear ORE was evident, the covariation in performance across tasks suggests that similar mechanisms are involved in processing own-race and other-race faces. That is, individual performance on own-race faces correlated to other-race faces. Consistently, an item-analysis revealed that participants from different races had similar patterns of response. An analysis of the shape and texture information from the face images showed that participants used image cues in judgements similarly for own-race and other-race faces. There was also no evidence that participants spent more time on own-race compared to other-race faces. A test on face trait judgement showed participants rated on dominance and trustworthiness in similar patterns of perception for own-race and other-race faces. Finally, an fMRI study showed that own-race and other-race faces are processed in a similar way in face-selective regions of the brain. Together, the results from this thesis show that faces from different races are processed using fundamentally similar mechanisms and thus challenge key predictions from the social cognitive theory of the ORE.

Table of Contents

Abstract	2
Table of Contents	3
List of Figures	6
List of Tables	9
Acknowledgements	10
Author's declaration	11
1. Introduction	12
1.1 Behavioural evidence for the ORE	13
1.2 Theoretical Perspectives on the ORE	16
1.2.1 Structural Homogeneity	16
1.2.2 Perceptual Learning Theory	17
1.2.3 Social Cognitive Theory	20
1.3 Neural correlates of the Other-Race Effect	22
1.3.1 Evidence of ORE using EEG	22
1.3.2 Evidence of the ORE from fMRI	23
1.4 The aim of this Thesis	27
2. Covariation in the Recognition of Own-Race and Other-Race Faces Argues Against the Role of Group Bias in the Other Race Effect.....	30
2.1 Introduction	30
2.2 Methods	32
2.2.1 Participants	32
2.2.2 Matching Tasks	33
2.2.3 Sorting Tasks	34

2.3 Results	36
2.3.1 Matching Task Results	36
2.3.2 Sorting Task Results	43
2.3.3 Comparison of face matching and card sorting tasks	50
2.4 Discussion	52
3. Similar Patterns of Neural Response to Own-race and Other-race Faces Argue against the Group Bias Account of the ORE.....	58
3.1 Introduction	58
3.2 Methods	61
3.2.1 Participants	61
3.2.2 Stimuli	61
3.2.3 Design and Procedure	62
3.2.4 Data acquisition and analysis	63
3.3 Results	67
3.3.1 Univariate Analysis	67
3.3.2 Multivariate Analysis	73
3.3.3 Individual Differences Analysis	83
3.4 Discussion	88
4. No Evidence For An Other-race Effect in Judgements of Dominance or Trustworthiness of Faces	93
4.1 Introduction	93
4.2 Methods	96
4.2.1 Participants	96
4.2.2 Stimuli and Procedure	96

4.3 Results	98
4.4 Discussion	102
5. Variation in the Shape and Texture of Faces from Different Races	106
5.1 Introduction	106
5.2 Methods	110
5.2.1 Stimuli	110
5.2.2 Principle Components Analysis	110
5.2.3 Deep Convolutional Neural Network	111
5.2.4 Behavioural Measurements	111
5.3 Results	111
5.3.1 Image Differences in Faces from Different Races	111
5.3.2 The Role of Shape and Texture on Judgements of Identity	112
5.3.3 DCNN Comparison of Own-Race and Other-Race Faces	115
5.4 Discussion	123
6. General Discussion	128
6.1 Background and Aims of the Thesis	128
6.2 Theoretical Implications	128
6.3 Limitations of Present Thesis and Future Directions	134
6.4 Conclusions	136
References	137

List of Figures

Figure 1.1 "Mirror-effect" pattern demonstrated in hit and false alarm responses to own-race and other-race faces	15
Figure 2.1 Examples of same identity and different identity trials from the Asian, Black and White matching tasks	35
Figure 2.2 Images from the Asian, Black and White sorting tasks	35
Figure 2.3 Performance on the matching task with Asian and White participants viewing Asian, Black and White faces	36
Figure 2.4 Correlation between d' values between different face matching tasks in Asian and White participants	39
Figure 2.5 Comparison of an item-analysis across the two participant groups on (A) same identity and (B) different identity trials	40
Figure 2.6 Task time for all matching tasks	44
Figure 2.7 Performance on sorting task	45
Figure 2.8 Correlation between pile number across different card sorting tasks in Asian and White participants	47
Figure 2.9 The probability of images being sorted into same pile and its correlation between Asian and White participants for the within identity	50
Figure 2.10 Task time of sorting tasks	51
Figure 3.1 Examples of images from the different stimulus conditions	64
Figure 3.2 Group analysis showing the location of face-selective and scene-selective selective regions	65

Figure 3.3 fMR-Adaptation in the FFA, OFA and STS to different race faces.....	70
Figure 3.4 Normalized fMRI response in the FFA, OFA and STS to different race faces	71
Figure 3.5 Neural response to pareidolic objects in the face regions.....	73
Figure 3.6 The spatial pattern of response between different race faces (Face-Face) comparing to the spatial pattern between faces and scenes (Face-Scene)	75
Figure 3.7 The spatial pattern of response between faces from the same race (Same Race) comparing to the spatial pattern between faces from different races (Different Race).....	77
Figure 3.8 The spatial pattern of response between White or between Asian faces comparing in Asian and White participants.....	79
Figure 3.9 The spatial pattern of response between different race faces (Face-Face) comparing to the spatial pattern between faces and pareidolic objects (Face-Object)	80
Figure 3.10 The spatial pattern of response to pareidolic objects(Object-Object) comparing to the spatial pattern between pareidolic objects and scenes (Object-Scene)	83
Figure 3.11 Correlation of individual differences between all Face Races matches for adaptations, normalized responses and spatial pattern of response, irrespective participant race	85
Figure 3.12 Correlation between Adaptation, Normalized response and Spatial patterns of response in the FFA across all participants	88
Figure 4.1 Reliability on the dominance and trustworthy task with Asian and White participants viewing Asian, Black and White faces	99
Figure 4.2 Correlation between item reliability of Asian and White participants across Asian, Black and White faces for dominance and trustworthy	101
Figure 4.3 Item analysis correlation between dominance and trustworthy across Asian, Black and White faces for (A) Asian and (B) White participants	102

Figure 5.1 Similarity matrices of correlation between Shape principle components and comparison of within-race and between-race similarity	113
Figure 5.2 Similarity matrices of correlation between Texture principle components and comparison of within-race and between-race similarity	115
Figure 5.3 The correlation between face matching behavioural task performance (proportion same) and face matching image pairs similarities in Shape for each face race of Asian participants and White participants.....	117
Figure 5.4 The correlation between face matching behavioural task performance (proportion same) and face matching image pairs similarities in Texture for each face race of Asian participants and White participants.....	120
Figure 5.5 Similarity Matrices from the Images in the Face Matching Task Calculated from the 13 Convolutional and 3 Fully-Connected Layers of the DCNN	123
Figure 5.6 The Correlation Between Pairwise Image Similarity for 16 layers of DCNN and Behavioural Performance of Asian participants and White participants in Proportion Same Response	124

List of Tables

Table 2.1 Correlation between Face Race for Asian and White participants in Same identity and Different identity trials	41
Table 3.1 Coordinates of face-selective and place-selective regions	67
Table 3.2 Individual differences in adaptation, normalized response and spatial pattern of response across all participants	86
Table 3.3 Covariance in adaptation, normalized response and spatial pattern of response across all participants	87
Table 4.1 Comparison of calculated reliability versus chance (50%)	100
Table 4.2 Three-way ANOVA of interaction between Identity, Face and Participant	103
Table 5.1 Within-race and Between-race Comparison of Shape	114
Table 5.2 Within-race and Between-race Comparison of Texture.....	116
Table 5.3 Comparison between Asian and White participants correlation values for Shape.....	119
Table 5.4 Comparison between Asian and White participants correlation values for Texture	121
Table 5.5 Within- and between-race comparison for VGG faces in t-value	122

Acknowledgements

There are a lot of people I would like to thank to for the help offered to me during my Ph.D. life. But first of all, I would like to express my appreciation to my supervisor, Professor Tim Andrews, for all the guidance, patience, inspiration, and support you gave me. It is my fortune to have you as my mentor in this period of my life, you raised me up to a level that I could hardly imagine before. Thank you so much for enlightening me on the way to academia.

Secondly, I appreciate all the TAP members that gave me suggestions about this work, especially Professor Andy Young, who shared lots of valuable knowledge of literature and provided vital advice on the data presentation.

Then, I would like to thank all the helps I gained when I was conducting these experiments. Thank you, Gabriela, Magdalena, Craig, Sam and all the under-or post-graduates that ever joined this group, without your assistance, I will never collect this amount of data here. Without the support from my parents, I will not be able to start this PhD, so I would like to thank them for the psychological and financial reinforcements they provided, and I will always appreciate your unconditional love.

Finally, it was a rather dramatic PhD life, considering I have encountered hate crime fight on a bus in Edinburgh, the COVID-19 pandemic which almost ground me in China, lockdown for months and melanoma-like mole removal surgery when I was writing this. I would like to thank all these unexpected dramas, thank you for sparing my humble life and forging me tougher, and please, no more.

Authors' Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

1. INTRODUCTION

Humans recognize the identity of faces from their own-race more accurately than those from another race. This phenomenon is known as the other-race effect (ORE), own-race bias, cross-race effect, and the cross-race recognition deficit (Meissner & Brigham, 2001). One of the earliest references to the ORE was by Feingold in 1914.

It is well known that, other things being equal, individuals of a given race are distinguishable from each other in proportion to our familiarity, to our contact with the race as a whole. Thus to the uninitiated American, all Asiatics look alike, while to the Asiatic all white men look alike.

Since then a large number of behavioural studies have shown the ORE demonstrating a clear advantage for the recognition and perception of own-race faces advantages (Bothwell et al., 1989). However, despite agreement on the existence of the ORE, the underlying reason for this effect remains hotly debated (Teitelbaum & Geiselman, 1997). The aim of this chapter is to describe the key empirical evidence and theories for the ORE. First, it will review the behavioural studies, exploring the methods used to examine the magnitude and robustness of ORE. Next, it will describe the key theories and how these fit with the existing empirical literature. Finally, this review will provide an overview of recent studies on the neural correlates of the other-race effect.

1.1 Behavioural evidence for the ORE

The first empirical evidence in support of the ORE came 50 years later when Malpass and Kravitz (1969) conducted a recognition memory experiment testing black and white subjects with black and white faces. They found that subjects recognized faces of own-race better than of other races. Although similar experiments provide support for the existence of the ORE, there has been some variability in the consistency of the ORE across studies (Cross et al., 1971; Lindsay et al., 1991; Luce, 1974; Malpass, 1974). It has not been clear whether the ORE is of a similar magnitude across racial groups. For example, Lindsay and colleagues (1991) showed that, while white participants performed significantly more poorly with black faces, there was no effect on black participants. Some of these studies have investigated possible moderators of the ORE, such as racial attitude or inter-racial contact. However, the evidence for these effects has not been clear.

To address these issues a number of meta-analyses have been performed on behavioural studies investigating the ORE (Anthony et al., 1992; Bothwell et al., 1989; Meissner & Brigham, 2001; Shapiro & Penrod, 1986). The most comprehensive of these meta-analyses was performed by Meissner and Brigham (2001) who analysed 91 independent samples involving nearly 5000 participants. They found that the ORE was highly consistent across studies. Overall, the results indicated a mirror effect (see Figure 1.1) in which own-race faces receive a higher proportion of hits and a lower proportion of false alarms compared to other-race faces. Interestingly, the ORE was larger in white participants compared to black or other-race participants. One explanation for this could be sample bias, because the majority of studies were conducted in countries in which whites make up the majority (Cui et al., 2020). There was no consistent effect of racial attitude, but there was a significant effect of inter-racial contact, which reduced the ORE.

MEISSNER AND BRIGHAM

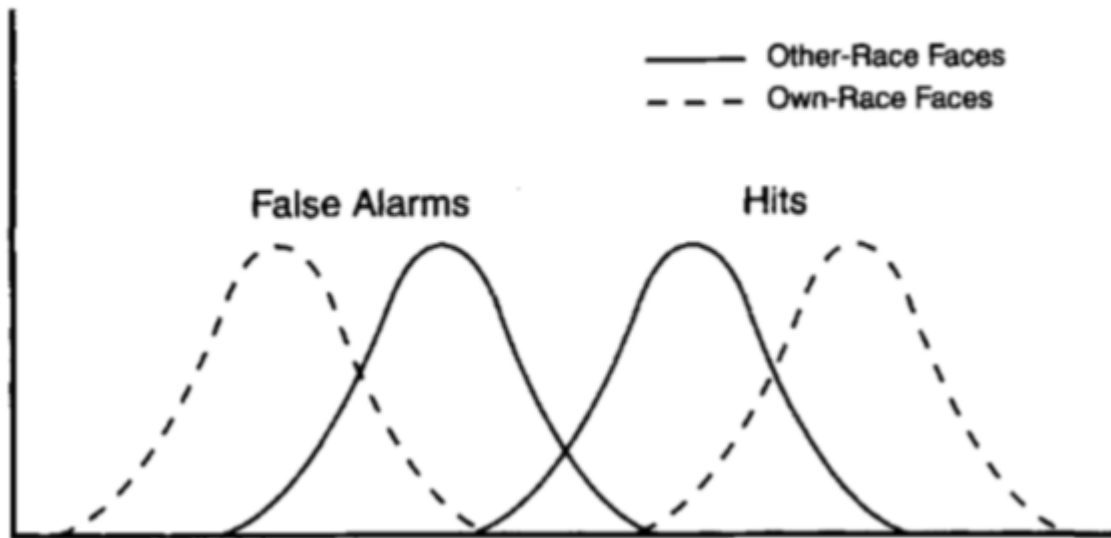


Figure 1.1. "Mirror-effect" pattern demonstrated in hit and false alarm responses to own-race and other-race faces.

Unlike the robust reliability found in most the memory tests (see Malina et al., 1998; Warrington, 1984; Soukup, Bimbela, & Schiess, 1999), laboratory face-recognition tests have yielded moderate reliability estimates (Messner & Brigham, 2001). However, it is possible that these laboratory tests did not test ORE in more real-world situations (Lindsay & Wells, 1983). To address this issue, other studies have used paradigms that could be applied to forensic settings, such as eye-witness testimony (Linville & Jones, 1980; Linville et al., 1989; Quattrone & Jones, 1980). In their meta-analysis, Meissner and Brigham (2001) found that the ORE is slightly larger in these real-world situations. This implies that eyewitnesses were found more likely to misidentify suspects of other-races compared to their own race suspects. Interestingly, Meissner and Brigham (2001) found that the ORE was greater in studies in which different images were used at learn and test stages. This could explain why there was a

greater ORE in real-world paradigms, as having different images with the same identity at the learn and test stages is standard in these studies.

The majority of research on the ORE has been carried out in the USA. This raises the question as to whether the ORE is unique for people in this country or whether it is a universal property? Studies have shown that the ORE is not confined to the North American continent, but is evident globally in all cultures in which it has been tested (Chiroro & Valentine, 1995; Walker & Hewstone, 2006; Wright et al., 2001, 2003; Sporer, 2001). A related issue is whether the effect generalizes to other races, as the majority of studies have used black and white participants. Evidence in support of the generality of the ORE was found in studies involving East Asian (China, Japan, Korea) (Chance et al., 1982; Chance et al., 1975; Goldstein & Chance, 1980; Luce, 1974; Ng & Lindsay, 1994), Middle Eastern (Megreya et al., 2011) and Hispanic (Gross, 2009; MacLin & Malpass, 2001; Platz & Hosch, 1988) participants. Therefore, the ORE transcends racial group membership.

As many experiments have examined the ORE in countries with a dominant ethnic group, it could be that the ORE is only evident for the dominant group. However, both majority and minority groups show the ORE (Platz & Hosch, 1988; Wright et al., 2001). For instance, Platz and Hosch conducted a memory study with Mexican, Black and White convenience store workers in the USA (1988). They examined the performance of workers from these three ethnic groups in remembering customers of these same three ethnicities. They found the response was more accurate for participants from the worker's own-race face than faces from any other ethnic groups. This result suggests the ORE was not influenced by whether the ethnic group was in the majority or minority.

1.2 Theoretical Perspectives on the ORE

There is a large amount of empirical support for the existence of the ORE. Many behavioural studies have investigated how the ORE is modulated by other factors, such as inter-racial attitudes or contact. These studies have provided insights into the possible mechanisms that might underlie the ORE. This section will outline the key theories that attempt to explain the ORE.

1.2.1 Structural Homogeneity

A prominent early theory of the ORE is that the faces of other races show less structural (physiognomic) variation compared to Caucasian faces (Malpass and Mravitz, 1969). This theory explained the ORE by explaining that Caucasians have an impaired facial recognition ability toward other-race faces because of the structural homogeneity of the other-race faces. Despite the fit between this theory and the perceptual experience of white participants, it has two main challenges: The first is that the ORE generalizes across races. For example, Caucasian and Asian participants have reduced recognition of Asian and Caucasian faces, respectively, compared to own-race faces. If the faces from one race were less variable, then recognition of faces from this race should be impaired regardless of the race of the observer (Brigham & Barkowitz, 1978; Chance et al., 1982; Chance et al., 1975; Goldstein & Chance, 1980; Luce, 1974; Meissner & Brigham, 2001; Ng & Lindsay, 1994; O'Toole et al., 1994; Platz & Hosch, 1988; Valentine & Endo, 1992). Although there is some evidence of a difference in the magnitude of the ORE across races in some studies, this is typically explained by other factors (Meissner & Brigham, 2001). The second problem is the extent to which there is

differential variability in the structure of faces of different races. A number of studies have failed to find any significant differences in the variability of Asian, Black, and Caucasian faces (Goldstein, 1979). Therefore, it was concluded by Goldstein and Chance (1979) that structural homogeneity fails to provide a general comprehensive explanation of ORE. However, it is important to note that differences in facial features across races may influence the ORE (Meissner & Brigham, 2001).

1.2.2 Perceptual Learning Theory

A key theory that attempts to explain the ORE is based on the idea that our experience or contact with own-race faces leads to a more robust cognitive representation through the process of perceptual learning (Byatt & Rhodes, 2004; Chiroro & Valentine, 1995; Corenblum & Meissner, 2006; Furl et al., 2002; Hills & Lewis, 2006). The main idea of the perceptual learning theories is that people differ in their experience of recognizing their own-race and other-race faces. As we have extensive opportunities to recognize own-race faces, we become experts in processing these faces. In contrast, we have less experience with other-race faces and thus have less opportunity to develop an equivalent level of expertise.

Evidence in support of the Contact Hypothesis comes from a study that compared the face recognition abilities of African American and Caucasian children from segregated and integrated schools. The results showed a larger ORE for children in segregated schools than for children in integrated schools, particularly when the racial composition of the neighbourhood was factored in. In a related study, Cross et al. (1971) found that Caucasian children from integrated neighbourhoods showed a smaller other-race effect than their counterparts from segregated neighbourhoods. In this study, there was no difference in the way African American adolescents recognized African Americans and Caucasians equally well.

Other studies provide further support for the importance of contact for the development of the ORE (Ferguson et al., 2009; Furl et al., 2002; Goodman et al., 2007; Pezdek et al., 2003; Walker & Hewstone, 2006; Estudillo et al., 2020).

The importance of experience is nicely demonstrated in a cross-race adoption study. Sangrigoli and colleagues (2005) compared the ORE in French participants who had lived all their lives in France, Korean participants who had been adopted as children in France and Korean participants who had lived in Korea as children but who were now living in France. They found a difference between own-race and other-race faces in all groups. However, they found the direction of the ORE was different for the Korean participants who had been adopted. They were more able to discriminate Caucasians compared to Korean faces. Interestingly, the time that the other Korean group has spent in France did not affect the magnitude of the ORE.

These studies imply that experience or contact with other-race faces increases the ability to discriminate these faces. However, there has been some debate about when the ORE develops (Anzures et al., 2010; Bar-Haim et al., 2006; Hayden et al., 2007; Liu, et al., 2007; Kelly et al., 2007; Kelly et al., 2005; Quinn et al., 2008). Chance and colleagues show that the magnitude of the ORE increases gradually during development (Chance et al., 1982). They found that children at 6 years old, recognized faces of both races equally well. However, by 10 years of age, there was a recognition accuracy advantage for Caucasian faces, which became successively larger for the older participants. More recent studies have found that the ORE is evident at even earlier stages of development (Kelly et al., 2005; Anzures et al., 2013). For example, Kelly and colleagues proposed that newborns show no racial preferences until 3 months, at which point infants tend to look at faces that with experience (Kelly et al., 2005). These studies suggest that early visual and sociocultural experiences shape the

processing of familiar and unfamiliar faces.

Although the importance of experience in the ORE is clear, it is not clear how the bias for own-race faces occurs. A cognitive model to explain the perceptual learning theory was proposed by Valentine (Valentine, 1991; Valentine & Endo, 1992; Valentine et al., 2001). His multidimensional face space assumes that each facial dimension has a range of values that are distributed normally across a population. Each face can therefore be coded by its position in this multidimensional face space. The dimensions intersect at the most typical values or the average face. Differences from the average face are used to discriminate identity. Because the model is based on the population of faces, it will be biased toward faces with which we have had the most contact. Thus, own-race faces will dominate the representation of an individual's face space. Differences in the average dimensionality of other-race faces lead to them being clustered more closely in a peripheral region of an individual's face space and will thus be less easy to discriminate. Although there has been some debate over whether face recognition uses a norm-based model, a similar argument could be made for any multidimensional model of face processing that is sensitive to experiences.

Other models have suggested that the categorization of own-race and other-race faces lead to different types of processing (Rhodes et al., 1989; Rossion et al., 2006; Tanaka et al., 2004). For example, it has been suggested that greater experience with own-race faces leads to configural processing, whereas the more limited experience of other-race faces leads to feature processing that is associated with lower levels of expertise. Configural processing, in the context of face encoding, is typically defined as extracting the relationship and orientation between fixed properties of the face (such as nose, eyes, and mouth). The extraction of such characteristics has been argued to allow for more efficient encoding, and may even allow the face to be processed as a unified object, rather than as a set of separate

facial features or structures (see Maurer, Le Grand, and Mondloch, although see Burton et al., 2015).

1.2.3 Social Cognitive Theory

A number of social cognitive theories have emerged to provide an alternative explanation for the ORE. For example, it was suggested that racial attitudes might explain the ORE. That is, if an individual has a negative or prejudiced attitude to another race, this would lead to an unwillingness to interact and thus discriminate other-race faces (Secord et al., 1956; Secord et al., 1956). Support for the role of racial attitudes has been mixed with some studies showing that racial bias does influence the size of the ORE and other studies showing no effect (Allport & Kramer, 1946; Brigham & Barkowitz, 1978; Elliott & Wittenberg, 1955; Lavrakas et al., 1976; Platz & Hosch, 1988; Slone et al., 2000). Meissner and Brigham (2001), found no consistent effect of racial attitude in their meta-analysis.

More recent social-cognitive models are focussed on the concept of group bias. Membership of social groups plays a significant role in guiding our perception of the world (Sherif et al., 1961; Amodio et al., 2014; Xiao et al., 2016). The value humans place on social groups is illustrated by the ease and rapidity with which humans form groups and the psychological benefits gained by being a member of a group (Turner et al., 1987). Group membership leads individuals to generate positive impressions of in-group members and more stereotypical and negative impressions of out-group members. This has led to the idea that other-race faces are perceived as being part of an out-group and are therefore processed qualitatively differently than own-race faces.

A dominant social-cognitive theory is that other-race faces are perceived categorically, whereas own-race faces are perceived at the individual level (Levin, 1996; Levin, 2000;

Ostrom et al., 1993). Central to this theory is the idea that faces can be processed at different levels. For example, it is known that the sex, gender, and age of a face can be rapidly and automatically categorized (Ito and Urland, 1983; Brewer, 1988; Fiske and Neuberg, 1990; Freeman & Ambady, 2011). In contrast, the individuation of faces is a more challenging process (Burton et al., 2005; Hancock et al., 2000; Jenkins & Burton, 2011). This theory proposes that other-race faces are processed at the higher categorical level, whereas own-race faces are processed at the individual level. Support for this theory comes from studies showing that other-race faces are more quickly categorized by race than own-race faces (Levin, 1996). Further support comes from studies showing that our ability to discriminate a block of own-race faces is reduced following the discrimination of other-race faces (Young et al., 2009). This reduction in performance for own-race faces is thought to reflect the fact that other-race faces are now being perceived more categorically.

More, recent variants of this theory suggest that the categorical/individual difference in processing is related to motivation or attention (Hugenberg et al., 2010). That is, our motivation for processing other-race faces is less than for own-race faces. Support for the importance of motivation in processing own-race rather than other-race faces were provided by studies using ambiguous-race faces and showing that task and attentional load can have a significant effect on perception (Levin & Banaji, 2006; MacLin & Malpass, 2001, 2003; Michel et al., 2007). Rhodes and colleagues provided further support for the importance of motivation by showing that encouraging participants to individualize other-race faces can reduce the other-race effect (Rhodes et al., 2009).

1.3 Neural correlates of the Other-Race Effect

The majority of papers on the ORE have used behavioural methods. However, recent developments in neuroimaging have allowed researchers to explore the neural basis of the ORE. These studies have found evidence of the ORE at multiple levels of processing in the brain. These findings will be discussed in the context of the main theoretical perspectives of the ORE.

1.3.1 Evidence of ORE using EEG

Electroencephalography (EEG) and magnetoencephalography (MEG) monitoring the electrical activity of the brain. It measures voltage fluctuations across the brain via sensors distributed on the scalp of the participants. Event-related potentials (ERP) show the time course of the potential that is evoked by an event. The positive and negative deflections of these time courses have been linked to particular cognitive processes in the brain. For example, following the presentation of a face, a P100 response is followed by an N170 (Bentin et al., 1996). The P100 is thought to be involved in face detection, whereas the N170 is involved in face recognition (Lui et al., 2002).

A number of studies have investigated the ORE using EEG and MEG. Consistent with the role of the P100 in the early stages of face processing, these studies have not found a significant effect of race on the P100 (Caharel et al., 2011; Stahl et al., 2008). There is mixed support for an ORE in the amplitude of the N170. Some studies failed to show any difference in the N170 to own-race and other-race faces (Caldara et al., 2004; Caldara et al., 2003; Tanaka and Pierce, 2009). However, other reports showed higher amplitudes in N170 for own-race faces compared with other-race faces (Herrmann et al., 2005; Stahl et al., 2008; Walker et

al., 2008; Ito et al., 2004; Ito & Urland, 2003; Ran et al., 2014; Tüttenberg & Wiese, 2021). It has been suggested that these differences between findings might reflect uncontrolled, physical variation in the own-race and other-race faces used in these studies (Vizioli et al., 2010).

To address these issues, Vizioli and colleagues investigated the ORE using adaptation or repetition suppression (Vizioli et al., 2010). Adaptation or repetition suppression is the reduction in response when a stimulus is repeated. This paradigm can be used to reveal the nature of the underlying neural response (Grill-Spector et al., 2006). Participants viewed two faces: an adaptor and a target. The faces were of the same identity or a different identity. They found that adaptation of the N170 (a reduced response to the same identity compared to a different identity) was greater for own-race compared to other-race faces. Vizioli and colleagues found further evidence for an ORE in a study using face inversion. Inverted faces give rise to a larger N170 compared to upright faces. This inversion effect was found to be greater for own-race compared to other-race faces. Despite these findings, the consistency of the N170 ORE has been challenged by the studies showing more negative amplitudes for other-race compared to own-race faces (Stahl et al., 2010; Wiese et al., 2014).

1.3.2 Evidence of the ORE from fMRI

Models of face perception proposes that a network of brain regions is involved in different aspects of face processing. These regions have been subdivided into a core and an extended system (Haxby et al., 2000; Ishai, 2008). The core system comprises regions in the occipital and temporal lobes, such as the occipital face area (OFA), the fusiform face area (FFA), and the superior temporal sulcus (STS). The OFA is proposed to have a feedforward projection to both the STS and the FFA. The connection between the OFA and STS is thought to be

important in processing dynamic changes in the face that are important for social interactions, whereas the connection between the OFA and FFA is important for the representation of invariant facial characteristics that are used for recognition (Andrews and Ewbank, 2004; Hoffman and Haxby, 2000; Winston et al., 2004).

The extended face-processing system includes regions such as the amygdala, inferior frontal gyrus, intraparietal sulcus, orbitofrontal cortex, and anterior temporal regions (Fairhall and Ishai, 2007; Haxby et al., 2000). It has been suggested that the core regions interact with the extended regions through two parallel routes: one from the FFA to the anterior temporal lobe, and another from the STS to the amygdala and other regions in the extended system (Haxby et al., 2000).

A number of studies have used fMRI to investigate the neural basis of the ORE. These studies find neural correlates of the ORE at different stages of face processing. This provides some insights into whether the ORE reflects the structural representation of faces (as predicted by perceptual learning theories) or higher processes involved in categorization and motivation (as predicted by social cognitive theories).

One approach to understanding the neural correlates of the ORE is to compare the overall response to own-race compared to other-race faces. For example, Golby and colleagues found that in black and Caucasian participants there was a larger response in the FFA to own-race faces. However, the only activity in the left FFA correlated with the memory differences between own-race and other-race faces (Golby et al., 2001). In a similar study, Kim and colleagues (2006) found that there was a larger response to own-race compared to other-race unfamiliar faces in the FFA. However, this effect was not evident for familiar faces. Feng et al. (2011) found that the ORE was evident in the response of the OFA and IFG, in addition to the FFA. Natu and colleagues (2011) found an ORE in the amplitude of the initial

response of the FFA, but interestingly this reversed over time such that the response became greater to other-race faces.

Other studies have asked whether there are differences in the pattern of response to own-race and other-race faces. For example, Natu and colleagues (2011) used multi-voxel pattern analysis to discriminate between Caucasian and Asian faces in Caucasian and Asian participants. The difference in the pattern of response was not evident in the response of the fusiform gyrus alone but only when combined with lateral occipital regions. Brosch and colleagues (2013) also found distinct patterns to own-race and other-race faces in the OFA and FFA, but this was only evident for individuals with high behavioural ORE. Ng and colleagues used an adaptation paradigm to investigate the representation of ethnicity and gender (Ng et al., 2006) in face regions. They found adaptation to ethnicity (as well as gender and identity). However, the regions showing adaptation had a distributed pattern and did not align with traditional face areas.

A number of studies have focussed on the role of the amygdala in the ORE (Cunningham et al., 2004; Phelps et al., 2000; Ronquillo et al., 2007; Sankar et al., 2018). The rationale for the focus on this region is the established role of this region in processing negatively valenced stimuli. Cunningham and colleagues (2004) found greater amygdala response to other-race compared to own-race faces, but only for participants who showed a greater own-race bias. Moreover, this difference in response was only evident when faces were presented for a short duration. Phelps et al., (2000) also found a greater response to other-race faces in the amygdala. The magnitude of this effect correlated with the degree of bias toward the other race. Interestingly, these effects were only evident for unfamiliar faces.

The magnitude of the ORE in the amygdala appears to be sensitive to tasks (Hart et al., 2000; Lieberman et al., 2005). Lieberman et al. (2005) showed that the amygdala showed

a greater response to other-race faces when participants were engaged in a perceptual task, but not when they were engaging in a verbal task. Hart and colleagues (2000) also found no ORE in the amygdala during the first scan of a gender categorization task. However, the ORE did emerge on the second scan, which was interpreted as habituation of the own-race faces. Wheeler and Fiske (2005) also found a higher response to other-race faces in the amygdala, but again only when participants were performing a social categorization task. They found no effect when participants were performing individuation or visual search task. Finally, Van Bavel and Cunningham used a design in which black and white faces were assigned randomly to the in-group or out-group. In this instance, the amygdala did not show a difference in response between black and white faces. However, there was a higher response in the amygdala, fusiform gyri, orbitofrontal cortex and dorsal striatum to in-group faces, irrespective of race.

Despite the fact that a number of studies have shown neural correlates of the ORE, these studies fail to directly address theories of the ORE. For example, do the results from these studies findings support the social cognitive theory or the perceptual experience theory. Understanding how these findings relate to behavioural results and explaining the ORE will be key to a full understanding of the ORE.

1.4 The Aims of this Thesis

The overall aim of this thesis is to investigate how own-race and other-race faces are represented in the brain. A key distinction in theories of the ORE is whether the process involves the enhanced perceptual encoding of own-race faces or social categorization of other-race faces.

The first aim of this thesis will be to establish robust behavioural measures of the ORE.

This will involve developing new tests of face matching and card sorting to determine the magnitude of the ORE using different paradigms across participants (Burton et al., 2010; Jenkins et al., 2011). The results will be used to determine whether individual performance on own-race faces predicts performance on other-race faces for both matching and card sorting. It will also be able to determine if there is any systematic bias in the response to other-race faces (i.e. they all look the same – as shown by more same responses in matching). I will then determine if there is any correlation between individual performance on the matching and card sorting task (i.e. higher performance on the same trials in matching is correlated with fewer piles in card sorting) and whether this is less evident for other-race faces. Finally, I will ask whether performance on card sorting could be explained by similarity in image properties and whether this correlation is less evident for other-race faces. Answers to these questions will help guide whether the ORE will provide useful evidence to address different ORE theories.

The second aim of the thesis will be to investigate the neural basis of the ORE. To address this, three inter-connected experiments will explore the neural correlates of the other-race effect. Experiment 1 will use an adaptation design to test the relative sensitivity to own-race and other-race faces. The principle behind fMRI adaptation is that repetition of a stimulus causes a reduction or habituation in the neural response, which leads to a lower fMRI signal (Grill-Spector & Malach, 2001; Andrews & Ewbank, 2004; Ewbank et al., 2005; Grill-Spector et al., 2006; Andrews et al., 2010, 2016; Psalta et al., 2014). The sensitivity of the neural representation can then be determined for different changes to a stimulus. If the underlying neural representation is less sensitive to a particular type of change in the stimulus (i.e. other-race faces), the release from adaptation of the fMRI signal be smaller than stimuli that the neural representation is more sensitive too (own-race faces). The hypothesis of this

study is that the neural adaptation to faces (different faces > same face) will be greater for own-race compared to other-race faces.

Experiment 2 will explore differences in the neural representation of other-race faces. Studies using MVPA have shown that different faces give rise to distinct spatial patterns of response in face regions. The aim of this experiment is to determine whether there are different patterns of response to faces from different races. That is, the spatial pattern of response to two different faces from the same race is more similar than to faces from a different race. Moreover, we will investigate whether the pattern of response to faces from one race is different if the faces are own-race or other-race.

The third aim of this thesis is to investigate the formation of facial impressions towards different face races in Asian and White participants. This will include an experiment which tests the reliability of trait judgements using a novel paradigm in which participants compared pairs of faces. In this study, participants will be asked to rate which of the two faces is more dominant or trustworthy in different trials. Reliability is measured for each face pair by measuring how often participants chose the same face. It will be possible to ask whether reliability for own-race faces was greater than for other-race faces. A cross-over design will be used to measure the performance of East-Asian and White participants when they view East-Asian, Black and White faces. Given that own-race faces are perceived more accurately than other-race faces and the effect of social categorization, our prediction is that participants should have lower reliability of trait judgements for other-race faces.

Finally, this thesis will establish an image analysis which evaluates differences in the shape and texture of faces from different races. The aim of this analysis was to investigate (1) how shape and texture vary across faces from different races and (2) how this information is used for judgements of face identity. To address this issue, a principal components analysis

will be applied to measure the shape and texture of face images from East Asian, Black and White faces. First, it will determine whether similarity in the shape or texture of images is better able to differentiate faces from different races. Next, I will investigate whether shape and texture information could be used to predict performance in human participants. And then I will ask whether the performance of a computer vision model of face recognition could also be predicted by behavioural responses on the matching task.

The aim of this thesis is to determine whether own-race and other-race faces are processed by different pathways as has been proposed in the social cognitive theory of the ORE. The experiments in my thesis will use large numbers of participants to obtain reliable, and replicable findings and a key feature will be the use of a cross-over design in which both the race of the face images and the race of the participants are varied.

2. COVARIANCE IN THE RECOGNITION OF OWN-RACE AND OTHER-RACE FACES ARGUES AGAINST THE ROLE OF GROUP BIAS IN THE OTHER-RACE EFFECT

2.1 Introduction

The other-race effect is a well-established phenomenon in face perception in which own-race faces are perceived more accurately and more quickly than other-race faces (Malpass and Kravitz, 1969). The ORE has since been demonstrated using a wide range of protocols and cultural settings (Meissner & Brigham, 2001). The majority of studies reporting the ORE have investigated face memory (Cross, Cross, & Daly, 1971; Lindsay, Jack, & Christian 1991; Sporer, 2001; Fu et al., 2012; Stelter & Degner, 2018). However, the ORE is also evident in perceptual tasks, such as matching tasks where participants decide whether a pair of face images is from the same or different identities (Lindsay et al., 1991; Megreya, White and Burton, 2011; Bate et al., 2019; Robertson et al., 2020) or sorting tasks where participants sort face images by identity (Laurence, Zhou and Mondloch, 2016), showing that it must also involve the encoding of faces.

Despite its robustness, the ORE has defied a simple explanation. One theory, founded on social identity theory (Tajfel et al., 1971), suggests that own-race and other-race faces are processed in fundamentally different ways. Own-race faces due to their in-group status are processed at an individual level, whereas other-race faces due to their out-group status are processed at a categorical level (Hugenberg et al., 2010; Rodin, 1987; Rhodes et al., 2009; Sporer, 2001). The perception of own-race and other-race faces is different depending on the outcome of the preceding categorization (MacLin & Malpass, 2001; MacLin, MacLin, Peterson, Chowdhry, & Joshi, 2009). Support for this theory comes from studies that show other-race faces are more efficiently categorized than own-race faces, whereas own-race faces are more

efficiently individuated (Levin, 1996). Another support for a group bias account of the ORE comes from studies that show that group differences that are not based on race can also lead to differences in face recognition similar to the ORE (Bernstein et al., 2007; Harrison, Hole & Habibi, 2020; Hugenberg, Young, Bernstein & Sacco, 2010; Rule et al., 2007, 2010). A prediction from social cognitive accounts of the ORE is that individual performance on own-race faces would not be highly predictive of performance on other-race faces, as they engage different cognitive processes. Moreover, participants should spend more time on tasks with own-race (in-group) faces compared to other-race (out-group) faces.

An alternative theory of the ORE proposes that the same-race advantage results from greater experience with own-race faces (Chiroro & Valentine, 1995; Furl et al., 2002; Goldstein & Chance, 1985; Rhodes et al., 1989; Rossion and Michel, 2011). Because of the higher exposure to own-race faces, the visual system becomes more 'tuned' to differentiate between individual own race compared to individual other-race faces (Kelly et al., 2005; Nelson et al., 2001; Tanaka & Pierce, 2009). The role of experience is shown in developmental studies which show an increase in the ORE with experience (Kelly et al., 2007) and the fact that the ORE can be reversed if one is exposed to another racial group during development (Sangrigoli et al., 2005). Although this theory predicts better performance for own-race compared to other-race faces, the same processes will be used for the recognition of own-race and other-race faces. Given that the same perceptual processes are involved, this theory would predict that individual performance on own-race faces would predict performance on other-race faces.

The aim of this study was to differentiate between these different explanations of the ORE. To do this, we have used an individual differences approach to determine whether performance with own-race faces predicts performance on other-race faces. We used two

different perceptual tasks of face recognition: matching and sorting. By applying these two tasks, we were able to compare different aspects of identity processing. In both tasks, black faces are included as the other-race face for Asian and White participants. We recruited a large population of Asian and White participants and tested them on these tasks with Asian, Black, and White faces. All tasks were self-paced, but we measured the time taken to complete each task. Our prediction from social cognitive theory is that performance on own-race faces would not predict performance on other-race faces. That is, the sensitivity to own-race faces should not correlate with the sensitivity to other-race faces, the pattern of response should be different for own- and other-race faces and participants would take more time with own-race faces.

2.2 Methods

2.2.1 Participants

We recruited an opportunity sample of 140 participants (70 Asian: 59 female, mean age: 24.2 and 70 White: 58 female, mean age: 20.3) for this study. The validity of the sample size was confirmed with G*power software. A total sample size of 100 participants (50 in each group) would be enough to detect the between-group effect with a power of 0.95 at alpha level equals 0.05, 1 non-sphericity and effect size of 0.3 in a 3 (face race) x 2 (participant race) repeated measures ANOVA. All Asian and White participants had grown up in East Asian and Western European countries, respectively. For Asian participants, their average time in the UK period was about 13 months (Mean \pm SEM: 12.9 \pm 2.1). All participants gave their written informed consent. The study was approved by the Psychology Ethics Committee at the University of York. All participants took part in Experiment 1 and 2.

2.2.2 Matching Tasks

There were three face matching tasks that were composed of images from either Asian, Black, or White male faces. Each matching task had 90 trials. In each trial, a pair of face images were presented together (Figure 1). In half of the trials, the faces were from the same identity and in the remaining half of the trials, the faces were from a different identity. The order of tasks was randomized and counterbalanced across all participants. There was no time restriction for each task, but the time spent on each task was recorded (e.g. how long a participant spent on Asian face matching task in seconds).

The White matching task used an existing test (Dowsett & Burton, 2015). To be consistent with this existing test, male faces were used for other tests. The images for the Asian and Black matching tasks were taken from a variety of websites for professional models. The images were cropped to display the face only. Images were selected which were free of occlusions, and showed front facing views. The images were cropped to 158 x 222 pixels. Participants viewed images at a distance of approximately 57 cm, such that each image subtended 7.8 x 10.2 degrees of visual angle. Participants were asked to indicate whether each pair of faces was from the same identity or a different identity. The task was self-paced, but the time spent on each task was recorded. We measured sensitivity (d') (Horry, Cheong & Brewer, 2015), by calculating hits (trial: same identity, response: same), misses (trial: same identity, response: different), false positives (trial: different identity, response: same) and correct rejections (trial: different identity, response: different). To further explore the pattern of performance for the two race groups in matching tasks, performance on same-identity and different-identity faces were determined separately for each task and participant group.

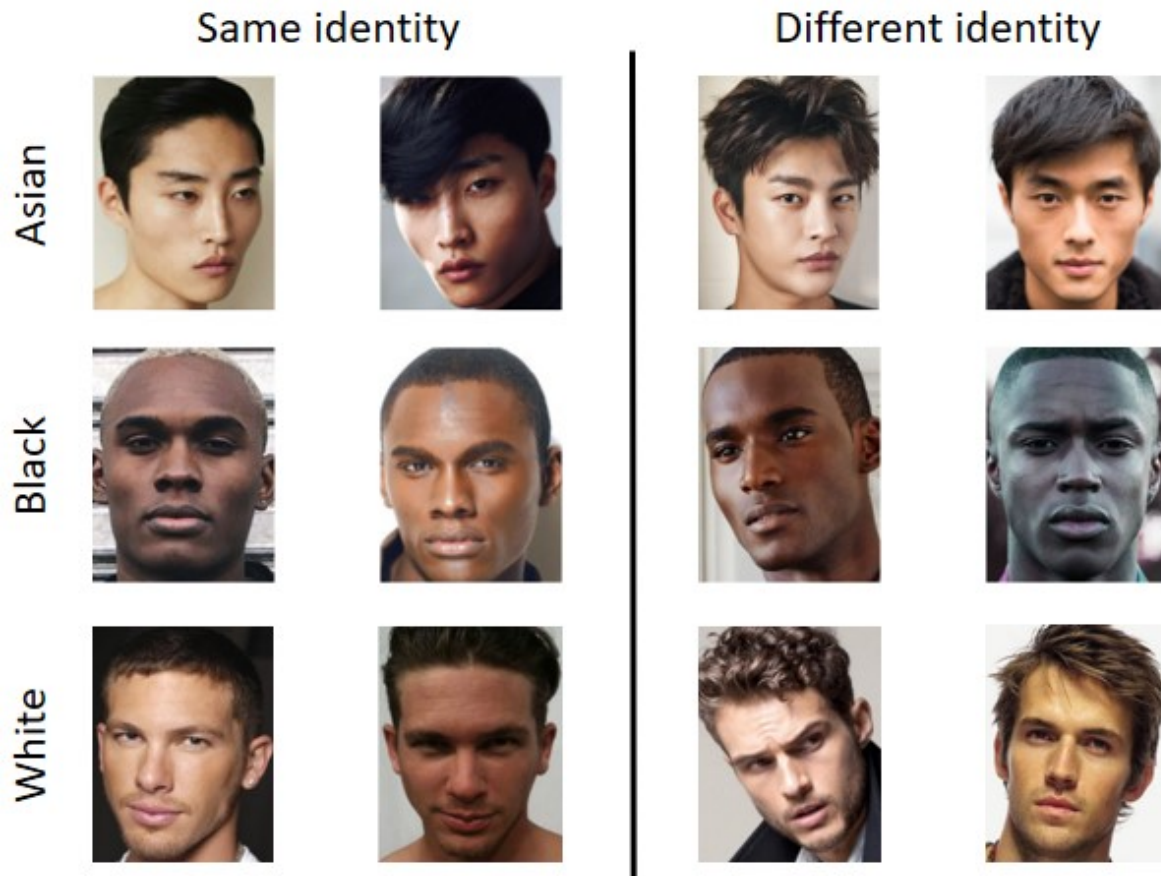


Figure 2.1 Examples of same identity and different identity trials from the Asian, Black and White matching tasks. Pairs of images were presented at the same time and participants were instructed to indicate if they were from the same or a different identity.

2.2.3 Sorting Tasks

There were three sorting tasks with images of either Asian, Black or White male faces. Each task had 20 images with 10 images from one identity and 10 images from a different identity. Images were cropped to a size of 158 x 222 pixels, printed in grayscale to a size of 7.3 x 5.6 cm, and then laminated (Figure 2). For each sorting task, participants were given a shuffled stack of the 20 face images. They were instructed to sort the faces into piles that had the same identity. The dependent measures were the number of piles and the number of errors (more than one identity in a pile). There was no time restriction for each task, but the time

spent on each task was recorded (e.g. how long a participant spent on Asian card sorting task in seconds).



Figure 2.2 Images from the Asian, Black, and White sorting tasks. Participants were instructed to sort the images into piles based on identity.

2.3 RESULTS

2.3.1 Matching Task Results

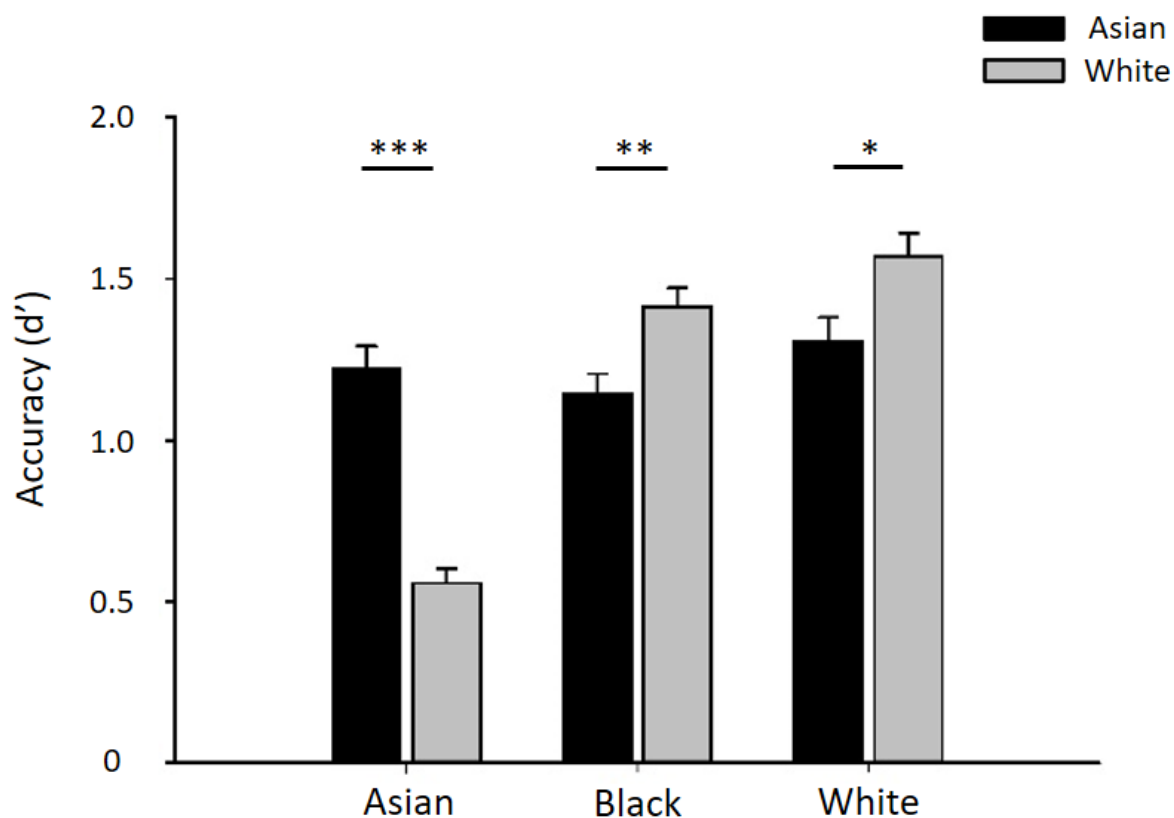


Figure 2.3 Performance (d') on the matching task with Asian and White participants viewing Asian, Black and White faces. The data show a clear ORE with higher performance on own-race compared to other-race faces. Error bars show +1 SEM. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Fig. 2.3 shows the average performance of Asian and White participants in the matching tasks. There was a significant interaction between stimulus race and participant race ($F(2, 276) = 75.135$, $p < .001$, Partial Eta Squared = .35). There is also a significant effect of Stimulus Race ($F(2, 276) = 83.205$, $p < .001$, Partial Eta Squared = .38). This was due to significantly different performance across the different face race tasks in Asian and White participants. For the Asian face matching task, there was a significantly higher d' in Asian participants compared to White participants ($t(69) = 7.81$, $p < .001$, $d = 1.36$). However, on the White face matching task, there was a significantly higher d' for White participants compared to Asian participants ($t(69) =$

3.15, $p < .01$, $d = .52$). For Black faces, White participants had a significantly higher d' compared to Asian participants ($t(69) = 2.81$, $p < .01$, $d = .50$). The higher recognition of Asian faces in Asian participants and White faces in White participants provides clear evidence of an ORE. Interestingly, we also found that there was a negative correlation in Asian participants between the difference in d' for Asian faces compared to White faces with the time spent in the UK ($r = -.297$, $p = .012$). That is the ORE was lower in participants who had spent more time in the UK.

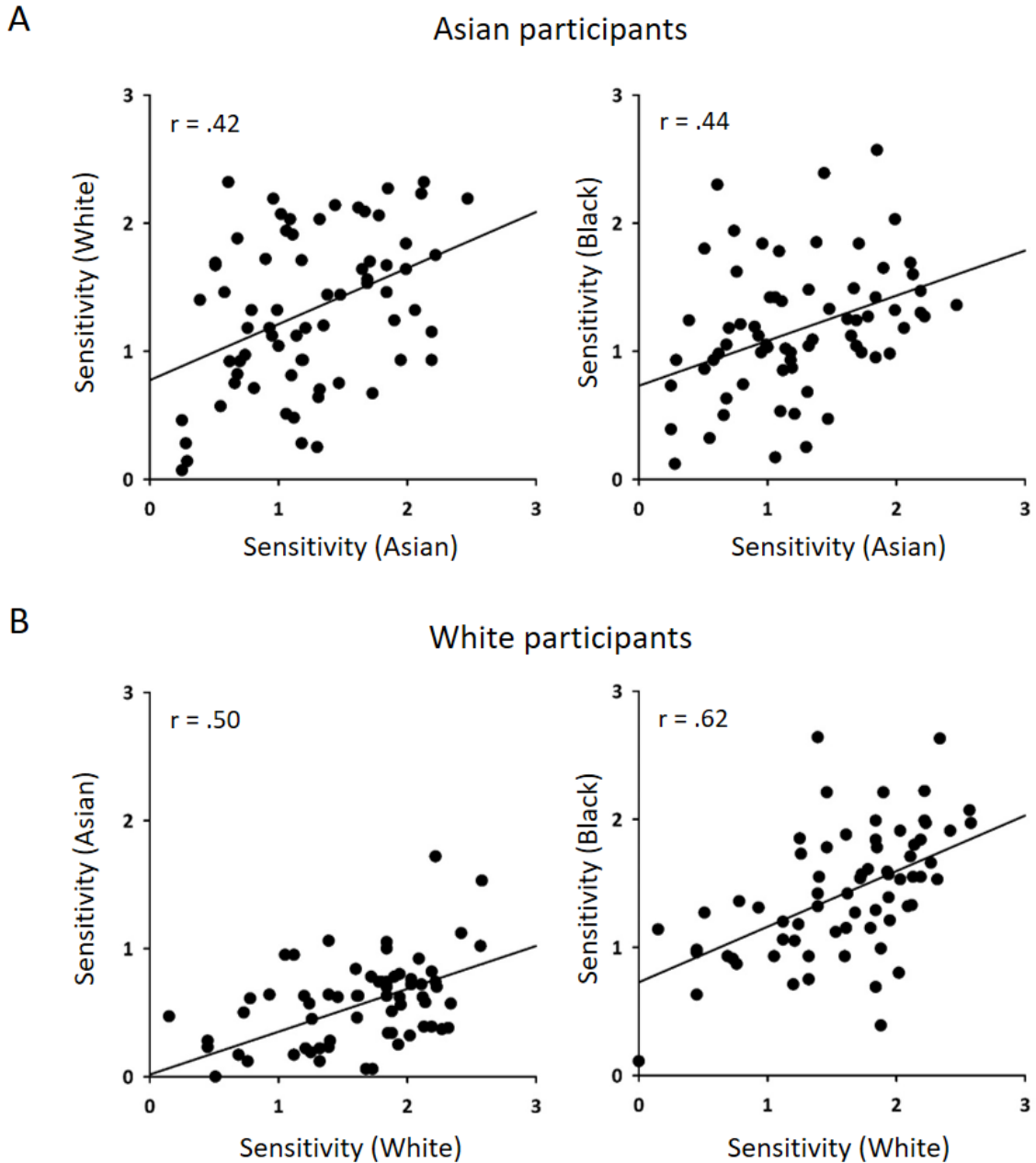


Figure 2.4 Correlation between d' values between different face matching tasks in Asian and White participants. Significant positive correlations were found for each matching task for both own-race and other-race faces suggesting that performance on own-race faces predicted performance on other-race faces.

Next, we used an individual differences approach to determine whether performance on own-race faces predicted performance on other-race faces. We found performance on own-race faces was positively correlated with other-race faces (Figure 2.4). For Asian participants, accuracy on Asian face matching was positively correlated with accuracy on Caucasian ($r_s =$

.421, $p < .001$) and Afro-Caribbean ($r_s = .440$, $p < .001$) face matching. For Caucasian participants, d' value of Caucasian face matching was positively correlated with Asian ($r_s = .499$, $p < .001$) and Afro-Caribbean ($r_s = .617$, $p < .001$) faces. This suggests that performance on own-race faces predicts better performance on other-race faces.

The d' analysis combines performance on same and different identity trials. In the next analysis, we asked if the ORE was evident for performance on both same identity trials ('putting faces together') and different identity trials ('telling faces apart') independently. To determine if there was any bias in the pattern of response on the same and the different trials, we measured the proportion of Same and Different answers that our participants regardless of accuracy. Asian and White participants gave a similar proportion of same responses (Asian faces: Asian = 46.7%, White = 47.4%; Black faces: Asian = 46.1%, White = 45.0%; White faces: Asian = 46.5%; White = 47.0%). Next, an ANOVA with Face Race (Asian, Black, White) and Participant Race (Asian, White) as factors was run separately for accuracy on the same identity and different identity tasks. There was a significant interaction of Face Race * Participant Race for both same identity ($F(2, 276) = 34.59$, $p < .001$, Partial Eta Squared = .20) and different identity ($F(2, 276) = 42.28$, $p < .001$, Partial Eta Squared = .23) faces. There were also significant main effect of stimulus for both same identity ($F(2, 276) = 34.08$, $p < .001$, Partial Eta Squared = .198) and different identity ($F(2, 276) = 43.257$, $p < .001$, Partial Eta Squared = .241) trials. For Asian faces, the accuracy of Asian participants was greater than for White participants with both same identity ((Asian mean: .68, White mean = .58; $t(138) = 5.02$, $p < .001$, $d = .85$) and different identity (Asian mean = .75, White mean = .63; $t(138) = 4.88$, $p < .001$, $d = .83$) face trials. For White faces, accuracy was higher for White compared to Asian participants on both same identity (White mean = .74, Asian mean = .69; $t(138) = 1.89$, $p = .061$, $d = .32$) and different identity (White mean = .79: Asian mean = .75; $t(138) =$

1.79, $p = .075$, $d = .30$) face trials, but this failed to reach significance. For Black faces, although there was no significant difference in accuracy for Asian and White participants for the same identity trials (Asian mean = .66, White mean = .69; $t(138) = 1.50$, $p = 0.14$, $d = .25$), but there was a significant difference on different identity trials (Asian mean = .76, White mean = .79; $t(138) = 2.23$, $p < 0.05$, $d = .38$). Together, these results show that performance on both same identity and different identity trials is biased toward own-race faces. However, similar to the d' analysis (see Fig. 2.4), performance on own-race faces predicted performance on other-race faces for both same-identity and different identity trials (Table 2.1).

Table 2.1 Correlation between Face Race for Asian and White participants in Same identity and Different identity trials

		<i>Same Identity</i>		<i>Different Identity</i>	
		r_s	p	r_s	p
Asian participants	<i>Asian / Black</i>	.514	.0001	.566	.0001
	<i>Asian / White</i>	.515	.0001	.571	.0001
	<i>Black / White</i>	.636	.0001	.554	.0001
White participants	<i>Asian / Black</i>	.665	.0001	.651	.0001
	<i>Asian / White</i>	.689	.0001	.641	.0001
	<i>Black / White</i>	.697	.0001	.663	.0001

We then asked whether ability on same-identity ('putting faces together') is correlated with ability on different-identity trials ('telling faces apart'). If performance on these measures are related, we would expect a significant positive correlation. For Asian participants, there was no significant correlation between same-identity and different-identity trials for Asian faces ($r_s = -.023$, $p = .852$). The correlation between performance on same and different trials for White faces was marginal ($r_s = -.207$, $p = .086$), but there was a significant negative

correlation for Black faces ($r_s = -.329$, $p < .01$). For White participants, there was no significant correlation between same-identity and different-identity trials for White faces ($r_s = -.095$, $p = .432$). However, there were significant negative correlations in performance for same and different identity trials with Asian faces ($r_s = -.445$, $p < .001$) and Black faces ($r_s = -.291$, $p < .05$). Together, these findings that there is no reliable covariation between performance on same-identity and different-identity trials in the matching task.

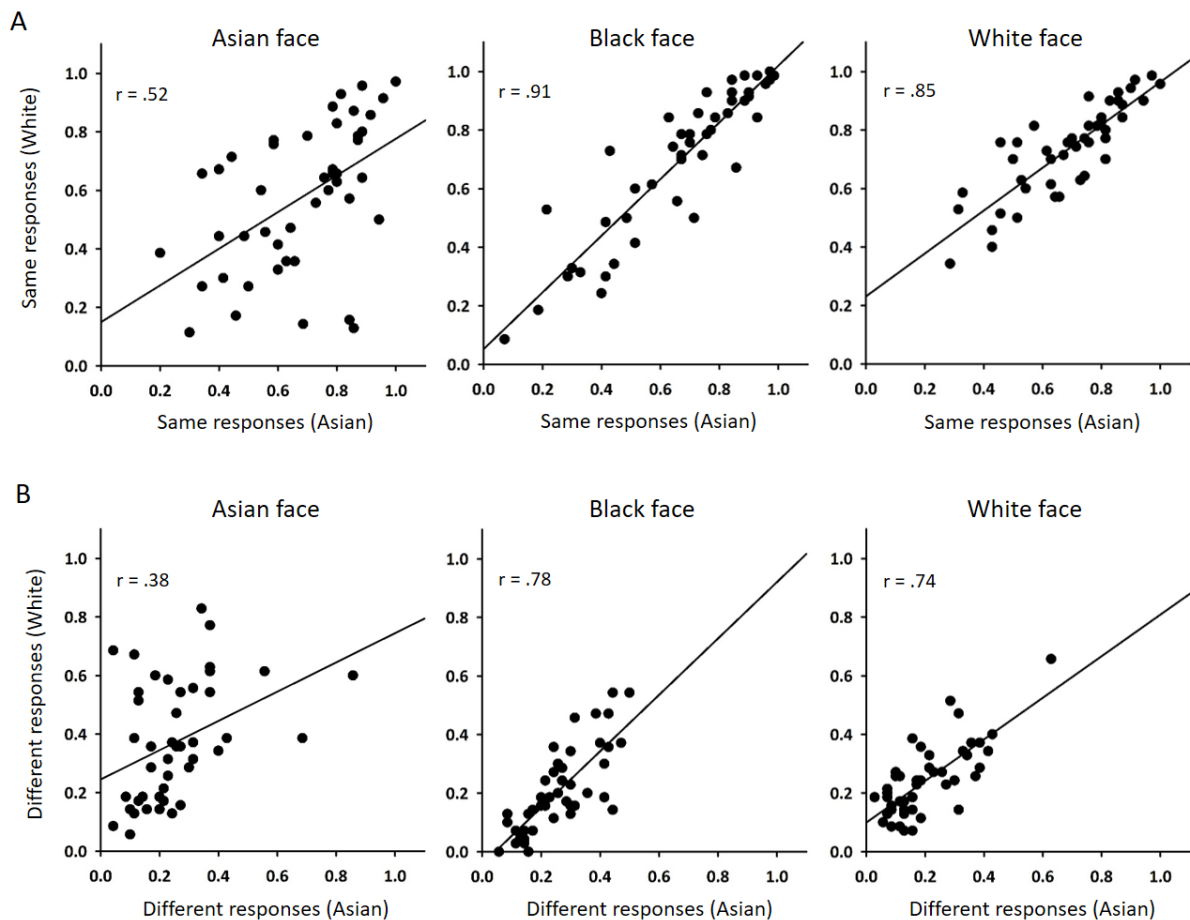


Figure 2.5 A comparison of an item-analysis across the two participant groups on (A) same identity and (B) different identity trials. Significant positive correlations show that Asian and White participants from different ethnicity made qualitatively similar responses on all matching tasks.

To determine whether there were differences in the way that individual trials were perceived by participants from different races, we performed an item-level analysis. We calculated the proportion of correct responses for each trial across Asian or White

participants. This gave a vector of 45 values for the same-identity trials and a vector of 45 values for the different-identity trials for each task in each participant group. We then correlated these vectors for Asian and White participants (Fig. 2.5). For the same-identity trials, Asian and White participants had positive correlations across all tasks (Asian: $r_s = .515$, $p < .001$; Black: $r_s = .909$, $p < .001$; White: $r_s = .844$, $p < .001$). For the different-identity trials, Asian and White participants also had positive correlations across all tasks (Asian: $r_s = .384$, $p < .01$; Black: $r_s = .776$, $p < .001$; White: $r_s = .735$, $p < .001$). This shows that the pattern of response across trials is similar in participants from different races.

Finally, we determined whether the ORE could be explained by participants spending more time on own-race face tasks. Fig 2.6 shows the time spent on the face matching tasks. There was no significant interaction between Stimulus Race and Participant Race ($F(2, 276) = 2.488$, $p = .085$, Partial Eta Squared = .18). For Asian participants, task time on Asian face trials was significantly less than for White face trials ($t(69) = -2.43$, $p < .05$, $d = .21$), but there was no significant difference with Black face trials ($t(69) = -1.59$, $p = .117$, $d = .118$). There was no significant difference between task time for Black and White face trials ($t(69) = -0.99$, $p = .324$, $d = .086$). For White participants, the task time for White face trials was not significantly different compared to Asian face trials ($t(69) = 0.29$, $p = .772$, $d = .020$), but was significantly higher for Black face trials ($t(69) = 2.358$, $p < .05$, $d = .115$). There was no significant difference between tasks times of Asian and Black ($t(69) = 1.34$, $p = .174$, $d = .103$) faces. There was also no difference task time for Black faces between Asian and White participants ($t(69) = -.936$, $p = .352$, $d = .135$). Overall, there does not seem to be any consistent evidence that participants spent more time on own-race compared to other-race faces.

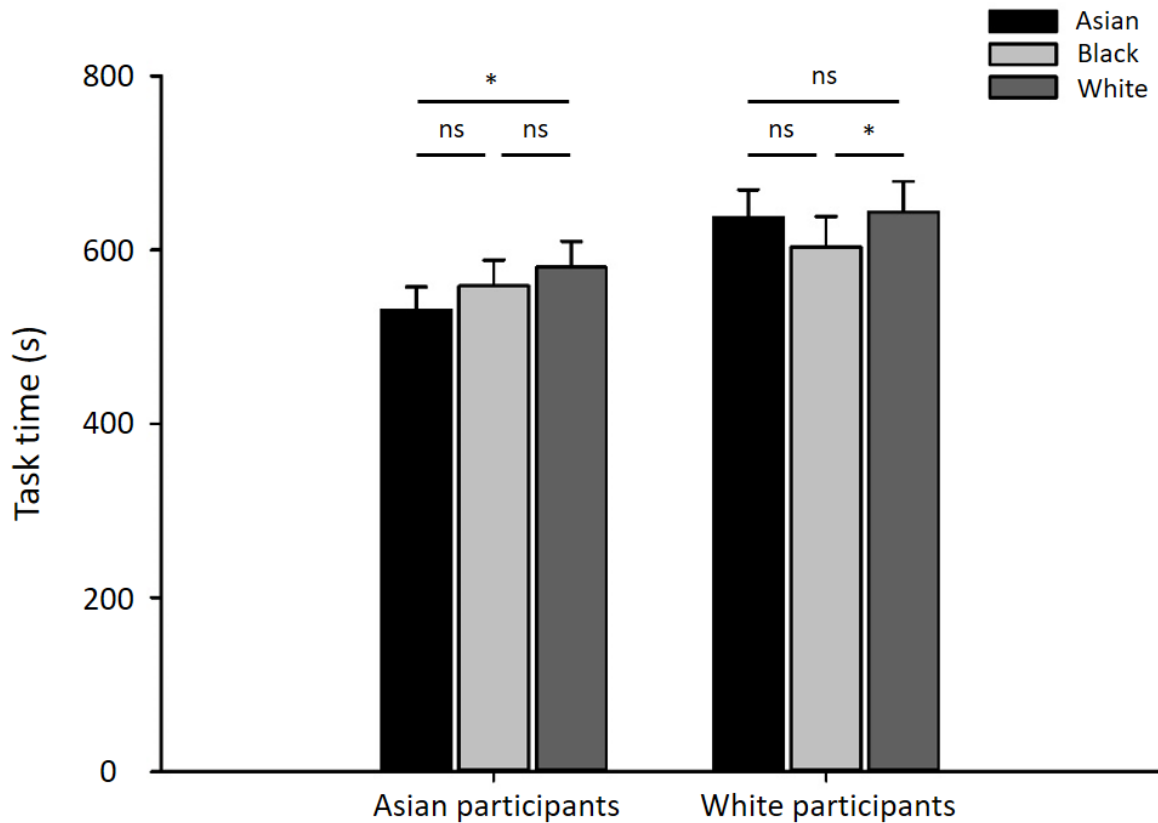


Figure 2.6 Task time for all matching tasks. There was no consistent evidence that participants spent more time on own-race faces compared to other-race faces. Error bars show +1 SEM. * $p < 0.05$.

2.3.2 Sorting Task Results

Fig. 2.7 shows mean performance on the sorting task for Asian and White participants. There was a clear ORE for both participant groups. For pile number, there was a significant interaction between stimulus race and participant race ($F(2, 276) = 27.977, p < .001$, Partial Eta Squared = .168). There is also a significant effect of Stimulus Race ($F(2, 276) = 10.657, p < .001$, Partial Eta Squared = .071). Asian participants generated fewer piles with Asian faces (mean \pm SEM: 5.3 ± 0.3) compared to White (mean \pm SEM: 6.5 ± 0.3 ; $t(69) = -4.03, p < .001, d = -.48$) and Black (mean \pm SEM: 7.5 ± 0.4 ; $t(69) = -6.33, p < .001, d = -.76$) faces. For wrong piles, there was a significant interaction between stimulus race and participant race ($F(2, 276) = 18.069, p < .001$, Partial Eta Squared = .116). However, there is no significant effect of Stimulus Race ($F(2, 276) = 2.650, p = .072$, Partial Eta Squared = .019). Asian participants also

made fewer errors with Asian faces (mean \pm SEM: 1.0 ± 0.1) compared to White (mean \pm SEM: 1.4 ± 0.2 ; $t(69) = -2.532$, $p < .05$, $d = -.30$) and Black (mean \pm SEM: 1.6 ± 0.1 ; $t(69) = -4.14$, $p < .001$, $d = -.50$) faces. Similarly, White participants generated fewer piles with White faces (mean \pm SEM: 5.8 ± 0.3) compared to Asian faces (mean \pm SEM: 7.5 ± 0.3 ; $t(69) = -5.24$, $p < .001$, $d = -.63$) and Black faces (mean \pm SEM: 6.8 ± 0.4 ; $t(69) = -3.07$, $p < .01$, $d = -.37$). White participants also made fewer errors with White faces (mean \pm SEM: 0.9 ± 0.1) compared to Asian faces (mean \pm SEM: 1.9 ± 0.2 ; $t(69) = -5.94$, $p < .001$, $d = -.71$) and Black faces (mean \pm SEM: 1.2 ± 0.2 ; $t(69) = -1.89$, $p = .062$, $d = -.23$)

Next, we asked if time in the UK could explain the size of the ORE in Asian participants. We found that there was no significant correlation in Asian participants between the time spent in the UK and the difference in pile number ($r = -.014$, $p = .907$) or errors ($r = .093$, $p = .444$) between Asian and White faces.

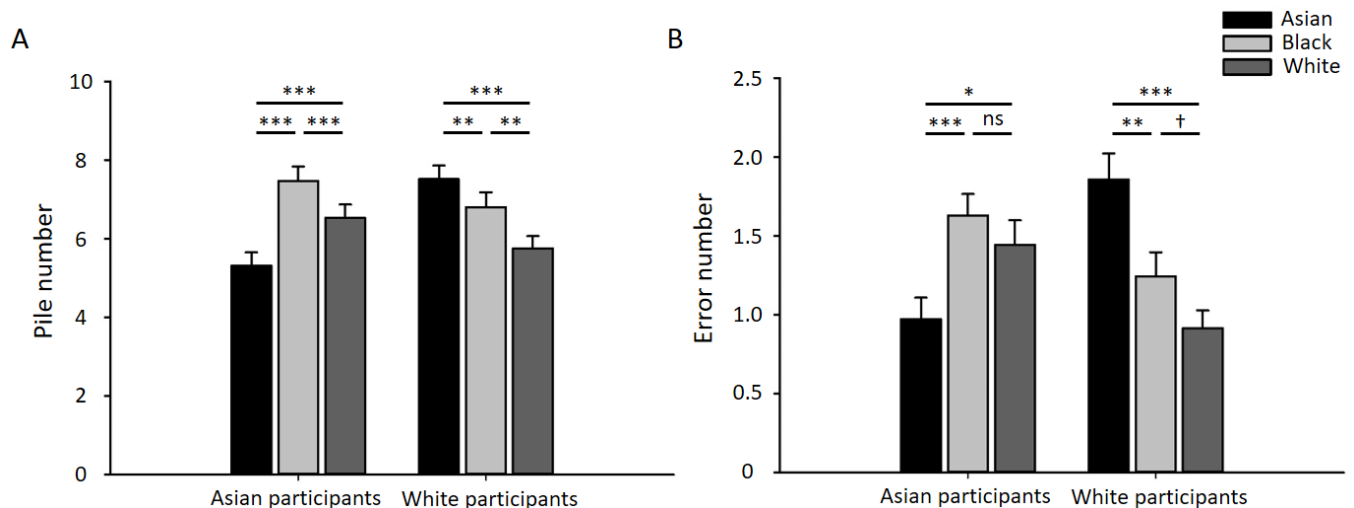


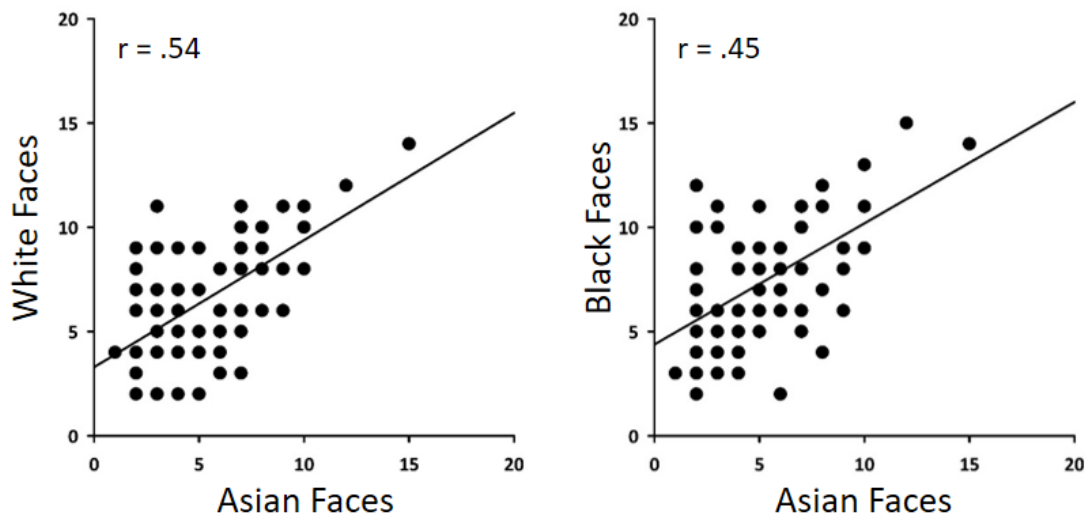
Figure 2.7 Performance on sorting task. Average pile number and Average wrong pile number made by Asian and White participant in Card sorting test. Error bars show +1 SEM. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, †, 0.01.

Next, we compared individual differences on the different sorting tasks to determine whether performance with own-race faces predicted performance with other-race faces. We found performance on own-race faces was positively correlated with other-race faces (Figure

9). For Asian participants, performance with Asian faces was positively correlated with White (pile: $r_s = .54$, $p < .001$; error: $r_s = .18$, $p = .139$) and Black (pile: $r_s = .45$, $p < .001$; error: $r_s = .20$, $p = .106$) faces. For White participants, performance with White faces was positively correlated with Asian (pile: $r_s = .51$, $p < .001$; error: $r_s = .42$, $p < .001$) and Black (pile: $r_s = .52$, $p < .001$; error: $r_s = .18$, $p = .138$) faces. This suggests that performance on own-race faces predicts better performance on other-race faces.

A

Asian participants



B

White participants

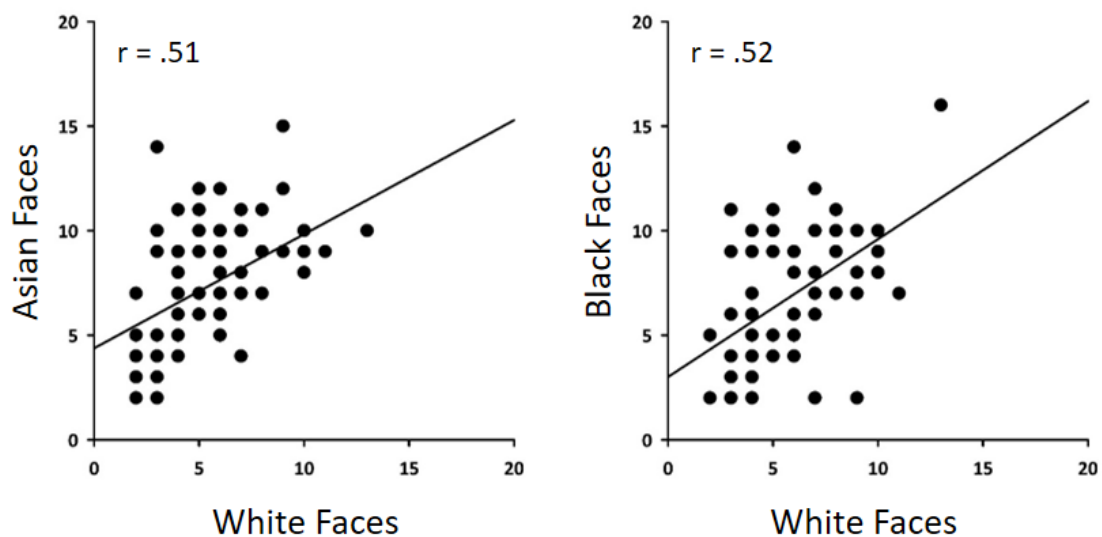


Figure 2.8 *Correlation between pile numbers across different card sorting tasks in Asian and White participants. Significant positive correlations were found for each sorting task for both own-race and other-race faces suggesting that performance on own-race faces predicted performance on other-race faces.*

We then asked whether performance on ‘putting faces together’ (pile number) is correlated with performance on ‘telling faces apart’ (error number). If performance on these measures is related, we would expect a significant positive correlation. For Asian participants, there was a significant positive correlation between pile number and errors for Asian faces ($r_s = .285$, $p < .05$). However, there was significant negative correlation between these two measures for Black faces ($r_s = -.256$, $p < .05$) and no significant correlation for White faces ($r_s = .021$, $p = .856$). For White participants, there was no significant correlation between pile number and errors for White faces ($r_s = -.152$, $p = .209$) and Black faces ($r_s = -.044$, $p = .717$), but there was a significant negative correlation for Asian faces ($r_s = -.300$, $p < .05$). Overall, there did not seem to be any consistent relationship between the ability to put faces together and the ability to tell faces apart.

In our next analysis of the sorting tasks, we compared the way in which the participants sorted individual items on the own-race and other-race face tasks. Fig. 9A shows the probability that each pair of images was sorted into the same pile. Participants typically sorted images into piles with the same identity, consistent with the low number of errors shown in Fig. 2.8. For Asian participants, the probability that two images with the same identity were placed in the same pile was significantly higher than the probability of two images from a different identity being placed in the same pile with Asian faces (within-person: 0.50 ± 0.013 ; between-person: 0.06 ± 0.004 ; $t(106.8) = -33.2$, $p < .001$), Black faces (within-person: 0.26 ± 0.012 ; between-person: 0.06 ± 0.004 ; $t(107.8) = -16.0$, $p < .001$) and White

faces (within-person: 0.32 ± 0.014 ; between-person: 0.07 ± 0.004 ; $t(105.6) = -17.7$, $p < .001$). Similarly, for White participants, the probability that two images with the same identity were placed in the same pile was significantly higher than for two images from a different identity with White faces (within-person: 0.41 ± 0.018 ; between-person: 0.07 ± 0.004 ; $t(97.6) = -18.8$, $p < .001$), Asian faces, (within-person: 0.22 ± 0.015 ; between-person: 0.07 ± 0.007 ; $t(131.5) = -9.9$, $p < .001$) with Black faces (within-person: 0.34 ± 0.011 ; between-person: 0.04 ± 0.004 ; $t(110.4) = -24.6$, $P < .001$).

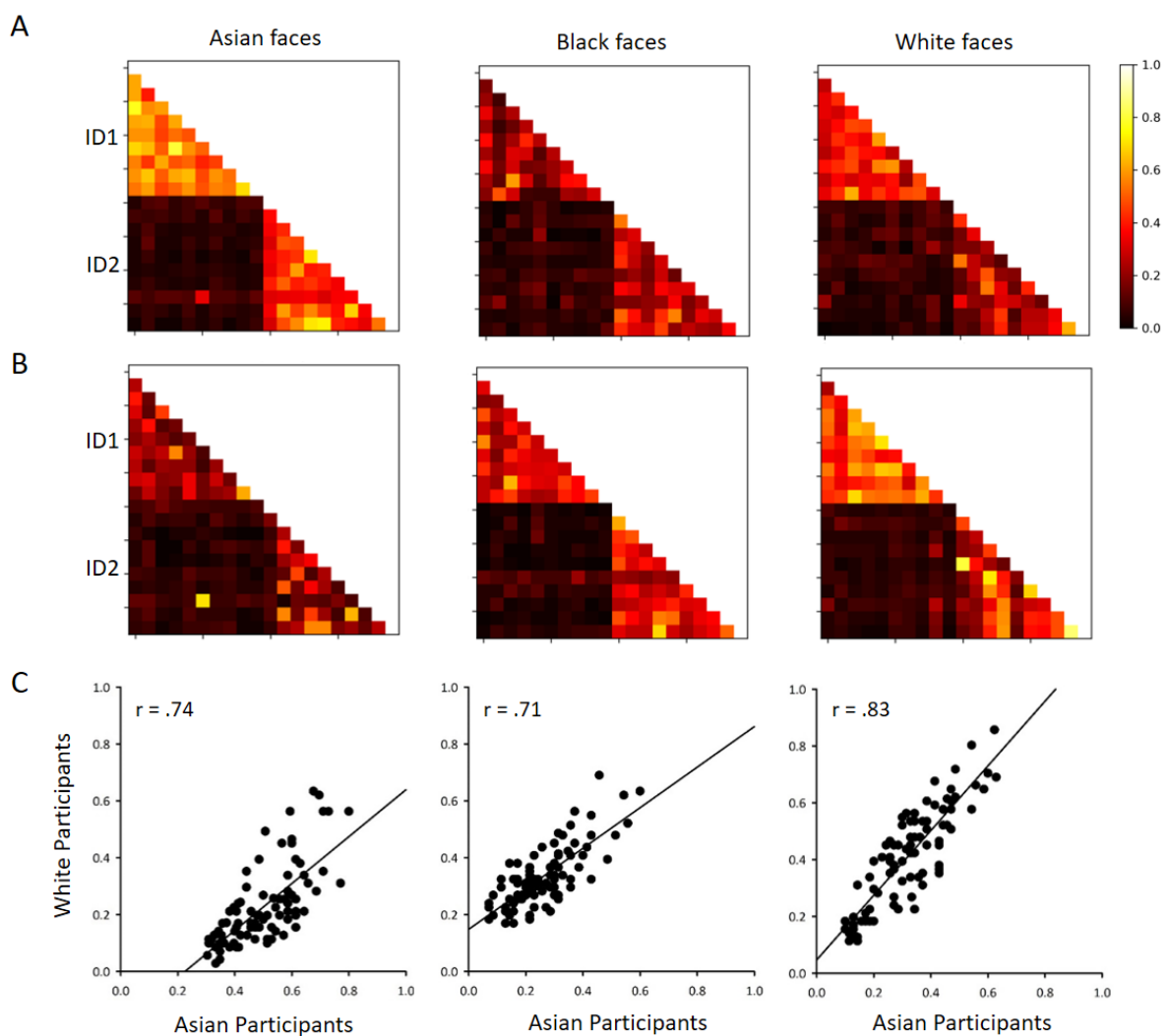


Figure 2.9 The probability of images being sorted into *the* same pile on each sorting task for (A) Asian and (B) White participants. (C) Correlation of the probability of images being sorted into *the* same pile for within identity images between Asian and White participants.

To determine whether the pattern of sorting was consistent across the two participant groups, we measured the similarity of the sorting matrices in Figure 2.9 A and B for the Asian and White participants. This was performed separately for within-identity and between-identity matches. The pattern of sorting between Asian and White participants was highly correlated for same-identity faces in all three tasks (Asian: $r_s = .738$, $p < .0001$; Black: $r_s = .710$, $p < .0001$; White: $r_s = .826$, $p < .0001$). Significant correlations were also evident for between-identity correlations (Asian: $r_s = .542$, $p < .0001$; Black: $r_s = .488$, $p < .0001$; White: $r_s = .294$, $p < .01$). This shows that participants from both races sorted the faces in a similar way.

Finally, we compared the time spent on each sorting task (Fig. 2.10). There was a significant interaction between stimulus race and participant race ($F(2, 276) = 12.414$, $p = .001$, Partial Eta Squared = .053). For Asian participants, task time with Asian faces was significantly lower than with both Black ($t(69) = -5.17$, $p < .001$, $d = .642$) and White ($t(69) = -2.43$, $p < .001$, $d = .478$) faces. There was no significant difference between time spent with Black and White faces ($t(69) = -0.99$, $p = .324$, $d = .086$). For White participants, task time with White faces was not significantly different to Asian faces ($t(69) = -1.24$, $p = .219$, $d = .161$), but was longer than with Black faces ($t(69) = -3.65$, $p < .01$, $d = .300$). There was no significant difference between task time with Asian and Black faces ($t(69) = -1.54$, $p = .129$, $d = .176$). There was also no difference in task time for Black faces between Asian and White participants ($t(69) = .421$, $p = .675$, $d = .075$). Overall, there was no evidence that participants spent more time on own-race compared to other-race faces.

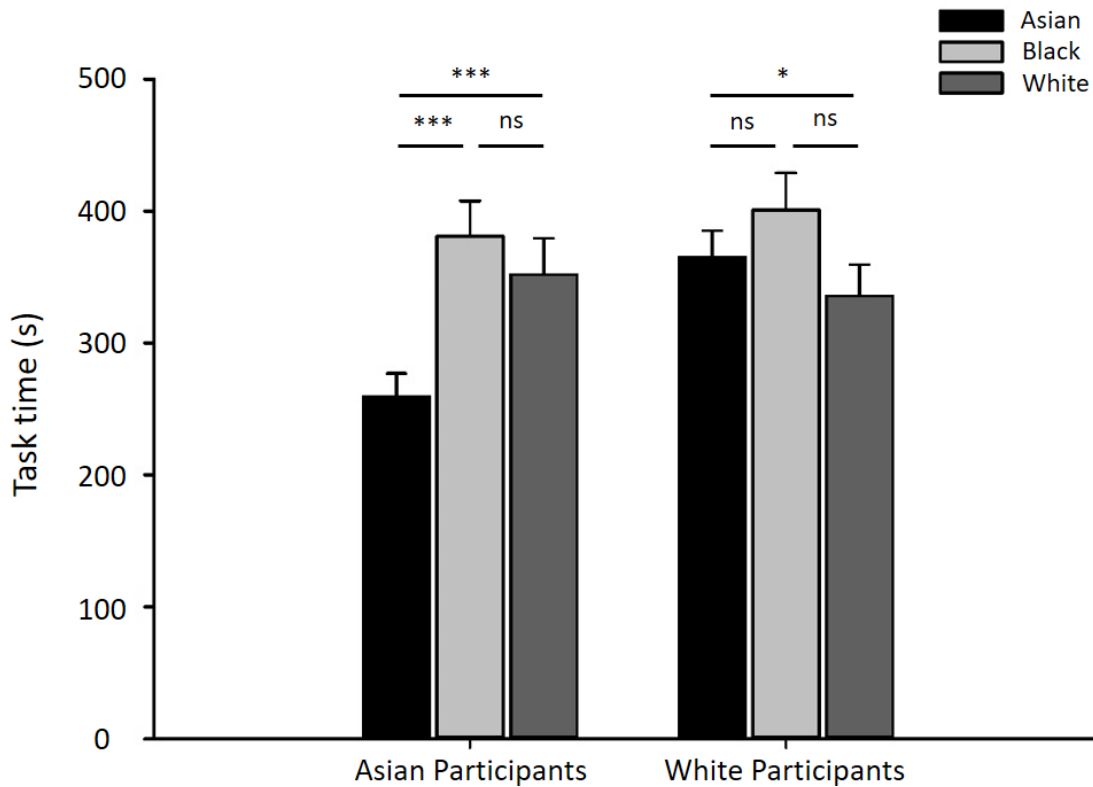


Figure 2.10 Task time of sorting tasks. There was no evidence that participants spent more time on own-race faces. Error bars show +1 SEM. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, †, 0.01.

2.3.3 Comparison of face matching and card sorting tasks

Next, we measured the covariation across behavioral measures in the matching and sorting tasks. Beginning with measures of ‘putting faces together’, we compared same-identity performance on the matching task with numbers of piles on the sorting task. Our prediction was that this should be negatively correlated if these measures are related. In other words, higher accuracy in judging whether two face images from the same identity are the same person in the matching task should be linked to a greater ability to group faces in the sorting task. For Asian participants, there was a significant negative correlation for Asian faces ($r_s = -.520$, $p < .001$). This correlation was smaller for Black faces ($r_s = -.272$, $p < .05$) and not significant for White faces ($r_s = -.158$, $p = .191$). For White participants, there was a significant negative correlation for White faces ($r_s = -.289$, $p < .05$), but also for Asian ($r_s = -.442$, $p < .001$)

and Black ($r_s = -.339$, $p < .01$) faces. Overall, this provides evidence that the ability to put faces together covaries across these two tasks.

To determine covariation in the ability to 'tell faces apart', we compared performance on the different-identity trials of the matching tasks with the numbers of errors on the sorting task. Again, if these measures were related, a negative correlation is predicted. In other words, if participants are more accurate in determining that two faces from different identities are different in the matching task, they should make fewer errors in the sorting task. For Asian participants, there was a significant negative correlation for Asian faces ($r_s = -.296$, $p < .05$), but also for Black ($r_s = -.313$, $p < .01$) and White ($r_s = -.251$, $p < .05$) faces. For White participants, there was a significant negative correlation for White faces ($r_s = -.257$, $p < .05$). There was also a significant negative correlation for Asian ($r_s = -.286$, $p < .05$), but not for Black ($r_s = -.019$, $p = .877$) faces. Overall, this shows evidence for covariance in the ability to tell faces apart across the two tasks.

Finally, we asked whether performance on the different measures of putting faces together or telling them apart could be predicted by the time participants spent on each task. On the matching task, there were no significant correlations between time and different identity trials with Asian participants (Asian: $r = -.013$, $p = .913$; Black: $r = .187$, $p = .120$, White: $r = .186$, $p = .124$) or White participants (Asian: $r = .031$, $p = .796$; Black: $r = .010$, $p = .932$, White: $r = -.030$, $p = .808$). There was no consistent relationship between time and accuracy on same identity trials for Asian participants (Asian: $r = .056$, $p = .644$; Black: $r = .275$, $p = .021$, White: $r = .161$, $p = .183$) or White participants (Asian: $r = .492$, $p < .001$; Black: $r = .239$, $p = .046$, White: $r = .332$, $p = .005$). On the sorting task, there were no significant correlations between time and errors with Asian participants (Asian: $r = .095$, $p = .433$; Black: $r = -.037$, $p = .762$, White: $r = -.009$, $p = .942$) or White participants (Asian: $r = -.154$, $p = .204$; Black: $r = -$

.138, $p = .254$, White: $r = -.016$, $p = .898$). There was also no consistent relationship between time and the number of piles for Asian participants (Asian: $r = .292$, $p = .014$; Black: $r = -.083$, $p = .495$, White: $r = -.081$, $p = .503$) or White participants (Asian: $r = -.245$, $p = .041$; Black: $r = .128$, $p = .292$, White: $r = .172$, $p = .153$). In sum, the ability of “putting face together” and “telling face apart” across two behavioural tasks did not correlate reliably with the time spent on each task.

2.4 Discussion

Our results provide clear evidence for the ORE on two tasks of face recognition: matching and sorting. We found that Asian participants performed better on Asian faces compared to White participants, whereas White participants performed better on White faces compared to Asian participants. Despite clear evidence for an ORE, we found that overall performance on own-race faces significantly predicted overall performance on other-race faces in both the matching and sorting tasks. That is, more accurate performance on own-race faces predicted more accurate performance on other-race faces. We found a similar covariation in performance between participants from different races in an item analysis. For example, trials on a matching task (irrespective of face race) that were found to be difficult for Asian participants were also found to be difficult for White participants, whereas trials that were easier for Asian participants were also easier for White participants. For the sorting task, we found that the pattern of sorting was very similar for participants from different races, irrespective of the face race. That is, faces that were more often put in the same pile by White participants were also more likely to be put in the same pile by Asian participants. Together, these findings show a strong covariance in performance across individuals from different races on own-race and other-race faces.

A dominant theory of the ORE proposes that other-race faces are processed in qualitatively different ways (Hugenberg et al., 2010; Rodin, 1987; Sporer, 2001). Own-race faces due to their in-group status are processed at an individual level, whereas other-race faces due to their out-group status are processed at a more categorical level (Levin, 1996; MaLin & Malpass, 2001). Thus, the perception of own-race and other-race faces is different depending on the outcome of the preceding racial categorization. Our results showing the covariation in performance with own-race and other-race faces demonstrates that the same perceptual processes are used for all face tasks, regardless of race. This argues against the idea that qualitatively different processes (e.g. categorization vs individuation) explain the ORE. All the tasks in this study were self-paced. This allowed us to ask whether participants spent more time on own-race faces. A prediction from social group theories of the ORE suggests that other-race faces are processed with lower levels of attention and motivation compared to own-race faces. However, we found no consistent evidence for participants spending more time on own-race faces. In fact, our results on the time spent for each task show a tendency to spend more time on other-race faces. Taken together, the covariation in performance on tasks involving own-race and other-race and the lack of any bias in task time for own-race faces suggests, the ORE that is clearly shown in this study cannot be accounted for by group-bias and differences in perceptual processing.

An alternative theory of the ORE is that it is based on differential exposure to same-race and other-race faces (Chiroro & Valentine, 1995; Furl et al., 2002; Goldstein & Chance, 1985; Rhodes et al., 1989; Rossion and Michel, 2011; Sangrigoli et al., 2005). This leads to recognition being optimized for processing variance in own-race faces. Nevertheless, the same perceptual mechanisms are used to perceive own-race and other-race faces, it is just more tuned to own-race faces. This suggests that a similar type of processing is used to

perceive faces regardless of race. A strong prediction is that individual performance on own-race and other-race faces should covary. Our results provide support for this prediction. Another prediction from this theory is that the ORE should vary as a function of exposure to other-race faces. We found a negative correlation between the duration that Asian participants were in the UK and the difference in performance on own-race and other-race faces in the matching task, but not in the sorting task. Although this provides support for the role of perceptual experience, this does not rule out the possibility of some role for group-bias in natural viewing. For example, a reduced motivation to interact with individuals from an out-group (such as people from a different race) could result in reduced perceptual experience (Chiroro and Valentine, 1995). This would then cause differences in experience that give rise to the perceptual differences reported here and in previous studies of recognition.

In this study, we had tasks that involved Asian and White faces that were performed by Asian and White participants. This part of the design is critical in studies of the ORE in order to show a cross-over interaction. This is important to rule out the possibility of the potential confound of differences in task difficulty. However, we also included in our design Black faces that were other-race for both Asian and White participants. Across the two tasks, performance on Black faces was higher for White compared to Asian participants. One possible explanation for this finding is the higher proportion of the population who are Black in the UK compared to in China (ONS, 2011; Castillo, 2013). This could also be related to different levels of group bias as a result of limited interactions. However, if this were the case then we would expect that Asian participants should spend less time on the Black face tasks compared to White participants and there is no evidence for any difference in task time.

Rather, it would seem that the difference between Asian and White participants with Black faces may reflect differences in perceptual experience.

Another example of the role of perceptual experience in face perception is shown by the effect of familiarity. The distinction between often seen familiar faces and unfamiliar faces that have not been previously encountered is central to our understanding of face recognition (Bruce & Young, 1986; Burton, Bruce, & Hancock, 1999; Young and Burton, 2017; 2018). While photographs of unfamiliar faces can be remembered and later recognized remarkably well, recognition performance breaks down as soon as any changes are made between studied and test images (Bruce, 1982; Hancock, Bruce, & Burton, 2000). In contrast, the behavioural hallmark of familiar face recognition is that it is remarkably successful across substantial changes in expression, viewing angle, and lighting conditions (Bruce, 1994; Bruce & Young, 2012; Burton, 2013). For example, if we had used familiar faces in the matching and sorting tasks that were used in this study, performance would have been at ceiling. The only difference between a familiar and unfamiliar face is the experience with that face and this is clearly what gives rise to the difference in performance (Kramer, Jenkins and Burton, 2016; Kramer, Young and Burton, 2018). Again, this suggests that differences in performance between familiar or unfamiliar faces or between own-race and other-race faces could be explained by perceptual experience.

One explanation for the covariance across own-race and different-race tasks is that it may reflect different levels of motivation across participants. To address this issue, we measured covariation across different dependent variables in each task. In the matching task, we correlated performance on **the** same identity trials with performance on different identity trials. In the sorting task, we correlated the number of piles with the number of errors. Our results do not show any inconsistent pattern of correlation between the dependent measures

on each task. For example, there was no correlation between same-identity and different-identity trials of Asian faces with Asian participants and no correlation between same-identity and different-identity trials of White faces with White participants. This suggests that the processes that lead to these judgments are to some extent different. However, the fact that these dependent covary across tasks suggests that processes are independent and rule out a general effect of motivation. We also looked at individual performance as a function of time spent and found no consistent pattern of covariation across the dependent measures in the matching and sorting task. Again, these findings are not consistent with a general effect of motivation.

Tasks measuring ability in face recognition require participants to determine (1) whether faces are from the same person (putting faces together) and (2) whether they are from different people (telling faces apart). For example, accuracy on same-identity trials in the matching task measures the ability to 'put faces together', whereas performance on the different-identity task measures the ability to 'tell faces apart'. Similarly, the number of piles in the sorting task reflects variation in the ability to 'put faces together', whereas errors in which images of different identities are included in the same pile reflects the ability to 'tell faces apart'. First, we asked whether measures of the ability to 'put faces together' across the two tasks were correlated. Because lower numbers of piles on the sorting task and higher accuracy on the matching task reveal higher performance, we predicted significant negative correlations if the ability to 'put faces together' was correlated across the two tasks. Consistent with this prediction, we found significant negative correlations across all but one of the different combinations of participant race and face race. Next, we asked whether measures of 'telling faces apart' in the two tasks were correlated. Again, because low numbers of errors on the sorting task, but high levels of accuracy on the matching task

indicate higher performance, we predicted significant negative correlations if the ability to ‘tell faces apart’ covaried across the two tasks. We found that performance on different-identity trials in the matching task was negatively correlated with the number of piles in all but one of the different combinations of participant race and face race. These results suggest that similar processes are involved despite different tasks (matching and sorting).

Finally, The ORE has often been framed as a problem with individuating (discriminating between) other-race faces, consistent with the claim that other-race faces all look similar (Feingold, 1914; see also Vizioli, Rousselet, & Caldara, 2010; but see Goldstein, 1979). However, we found that there was no difference in the proportion of responses (irrespective of accuracy) in the matching task. Moreover, in the sorting task, participants made more piles rather than less (see also, Laurence et al., 2016). This suggests that rather than all looking the same, other-race faces look more different.

In conclusion, many studies have debated whether the ORE reflects differences in the amount of perceptual experience with different faces or whether it reflects different ways of processing own-race and other-race faces. We addressed this issue in a large group of participants using two measures of face recognition ability: matching and sorting. We found that participants were more accurate with own-race faces compared to other-race faces in a matching task. Despite a clear ORE, performance on own-race faces was positively correlated with performance on other-race faces. The covariation in performance between own-race and other-race faces suggests that they engage similar perceptual processes and supports the role of perceptual expertise in the ORE. We found that the ORE could not be explained by different levels of attention or motivation, as participants did not spend more time with own-race faces compared to other-race faces and that different measures from each task covaried independently. Together, these findings suggest that own-race faces and other-race faces

engage the same perceptual mechanisms and suggest that differences in performance are more likely to reflect differences in perceptual experience.

3. SIMILAR PATTERNS OF NEURAL RESPONSE TO OWN-RACE AND OTHER-RACE FACES ARGUE AGAINST THE GROUP BIAS ACCOUNT OF THE ORE

3.1 Introduction

The other-race effect (ORE) in which own-race faces are perceived more accurately than other-race faces has been demonstrated across a wide variety of behavioural paradigms (Feingold, 1914; Malpass and Kravitz, 1969; Bothwell et al., 1989; Meissner and Brigham, 2001). Nevertheless, the underlying cause of the ORE remains unclear. One theory, founded in social identity theory (Tajfel et al., 1971), proposes that own-race and other-race faces are processed in fundamentally different ways depending on whether they are categorized as in-group or out-group (Levin, 1996; MacLin & Malpass, 2001; MacLin, MacLin, Peterson, Chowdhry, & Joshi, 2009). Own-race faces due to their in-group status are processed at an individual level, whereas other-race faces due to their out-group status are processed at a categorical level (Rodin, 1987; Sporer, 2001; Rhodes et al., 2009; Hugenberg et al., 2010). An alternative theory of the ORE proposes that the same-race advantage results from greater experience with own race faces (Goldstein & Chance, 1980, 1985; Rhodes et al., 1989; Valentine, 1991; Chiroro & Valentine, 1995; Furl et al., 2002; Rossion and Michel, 2011). Because of the higher exposure to own-race faces, the visual system becomes more 'tuned' to naturally occurring variation in the image features found in own-race faces compared to other-race faces (Nelson et al., 2001; Kelly et al., 2005, 2007; Tanaka & Pierce, 2009). Despite their differences, both theories of the ORE predict that there should be a more sensitive or sharpened representation of own-race faces.

Previous neuroimaging studies that have attempted to explain the behavioural differences evident in the ORE have focussed on face-selective regions of the human brain

(O'Toole and Natu, 2013; Molenberghs and Louis, 2018). A number of studies have compared the overall magnitude of the response to own-race and other-race faces, with a number of studies reporting a larger fMRI response to own-race faces in face-selective regions, such as the fusiform face area - FFA (Golby et al, 2001; Kim et al., 2006; Feng et al., 2011; Natu et al., 2011, although see Brosch et al., 2013). However, other neuroimaging paradigms have allowed for more sensitive approaches to explore the neural representation of faces. For example, fMR-adaptation - the reduced response to repeated exposures to the same stimulus – has been used to probe the sensitivity and selectivity of the neural response to faces (Grill-Spector et al., 1999; Andrews & Ewbank, 2004; Ewbank and Andrews, 2008; Andrews et al., 2010). Recently, two studies reported greater adaptation to own-race faces compared to other-race faces in the FFA (Hughes et al., 2019; Reggev et al., 2020). This increased sensitivity to own-race shown is consistent with theories of the ORE suggesting that own-race faces are processed at a more individual level compared to other-race faces (Hugenberg et al., 2010) or that there is a sharpened representation of own-race faces (Valentine, 1991). fMRI studies employing multivariate pattern analysis (MVPA) have also been used to explore the differences between the neural responses to own-race and other-race faces. Previous studies have shown that patterns of response in the temporal lobe can differentiate between own-race and other-race faces (Natu et al., 2011; Ratner et al., 2013). A difference in the pattern of response to own-race and other-race faces in the FFA was also reported by Brosch and colleagues (2013), but this was only observed with participants that showed a significant behavioural own-race bias. These findings provide further support for the idea that there is a more distinct or sharpened representation of own-race faces.

Although previous neuroimaging studies have reported findings that are consistent with an own-race bias in face-selective regions, a significant limitation in the interpretation of

previous reports has been that the race of the participants and the race of the face has not been varied orthogonally (cf. Feng et al., 2011; Van Bavel et al., 2012; Brosch et al., 2013; Hughes et al., 2019; Reggev et al., 2020). This leaves open the possibility that prior results are due to differences in the stimulus sets that are used for own-race and other-race faces. In some studies, the absence of a full cross-over design is exacerbated by low numbers of participants. Another limitation of past work is that in many studies participants were explicitly given tasks that are directly related to the stimuli such as **memorizing** or **categorising** targets. Given that there are established behavioural differences for own- and other-race faces, differences in neural response could have resulted from task difficulty.

The aim of this study was to use a combination of univariate and multivariate measures with a full cross-over design to explore the neural correlates of the other-race effect. We recruited a large group of Asian and White participants who viewed own-race and other-race faces. We also included Black faces that would be other-race to both Asian and White participants **to see whether there is a difference in the sensitivity of the ORE. All responses were compared to a baseline response to scenes. To avoid any confounds with task difficulty, participants performed an orthogonal non-face task. In addition, the response to own-race and other-race faces was compared to pareidolic objects - objects that are perceived as faces (Wardle, Taubert, Teichmann, & Baker, 2020; Taubert, Wardle, & Ungerleider, 2020). Although these objects give rise to the perception of a face, we did not expect that they would elicit a difference in response between the participants, this will allow us to validate our findings with a unified standard across all participants.** Our aim was to compare the pattern of response to own-race and other-race faces in the core face-selective regions using different univariate and multivariate approaches. Our hypothesis was that there should be a more sensitive and sharpened representation of own-race faces compared to

other-race faces in face-selective regions.

3.2 Methods

3.2.1 Participants

An opportunity sample of 28 East Asian (19 female, mean age = 22.0, SD = 3.0 years) and 29 white (20 female, mean age = 21.6, SD = 3.4 years) participants were recruited for this study. East Asian and white participants had grown up in East Asian or Western European countries, respectively. The sample size was validated by the G-power software with a calculated effect size for the main effect of Adaptation from the 3 (Face Race: Asian, Black, White) x 2 (Participant Race: Asian, White) x 2 (Adaptation: Same, Different) repeated measure ANOVA. For the interaction of Adaptation* Face*Participant, the calculated effect size of 0.53, with a power of 0.95 at alpha level equals 0.05, and a total sample size equal to 12 would be enough for the test of the interaction. For Asian participants, the average stay-in UK period was (mean \pm SEM: 10.7 \pm 0.57) months. All participants gave their written informed consent. All participants had normal or corrected to normal vision. The study was approved by the York Neuroimaging Centre (YNiC) Ethics Committee.

3.2.2 Stimuli

Asian and Black face images were taken from the range of freely available internet sources. White faces were taken from the Models Face Matching Test (Dowsett & Burton, 2015). The images were cropped to display the face only. Images were selected which were free of occlusions, and showed front facing views. Pareidolic objects were also taken from a range of freely available internet sources. Scene images were drawn from indoor, and outdoor

man-made natural stimuli from the SUN database (Xiao et al., 2010). Examples of the images are shown in Figure 3.1. Faces were cropped and re-sized to 480 x 591 pixels. Pareidolic object images were cropped and re-sized to 484 x 585 pixels and images of scene were 600 x 600 pixels. All of the stimuli images were superimposed on a mid-gray background. Images had a visual angle of approximately 10.7°, and were back-projected onto a custom in-bore acrylic screen at a distance of 57 cm from the participant. Stimulus presentation was controlled through Psychopy (Peirce, 2007).

3.2.3 Design and procedure

There were 5 image conditions (Asian face, Black face, White face, Pareidolic object, Scene). Images from these conditions were presented in a blocked design in two ways (Same Identity, Different Identity). Each block was 6 sec in duration and was composed of 6 images. Each image was presented for an 800 ms presentation with a 200 ms inter-stimulus interval. Blocks were separated with a 9-sec fixation screen. In the Same Identity blocks, one image was shown six times, whereas in different blocks, 6 different identity images were presented. The order of blocks and images was pseudo-randomized. Each stimulus condition was repeated 5 times. So, there was a total of 50 blocks. To maintain attention, participants were instructed to press a button with their right index finger on a response box whenever a green fixation cross appeared. Green fixation crosses occurred at random times during the stimulus presentation.

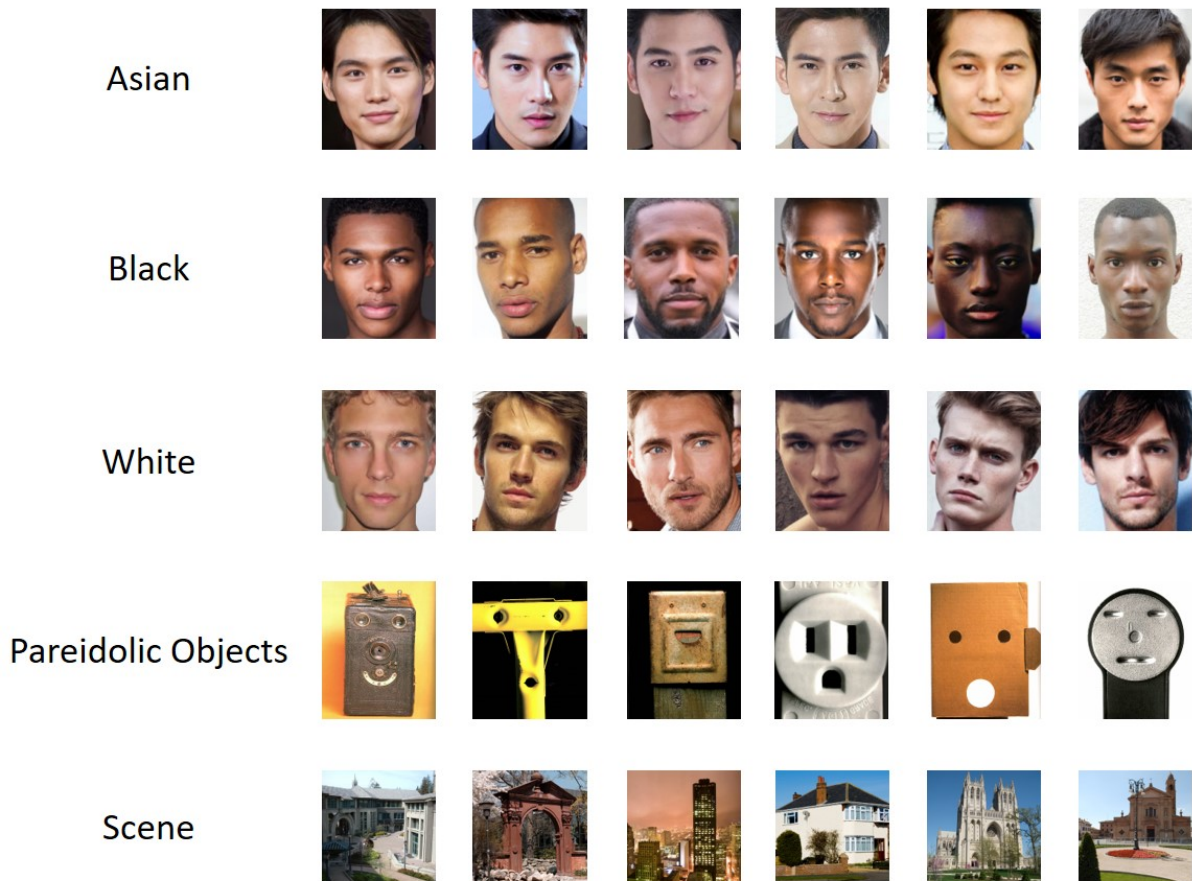


Figure 3.1 Examples of images from the different stimulus conditions.

3.2.4 Data acquisition and analysis

Structural and functional data were collected at the York Neuroimaging Centre with a 3T Siemens Magnetom Prisma MRI scanner (Siemens Healthcare, Erlangen, Germany) and a 20-channel phased array head coil. A gradient-echo echo-planar imaging (EPI) sequence was used to collect the functional data from 38 contiguous axial slices (repetition time (TR) = 3000 msec, echo time (TE) = 35 msec, FoV = 192 x 192mm, matrix size = 80 x 80, voxel size = 3 x 3 x 3 mm, flip angle = 90) that provided whole-brain coverage. T-1 weighted MP-RAGE anatomical scans were also acquired for anatomically localizing functional activation. Structural data were recorded via matrix of 176 x 256 x 256 and voxel size 1 x 1 x 1mm, with repetition time (TR) = 2300ms, and echo time (TE) = 2.26ms.

fMRI data were analysed using the fMRI Expert Analysis Tool (FEAT) v6.0 (<http://www.fmrib.ox.ac.uk/fsl>). Motion correction was achieved via MCFLIRT, FSL (<http://www.fmrib.ox.ac.uk/fsl>) (Jenkinson, Bannister, Brady, & Smith, 2002). Slice timing correction **was** also applied and followed by temporal high-pass filtering (Gaussian-weighted least squares straight line fittings, $\sigma = 50$ s). Spatial smoothing (Gaussian, FWHM 5 mm) and pre-whitening were applied to remove temporal auto-correlation. For each condition, we generated parameter estimates by regressing the hemodynamic response of each voxel against a box-car that was convolved with a single-gamma HRF. Functional data were registered to a high-resolution T1-anatomical image, and then onto the standard MNI brain (ICBM152).

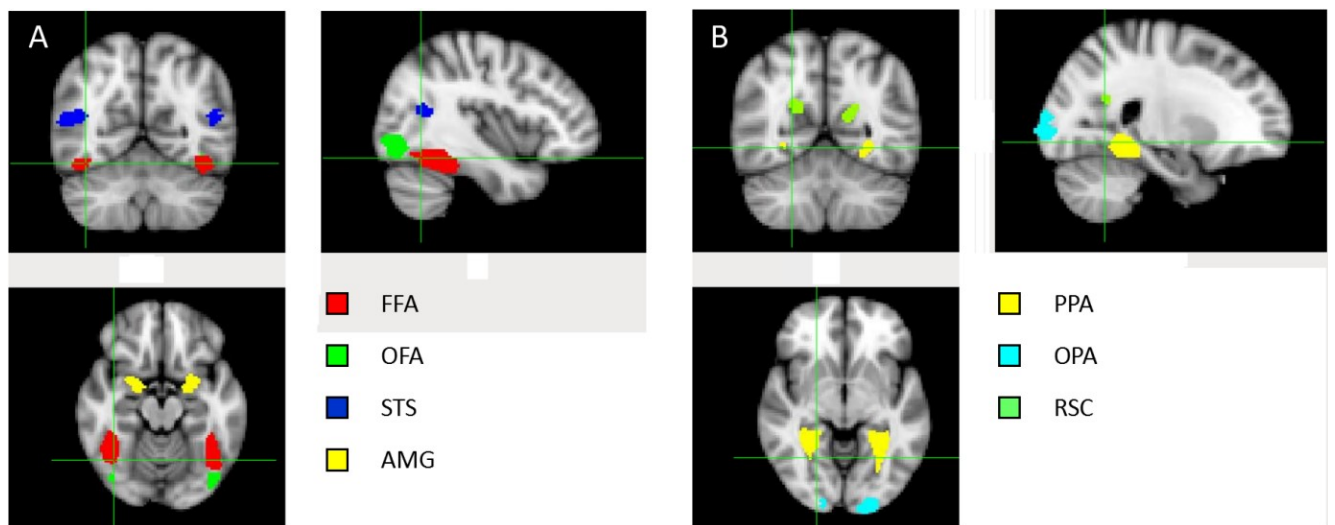


Figure 3.2 Group analysis showing the location of (A) face-selective ($x=40, y=-60, z=-16$) and (B) scene-selective regions ($x=24, y=-58, z=-6$). Regions are superimposed on the MNI152 brain.

To avoid bias, we defined regions of interest (ROIs) across the brain using fMRI data from both Asian and White participants (see also Golby et al, 2001; Feng et al., 2011; Hughes et al., 2019; Reggev et al., 2020). To define the ROIs, the response to all face conditions (Asian, Black, White) was contrasted with the response to scene conditions. This allowed the definition of the face-selective regions: fusiform face area (FFA), occipital face area (OFA), superior temporal sulcus (STS), and amygdala (AMG). The peak face-selective and scene-selective voxels (i.e. those with the highest z value) were identified and a flood fill algorithm was used to identify a maximum cluster of 500 spatially contiguous voxels for each ROI to a lower threshold of $Z > 2.3$ (Weibert and Andrews, 2015). If it was not possible to define a 500 voxel ROI for a region, the region was defined by the largest size to the nearest 100 (Table 3.1). 500 voxel ROIs were found bilaterally for the FFA and OFA. It was possible to define a 500 voxel ROI in the right STS, but only 200 voxels ROI in the left STS. The amygdala was defined by 200 voxels ROIs in the left and right hemispheres.

For the univariate analysis, we measured the % signal change in each ROI for each of the 10 conditions for each participant. The magnitude of adaptation to each face condition was measured by subtracting the same and different responses to each face condition. Our prediction was that there should be a greater adaptation for own-race compared to other-race faces.

To measure the overall response to different race faces, we combined the same identity and different identity conditions. To take into account individual variation in the magnitude of the BOLD response, overall responses to each face condition were normalized by subtracting the response to scenes in each participant. Our prediction was that there should be a greater overall response to own-race compared to other-race faces.

Table 3.1 – Coordinates of face-selective and place-selective regions

ROI	hemisphere	x	Y	z	voxels	face > scene (z)
FFA	Left	-42	-62	-16	500	6.4
	Right	44	-52	-18	500	7.9
OFA	Left	-40	-80	-10	500	6.3
	Right	48	-76	2	500	8.1
STS	Left	-48	-64	12	200	3.2
	Right	48	-76	8	500	6.1
AMG	Left	-20	- 4	-14	200	3.5
	Right	20	- 4	-10	200	4.7
PPA	Left	-24	-46	-10	500	-7.9
	Right	30	-46	- 6	500	-8.9
OPA	Left	-14	-102	2	500	-7.1
	Right	18	-98	2	500	-6.2
RSC	Left	-20	-58	18	100	-4.2
	Right	18	-54	18	100	-4.8

For the multivariate analysis, parameter estimates for each condition were normalized by subtracting the mean response across all conditions for each voxel. Group analyses were then conducted with one participant being left out for each iteration of the analysis. For each pairwise combination of conditions, the pattern of response in each participant was compared with the corresponding group pattern with the remaining participants. This leave-one-participant-out (LOPO) cross-validation paradigm was repeated for each participant for each combination of conditions (Rice et al., 2014). The MVPA was implemented using the PyMVPA toolbox (<http://www.pymvpa.org>; Hanke et al., 2009). The Pearson correlation coefficients were then used to calculate the representational similarity in the patterns of response to different conditions. A Fisher's z-transformation was then applied to the correlations prior to further statistical analysis.

We performed three main analyses of the MVPA data. These analyses were performed separately for Asian and Caucasian participants. First, we explored whether there were distinct patterns of response to the general category of faces. To do this we asked whether the similarity of response to faces from different races was greater than between faces and

scenes. To do this, we compared face-face correlations (Asian-Black, Asian-White, Black-White) with face-scene correlations (Asian-Scene, Asian-Scene, Black-Scene). Our prediction was that there would be higher correlations for face-face comparisons. Second, we asked whether there were different patterns of response to faces from different races. To do this we compared the correlations **between** the same race faces (Asian-Asian, Black-Black, White-White) with the correlations between different race faces (Asian-Black, Asian-White, Black-White). If there are distinct patterns of response to faces from different races, then the same race face correlations should be higher than the different race face correlations. Third and most critically, we asked whether there was a distinct pattern of response to own-race faces. To do this, we compared Asian-Asian and White-White correlations in Asian and White participants. Our prediction was that if there is a more distinct response to own-race faces, then Asian-Asian correlations would be higher in Asian participants and White-White correlations would be higher in White participants.

3.3 Results

3.3.1 Univariate Analysis

First, we measured adaptation to faces from different races in the face-selective regions of participants from different races (Fig. 3.3). A 3 (Face Race: Asian, Black, White) x 2 (Participant Race: Asian, White) x 2 (Adaptation: Same, Different) x ROI (FFA, OFA, STS, amygdala) mixed ANOVA was performed on the core face-selective regions. There was a significant effect of Adaptation ($F(1, 55) = 105.4, p < .001, \eta_G^2 = .657$), but there were no Adaptation*Face*Participant ($F(2, 110) = 1.25, p = .291, \eta_G^2 = .022$) or Adaptation*Face*Participant* ROI ($F(6, 330) = .387, p = .829, \eta_G^2 = .007$) interactions. There

was an interaction between Adaptation * ROI ($F(3, 165) = 54.9, p < .001, \eta_G^2 = .500$). To explore this effect, we analyzed the data in each ROI.

There was a significant main effect of Adaptation in the FFA ($F(1, 55) = 131.61, p < .001, \eta_G^2 = .705$), OFA ($F(1, 55) = 127.57, p < .001, \eta_G^2 = .699$) and amygdala ($F(1, 55) = 28.28, p < .001, \eta_G^2 = .336$), but not in the STS ($F(1, 55) = .444, p = .508, \eta_G^2 = .008$). There was also a significant Face*Adaptation interaction in each region (FFA: $F(2, 110) = 5.906, p < .01, \eta_G^2 = .097$; OFA: $F(2, 110) = 8.477, p < .001, \eta_G^2 = .134$; STS: $F(2, 110) = 8.595, p < .001, \eta_G^2 = .135$; AMG: $F(2, 110) = 8.635, p < .000, \eta_G^2 = .136$). This shows that adaptation varied according to the stimulus set, with higher adaptation to Asian faces. However, consistent with the omnibus ANOVA, there was no interaction between Face*Participant*Adaptation in any of the face regions (FFA: $F(2, 110) = .125, p = .882, \eta_G^2 = .002$), OFA: $F(2, 110) = 1.418, p = .247, \eta_G^2 = .025$, STS: $F(2, 110) = 1.868, p = .159, \eta_G^2 = .033$, amygdala: $F(2, 110) = .676, p = .511, \eta_G^2 = .012$). Together, this shows that there was no difference in the adaptation to own-race and other-race faces in the face regions.

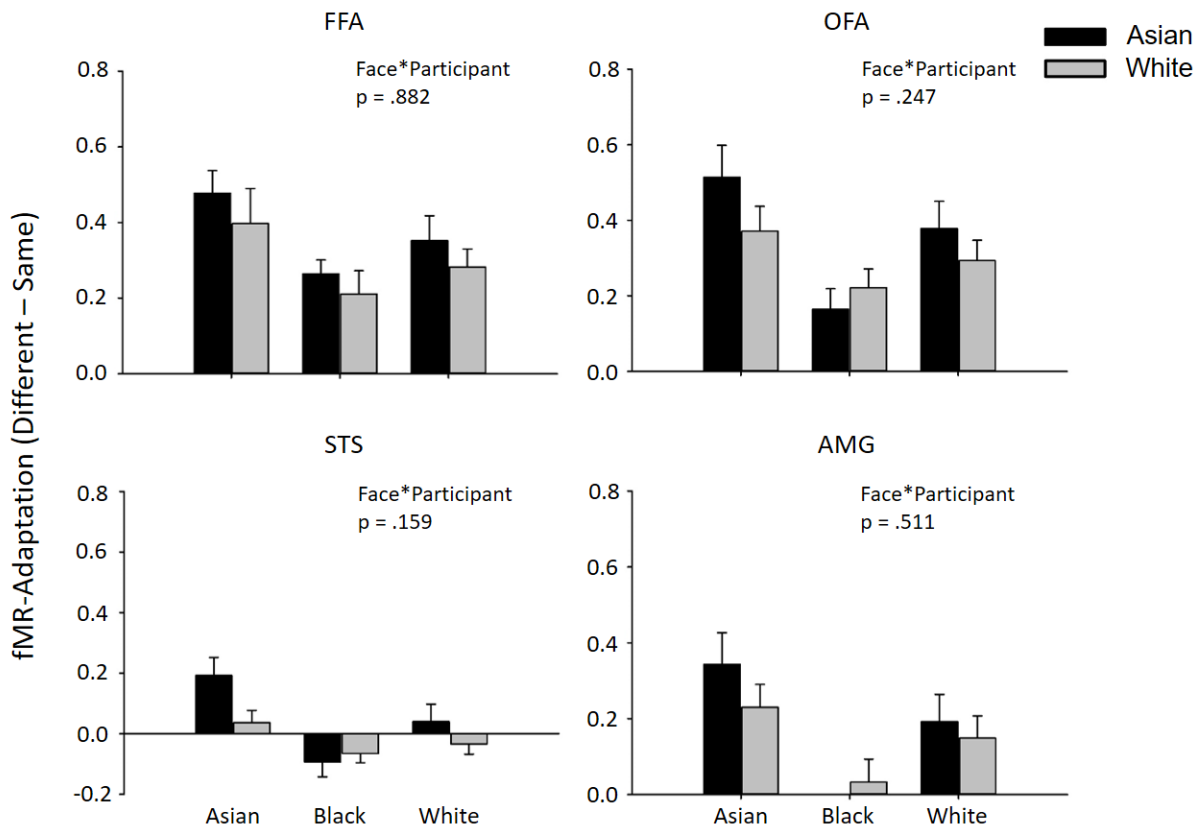


Figure 3.3 fMRI-adaptation in the FFA, OFA, STS and AMG to different race faces (Asian, Black, White) in Asian and White participants. There was a significant adaptation in FFA, OFA and STS (Different-Same > 0). However, there was no interaction between Face*Participant in the fMRI-adaptation (different – same) of any of the face-selective regions. This shows that the magnitude of adaptation was not modified by the race of the participants. Error bars represent SEM.

We also measured adaptation to a non-face condition (scenes) in the face-selective regions of Asian and White participants. There was a significant effect of Adaptation ($F(1, 55) = 18.6$, $p < .001$, $\eta_G^2 = .252$), but there was no Adaptation*Participant interaction ($F(1, 55) = .542$, $p = .465$, $\eta_G^2 = .010$). However, there was an Adaptation*ROI interaction ($F(3, 165) = 8.28$, $p < .001$, $\eta_G^2 = .131$). To explore this in more detail, we investigated the individual ROIs. There was an effect of Adaptation in the FFA ($F(1, 55) = 28.52$, $p < .001$, $\eta_G^2 = .341$) and the OFA ($F(1, 55) = 24.60$, $p < .001$, $\eta_G^2 = .309$), but not in the STS ($F(1, 55) = 1.02$, $p = .318$, $\eta_G^2 = .018$) or the AMG ($F(1, 55) = 1.69$, $p = .198$, $\eta_G^2 = .030$). There was no interaction between Adaptation*Participant in any of the face-selective regions (FFA ($F(1, 55) = 1.69$, $p = .199$, $\eta_G^2 =$

.030), OFA ($F(1, 55) = .043, p = .84, \eta_G^2 = .001$), STS ($F(1, 55) = 1.10, p = .298, \eta_G^2 = .020$) and AMG ($F(1, 55) = 0.07, p = .793, \eta_G^2 = .001$). This shows as expected that Asian and White participants showed similar levels of adaptation to scenes.

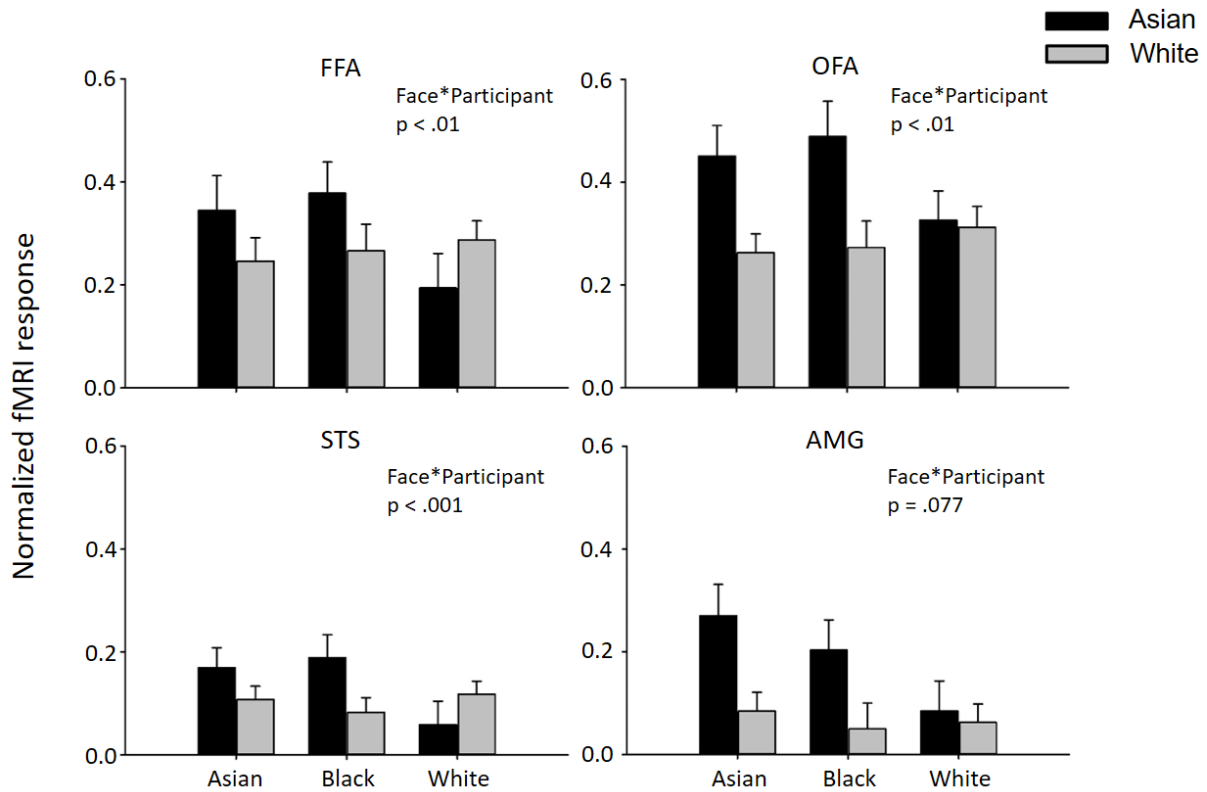


Figure 3.4 Normalized fMRI response in the FFA, OFA, STS and AMG to different race faces (Asian, Black, White) in Asian and White participants. There was an interaction between participant race and face race in the FFA, OFA and STS. For example, in the FFA, the response to Asian and White faces was greater in Asian and White participants, respectively. Error bars represent SEM.

In the next stage of the univariate analysis, we measured the overall magnitude of the response to faces in the face regions by combining the same and different responses. The responses were normalized to scenes to take into account individual variation in the BOLD response. A 3 (Face Race: Asian, Black, White) x 2 (Participant Race: Asian, White) x ROI (FFA, OFA, STS, amygdala) mixed ANOVA was performed on the core face-selective regions. There was a significant interaction of Face*Participant ($F(2, 110) = 8.043, p < .001, \eta_G^2 = .128$), but no interaction of Face*Participant * ROI ($F(6, 330) = .545, p = .774, \eta_G^2 = .010$). Figure 3.4

shows the responses in the different ROIs. There was a significant Face*Participant interaction in the FFA ($F(2, 110) = 7.588, p < .001, \eta_G^2 = .121$), OFA ($F(2, 110) = 5.189, p < .01, \eta_G^2 = .086$) and STS ($F(2, 110) = 8.912, p < .001, \eta_G^2 = .139$). There was also a trend toward a Face*Participant interaction in the amygdala ($F(2, 110) = 2.619, p = .079, \eta_G^2 = .045$). This shows that there was a differential response to faces from different races in participants from different races. In the FFA, consistent with the ORE, Asian participants responded relatively more to Asian faces than to White faces, whereas White participants responded relatively more to White than to Asian faces.

Next, we performed a univariate analysis of the pareidolic objects. These objects are a good control stimulus as they have a face-like appearance, but they do not have an explicit ethnicity. Our prediction was that there should not be any difference in the response to pareidolic objects from Asian and White participants. Figure 3.5A shows the adaptation to pareidolic objects in Asian and White participants. There was a significant effect of Adaptation ($F(1, 55) = 27.60, p < .001, \eta_G^2 = .334$), but no significant Adaptation*Participant adaptation ($F(1, 55) = .223, p = .639, \eta_G^2 = .004$). There was, however, an Adaptation*ROI interaction ($F(1, 55) = 21.60, p < .001, \eta_G^2 = .282$). We found adaptation to pareidolic objects in the FFA ($F(1, 55) = 3.008, p = .088, \eta_G^2 = .052$) and OFA ($F(1, 55) = 3.371, p = .072, \eta_G^2 = .058$), but not in the STS ($F(1, 55) = 1.457, p = .233, \eta_G^2 = .026$) or amygdala ($F(1, 55) = .044, p = .836, \eta_G^2 = .001$). Consistent with the omnibus ANOVA, there was no interaction between Adaptation*Participant in any of the face regions (FFA: ($1, 55) = 2.923, p = .093, \eta_G^2 = .050$; OFA: $F(1, 55) = .178, p = .675, \eta_G^2 = .003$; STS: ($1, 55) = 1.681, p = .200, \eta_G^2 = .030$; amygdala: $.201, p = .655, \eta_G^2 = .004$). Figure 5B shows the overall response to pareidolic objects normalized to scenes. There was no difference in response to pareidolic objects between Asian and White participants (FFA: $F(1, 55) = .437, p = .511, \eta_G^2 = .008$; OFA: $F(1, 55) = .239, p$

= .627, $\eta^2 = .004$; STS: $F(1, 55) = .067$, $p = .797$, $\eta^2 = .001$; amygdala: $F(1, 55) = 1.577$, $p = .215$, $\eta^2 = .028$). Together, these analyses show that the face regions of Asian and White participants showed a similar level of adaptation and a similar overall response to pareidolic objects.

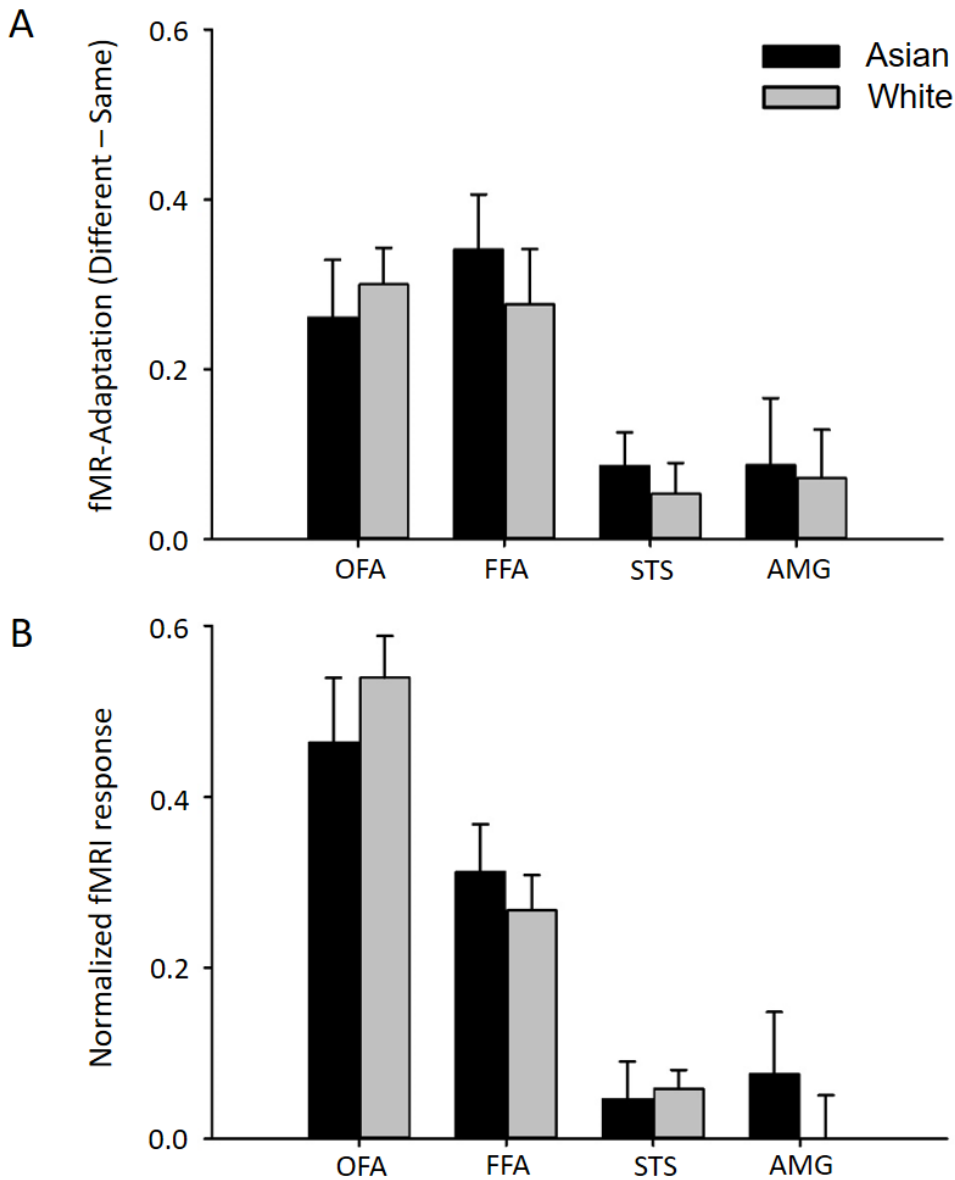


Figure 3.5 Neural response to pareidolic objects in the face regions. (A) All regions showed adaptation to pareidolic objects. However, there was no difference in the magnitude of adaptation between White and Asian participants. (B) The normalized response to pareidolic objects was not significantly different between White and Asian participants. Error bars represent standard error of the mean.

3.3.2 Multivariate Analysis

To explore differences in spatial pattern of response to own-race and other-race faces, we first asked if there were distinct patterns of response to the general category of faces, irrespective of race. To do this, we compared the spatial pattern of response of faces from different races (Face-Face: Asian-Black, Asian-White, Black-White) with the spatial pattern of response between faces and scenes (Face-Scene: Asian-Scene, Black-Scene, White-Scene) (Figure 3.6). The data was analysed by a Category (Face-Face, Face-Scene) * Participant (Asian, White) * ROI (FFA, OFA, STS, amygdala) ANOVA. If there are distinct patterns of response to faces (irrespective of race), we would expect a significant effect of Category with a higher correlation for Face-Face compared to Face-Scene. There was a significant effect of Category ($F(1, 55) = 161.2, p < .001; \eta^2 = .746$). There was also a significant Category*ROI interaction ($F(3, 165) = 24.80, p < .001; \eta^2 = .311$). This reflected significantly higher correlations in the patterns of response to different race faces (Face-Face) compared to between faces and scenes (Face-Scene) in the FFA ($F(1, 110) = 73.458, p < .001, \eta^2 = .400$; Asian: $t(27) = 8.681, p < .001, \text{Cohen's } d = 2.057$; White: ($t(28) = 5.056, p < .001, \text{Cohen's } d = 1.073$), OFA ($F(1, 110) = 101.982, p < .001, \eta^2 = .481$); Asian: $t(27) = 7.591, p < .001, \text{Cohen's } d = 2.501$; White: $t(28) = 4.651, p < .001, \text{Cohen's } d = 1.291$) and amygdala ($F(1, 110) = .007, p = .936, \eta^2 = .000$; Asian: $t(27) = 4.768, p < .001, \text{Cohen's } d = 12.844$; White: $t(28) = 2.092, p < .05, \text{Cohen's } d = .059$), but not in the STS (Category: $F(1, 110) = 2.030, p = .157, \eta^2 = .018$; Asian: $t(27) = 1.183, p = .247, \text{Cohen's } d = .248$; White: STS: $t(28) = .565, p = .577, \text{Cohen's } d = .113$). This shows that in all the face regions, except the STS, there were distinct responses to faces.

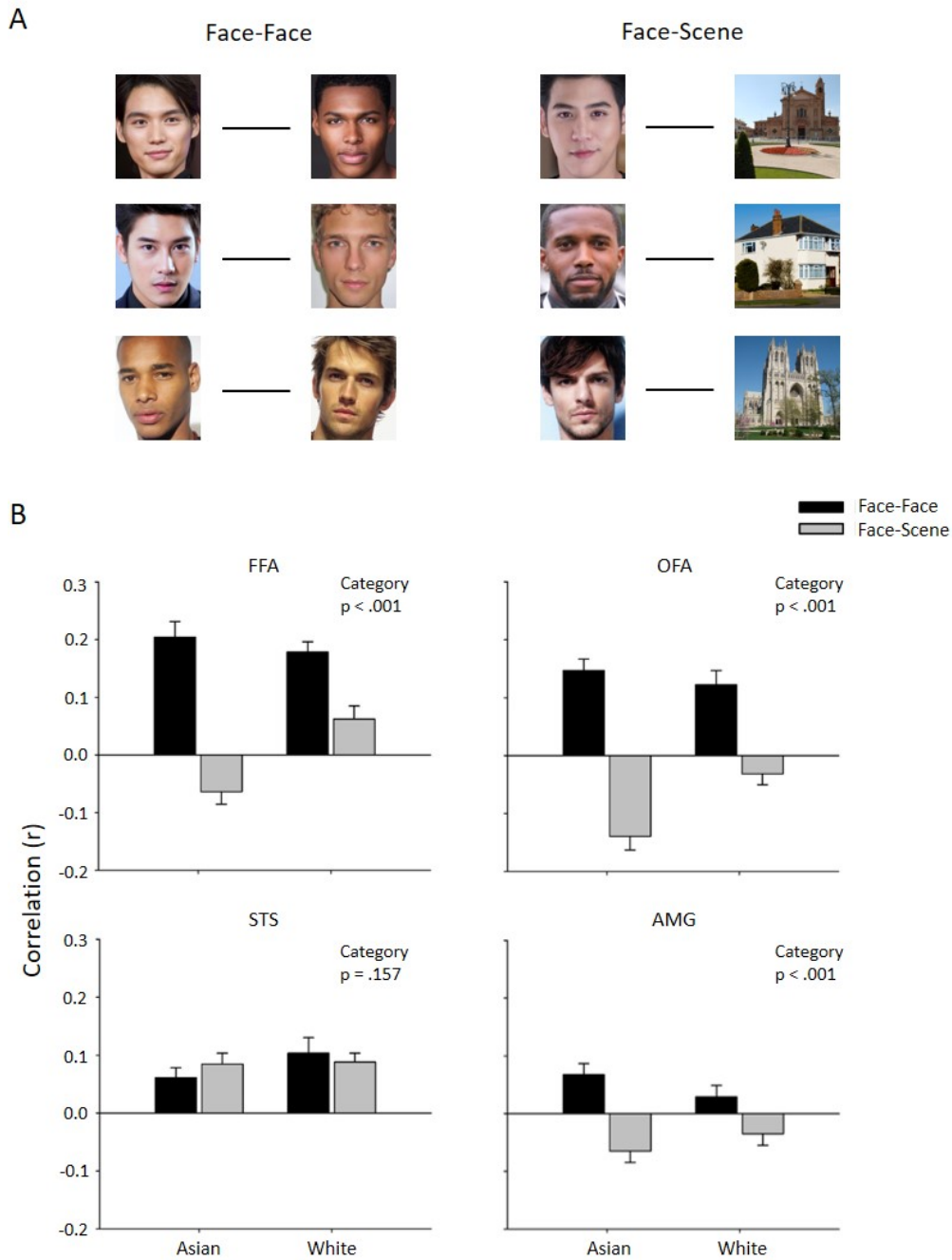


Figure 3.6 (A) The spatial pattern of response between different race faces (Face-Face) was compared to the spatial pattern between faces and scenes (Face-Scene) in face regions of Asian and White participants. (B) The results reveal an effect of Category with more similar patterns of response to different race faces (Face-Face) compared to the patterns between faces and scenes (Face-Scene). This shows that the face-selective regions had distinct patterns of response to the general category of faces. Error bars represent standard error of the mean.

Next, we asked if there were distinct spatial patterns of response to faces from the same race, irrespective of whether they are own-race or other-race. Figure 3.7 shows the similarity in the patterns of response between same race faces (Asian-Asian, Black-Black, White-White) compared with the similarity in the patterns of response between different race faces (Asian-Black, Asian-White, Black-White). A Face Race (Same Race, Different Race) * Participant Race (Asian, White) * ROI (FFA, OFA, STS, amygdala) ANOVA revealed a significant effect of Face Race ($F(1, 55) = 42.62, p < .001, \eta_G^2 = .437$) and a significant Face Race*ROI interaction ($F(3, 165) = 5.042, p < .01, \eta_G^2 = .084$). This interaction reflected a significant effect of Face Race in the OFA (Face Race: $F(1, 110) = 9.665, p < .01, \eta_G^2 = .081$) and amygdala (Face: $F(1, 110) = 6.403, p < .05, \eta_G^2 = .055$), but no significant effect of Face Race in the FFA (Face Race: $F(1, 110) = .438, p = .509, \eta_G^2 = .004$) or the STS (Face: $F(1, 110) = 3.148, p = .079, \eta_G^2 = .028$). There was no Face Race*Participant Race interaction in any of the face regions (FFA: $F(1, 110) = .370, p = .544, \eta_G^2 = .003$; OFA: $F(1, 110) = 3.233, p = .075, \eta_G^2 = .029$; STS: $F(1, 110) = .279, p = .598, \eta_G^2 = .003$; AMG: $F(1, 110) = .248, p = .620, \eta_G^2 = .002$). This shows that there are distinct patterns of response to faces from different races in the OFA and amygdala, but not in the FFA, where the patterns were similar to own-race and other-race faces.

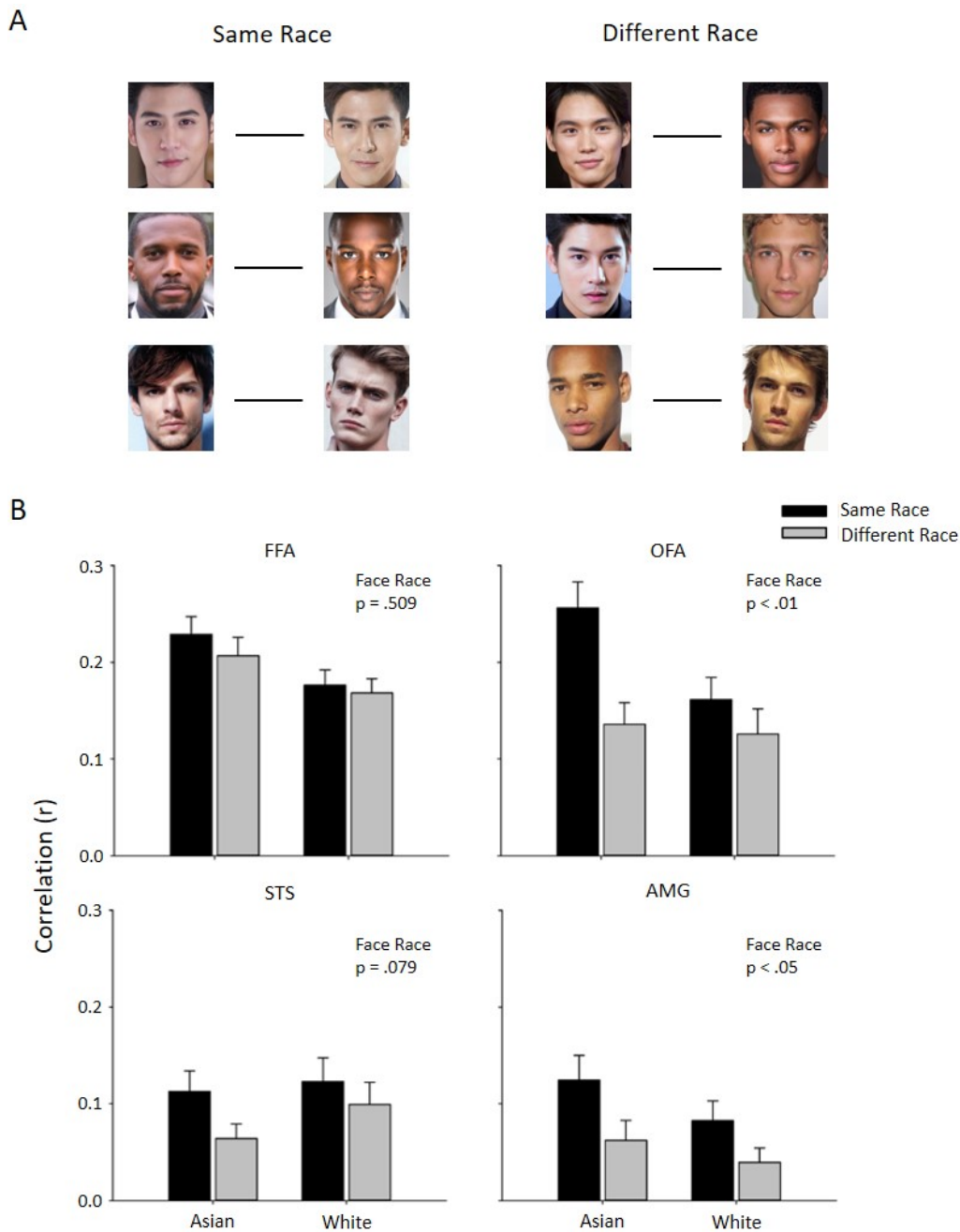


Figure 3.7 (A) The spatial pattern of response between faces from the same race (Same Race) was compared to the spatial pattern between faces from different races (Different Race) in face regions of Asian and White participants. (B) The results reveal an effect of Face Race in the OFA and AMG, with more similar patterns of response to faces from the same race (Same Race) compared to faces from different races (Different Race). However, there was no effect of Face Race in the FFA or STS. Error bars represent standard error of the mean.

We then asked the critical question of whether the spatial patterns of response were more distinct for own-race faces compared to other-race faces (Fig. 3.8). To address this question directly, we restricted the analysis to Asian and White faces and performed a Face

(Asian-Asian, White-White) * Participant (Asian, White) * ROI (FFA, OFA, STS, amygdala) ANOVA. If own-race faces are represented more distinctly than other race faces, we would predict an interaction between Face and Participant with the spatial pattern of response between Asian faces being more distinct for Asian participants, whereas White faces would be more distinct for White participants.

Contrary to our prediction, there was no significant Face*Participant interaction ($F(1, 55) = .057, p = .812, \eta^2 = .001$). There was an effect of ROI ($F(3, 165) = 4.73, p = .003, \eta^2 = .079$), but no Face*Participant*ROI interaction ($F(3, 165) = 1.345, p = .262, \eta^2 = .024$). There was no difference in the pattern of response to own-race and other-race faces in the FFA ($F(1, 55) = .170, p = .682, \eta^2 = .003$; Asian: $t(27) = .052, p = .959, \text{Cohen's } d = .014$; White: $t(28) = .663, p = .513, \text{Cohen's } d = .199$), OFA ($F(1, 55) = 3.698, p = .060, \eta^2 = .063$ (Asian ($t(27) = 1.850, p = .075, \text{Cohen's } d = .396$; White ($t(28) = .928, p = .361, \text{Cohen's } d = .186$), STS ($F(1, 55) = .069, p = .795, \eta^2 = .001$; Asian: $t(27) = .775, p = .445, \text{Cohen's } d = .174$; White: $t(28) = 1.241, p = .221, \text{Cohen's } d = .280$) or amygdala ($F(1, 55) = .191, p = .664, \eta^2 = .003$; Asian: $t(27) = .033, p = .974, \text{Cohen's } d = .007$; White: $t(28) = .599, p = .554, \text{Cohen's } d = .017$). This shows that there was no significant difference in the pattern of response between own-race and other-race faces.

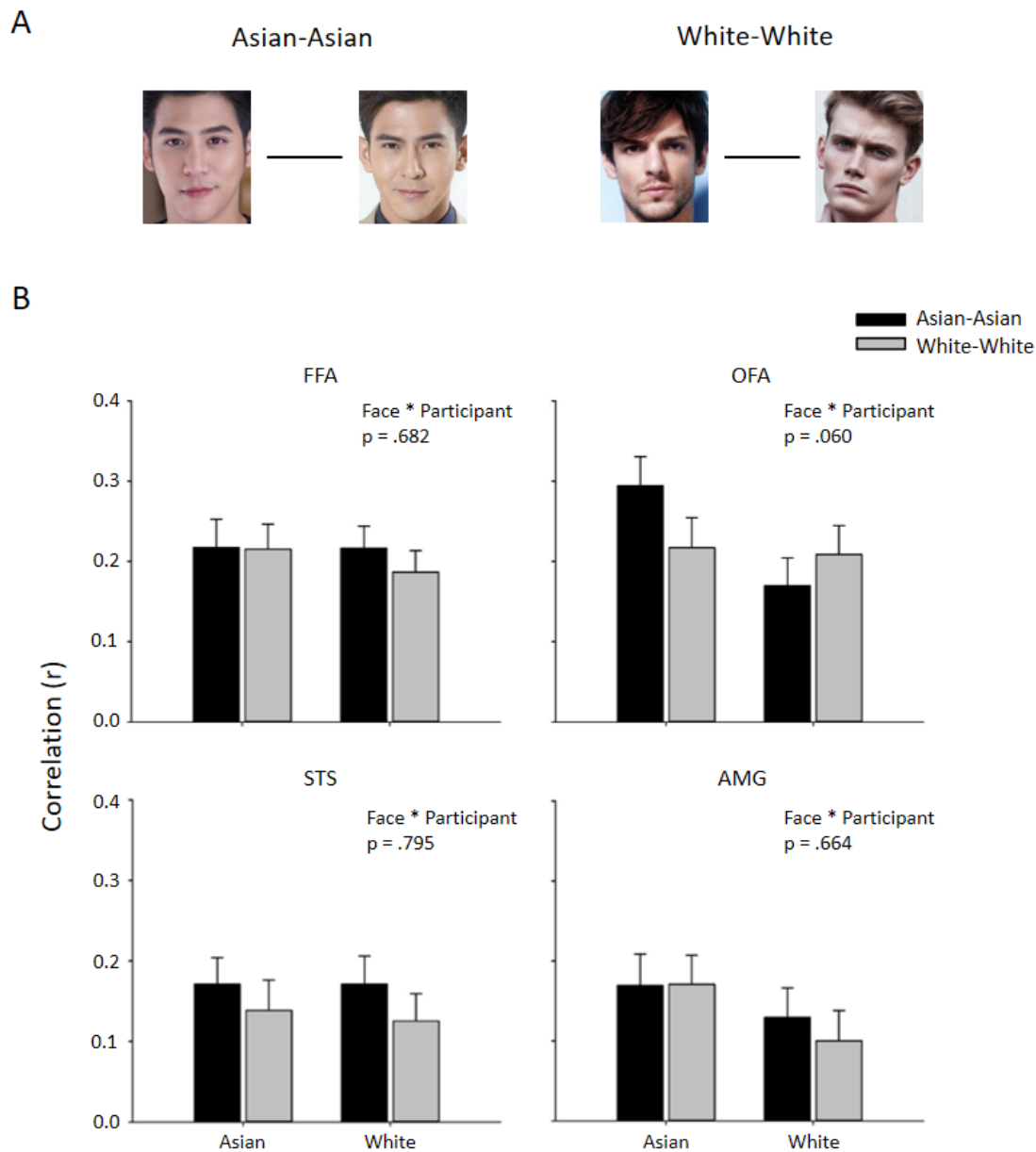


Figure 3.8 (A) The spatial pattern of response between White or between Asian faces was compared in Asian and White participants. (B) The results reveal that there was no interaction between Face Race and Participant Race in any of the face regions. This suggests that the spatial pattern of response to own-race faces is not distinct from the pattern of response to other-race faces. Error bars represent standard error of the mean.

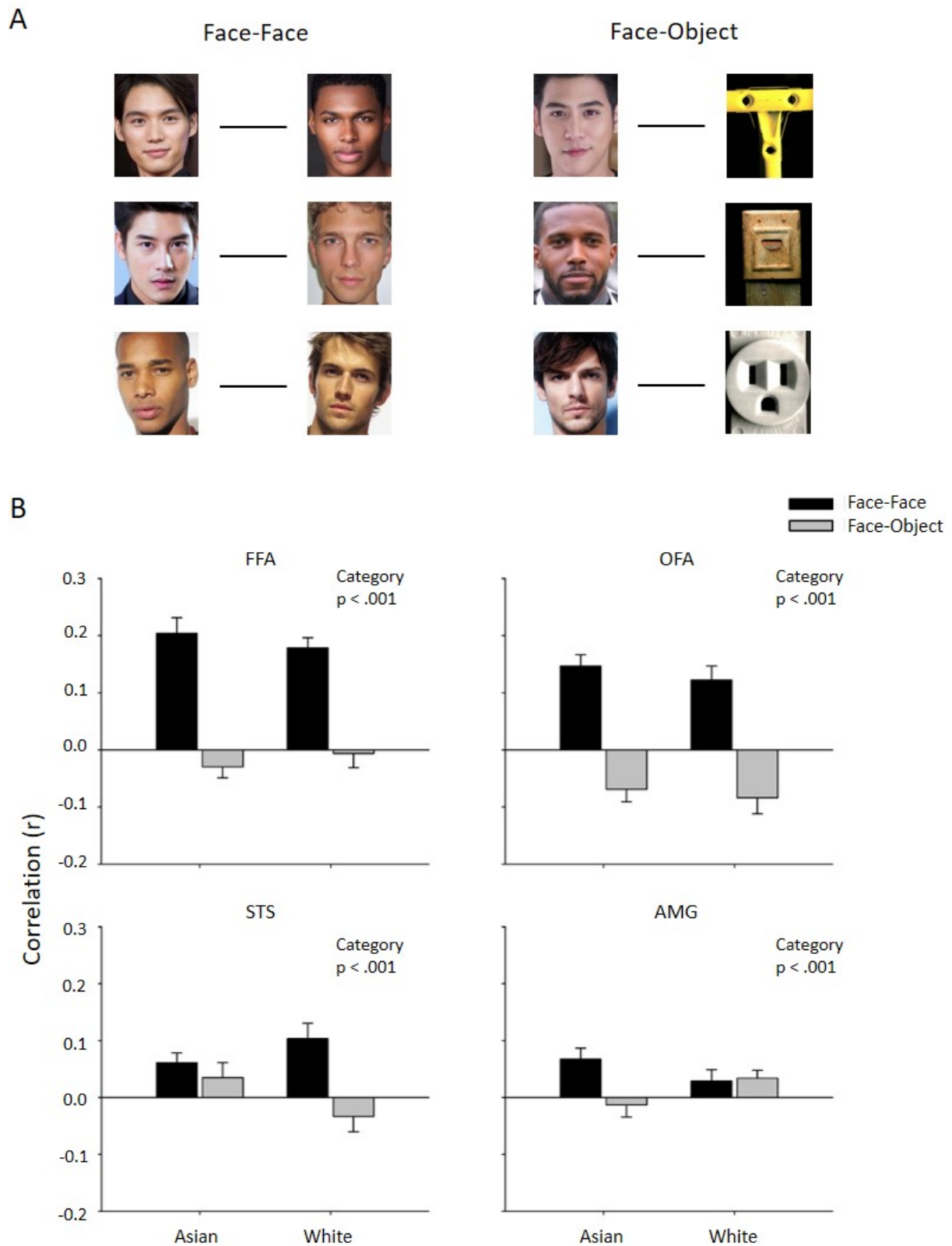


Figure 3.9 (A) The spatial pattern of response between different race faces (Face-Face) was compared to the spatial pattern between faces and pareidolic objects (Face-Object) in Asian and White participants. (B) The results reveal a significant effect of Category due to more similar patterns of response between faces (Face-Face) compared to the patterns between faces and objects (Face-Object). Error bars represent standard error of the mean.

We also explored the spatial pattern of response to pareidolic faces in the face regions. First, we asked if pareidolic objects that give rise to faces generate a different spatial pattern compared to faces. To do this, we compared the spatial pattern of the response of faces from different races (Face-Face: Asian-Black, Asian-White, Black-White) with the spatial pattern of response between faces and pareidolic objects (Face-Object: Asian-Object, Black-Object, White-Object). The data was analysed by a Category (Face-Face, Face-Object) * Participant (Asian, White) * ROI (FFA, OFA, STS, amygdala) ANOVA. There was a significant effect of Category ($F(1, 55) = 113.4, p < .001, \eta^2 = .673$) and a significant Category*ROI interaction ($F(3, 165) = 6.622, p < .001, \eta^2 = .107$). This interaction reflects differences in the effect of Category across the face regions (FFA: $F(1, 110) = 83.426, p < .001, \eta^2 = .431$; OFA: $F(1, 110) = 101.117, p < .001, \eta^2 = .479$; STS: $F(1, 110) = 14.150, p < .001, \eta^2 = .114$; amygdala: $F(1, 110) = 21.047, p < .001, \eta^2 = .161$). There was no interaction between Category and Participant in the FFA ($F(1, 110) = 1.393, p = .241, \eta^2 = .013$) or the OFA ($F(1, 110) = .547, p = .461, \eta^2 = .005$), but there were significant interactions in the STS ($F(1, 110) = 7.150, p < .01, \eta^2 = .061$) and the AMG ($F(1, 110) = 4.619, p < .05, \eta^2 = .040$). These findings show that the pattern of response to pareidolic objects is distinct from the pattern of response to faces in the core face regions.

We then asked if the pattern of response to pareidolic objects was different to the pattern of response to scenes. To do this, we compared the spatial pattern of response of pareidolic objects (Object-Object) with the spatial pattern of response to pareidolic objects and scenes (Object-Scene). The data was analysed by a Category (Object-Object, Object-Scene) * Participant (Asian, White) * ROI (FFA, OFA, STS, amygdala) ANOVA. There was a significant effect of Category ($F(1, 55) = 61.43, p < .001, \eta^2 = .528$) and a significant Category*ROI interaction ($F(3, 165) = 11.71, p < .001, \eta^2 = .175$). This was due to significant

effects of Category in the FFA ($F(1, 110) = 49.391, p < .001, \eta_G^2 = .310$), OFA ($F(1, 110) = 18.338, p < .001, \eta_G^2 = .143$), and STS ($F(1, 110) = 47.674, p < .001, \eta_G^2 = .302$), but not in the AMG ($F(1, 110) = .036, p = .850, \eta_G^2 = .000$). There was no interaction between Category * Participant Race in the FFA ($F(1, 110) = .416, p = .520, \eta_G^2 = .004$), the STS ($F(1, 110) = .954, p = .331, \eta_G^2 = .009$) or amygdala ($F(1, 110) = .004, p = .950, \eta_G^2 = .000$). However, there was an interaction between Stimulus and Participant Race in the OFA ($F(1, 110) = 5.631, p < .05, \eta_G^2 = .049$), which reflected a greater difference in response to pareidolic objects and scenes in Asian participants. These findings show that the pattern of response to pareidolic objects is distinct from the pattern of response to scenes in the core face regions.

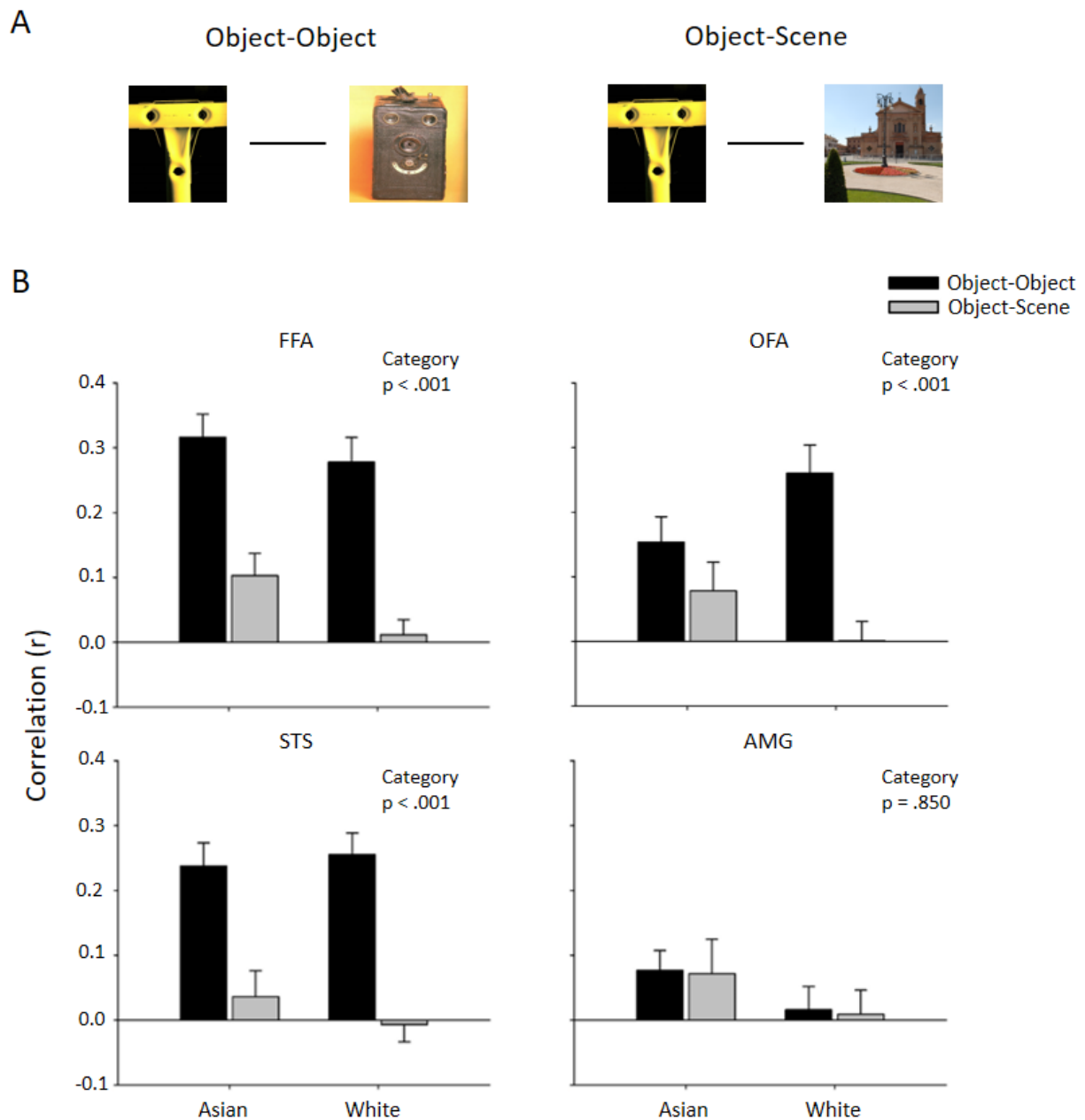


Figure 3.10 (A) The spatial pattern of response to pareidolic objects (Object-Object) was compared to the spatial pattern between pareidolic objects and scenes (Object-Scene) in Asian and White participants. (B) The results reveal an effect of *the* category with more similar patterns of response to pareidolic objects compared to between faces and objects. Error bars represent *the* standard error of the mean.

3.3.3 Individual Differences Analysis

In the final analysis, we compared individual differences in *adaptation*, *normalized response* and *MVPA* across all participants. First, we asked whether the magnitude of the effect for each measure was correlated across faces from different races (Fig. 3.11). In the FFA, we did not find any consistent covariation in the magnitude of adaptation to different race faces. For example, we found that adaptation to Asian faces was significantly correlated with Black faces ($r = .31$, $p = .017$), but there was no significant correlation between Asian and White faces ($r = .20$, $p = .147$) or between Black and White faces ($r = -.04$, $p = .762$). On the other hand, we found that the normalized response to different race faces did covary. For example, the normalized response to Asian faces was correlated with the normalized response to Black ($r = .90$, $p < .001$) and White ($r = .83$, $p < .001$) faces. Similarly, the normalized response to Black faces was correlated with the normalized response to White faces ($r = .84$, $p < .001$). To compare the MVPA across participants, we used the correlation between each individual's pattern and the group (leave one participant out) pattern for each race. This provides a measure of how similar the pattern of **the** response of an individual is compared to others in the group. There was no correlation in MVPA between Asian and Black ($r = .12$, $p = .377$) or Asian and White ($r = -.11$, $p = .408$) faces. There was also no correlation between the spatial pattern of response to Black and White faces ($r = .14$, $p = .309$). Together, these results show that the overall normalized response to faces from one race predicts the pattern of response to faces from another race. However, there was no similar covariation for adaptation or the spatial pattern of response. Similar patterns of response were evident in the other face-selective regions (Table 3.2).

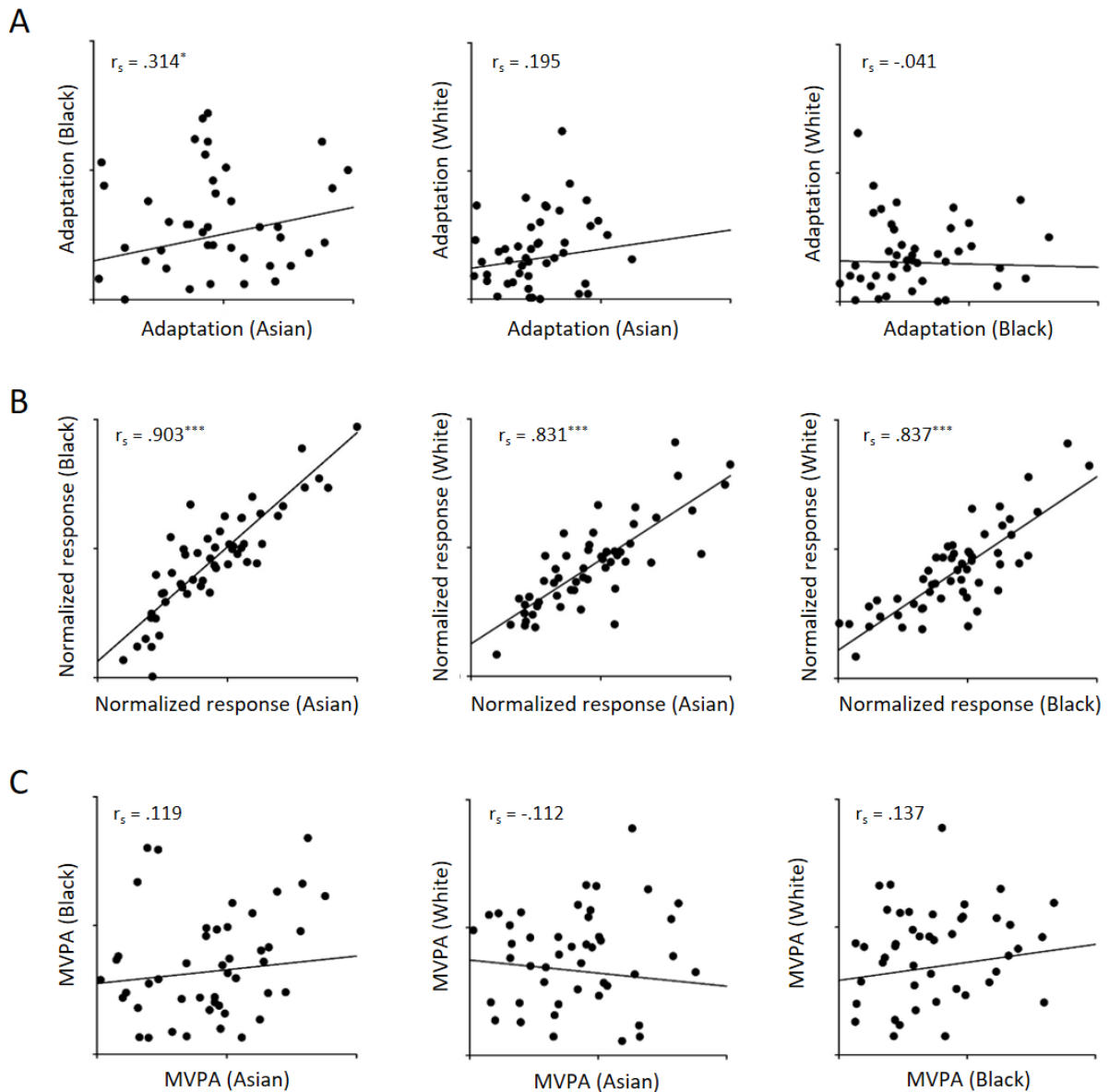


Figure 3.11 (A) Correlation of individual differences between all Face Races matches for adaptations, irrespective of participant race. Only Adaptation to Asian Faces and Adaptation to Black Faces are significantly correlated. (B) Significant positive correlations were found in all normalized response matches, suggesting a similar pattern was shared for all participants of all face races, after ruling out the effect of the scene. (C) No significant effect was found in all the Face Race matches of the spatial pattern of response.

Table 3.2 – Individual differences in *adaptation*, *normalized response* and *spatial pattern of response* across all participants.

		FFA		OFA		STS		AMG	
		r_s	p	r_s	p	r_s	p	r_s	p
Adaptation	Asian vs Black	.314	.017	-.052	.703	-.029	.829	.067	.619
	Asian vs White	.195	.147	.337	.010	.136	.314	.046	.733
	Black vs White	-.041	.762	-.071	.600	-.228	.087	.049	.719
Normalized response	Asian vs Black	.903	.000	.892	.000	.890	.000	.808	.000
	Asian vs White	.831	.000	.860	.000	.883	.000	.782	.000
	Black vs White	.837	.000	.862	.000	.864	.000	.830	.000
Spatial pattern of response	Asian vs Black	.119	.377	.239	.074	.272	.041	-.017	.902
	Asian vs White	-.112	.408	.324	.014	.281	.034	.109	.421
	Black vs White	.137	.309	.166	.216	.143	.289	.247	.064

Next, we again used an individual differences approach to ask how these different neural measures covaried (Fig. 3.12). In the FFA, we found a significant correlation between the magnitude of adaptation and the MVPA for Asian ($r_s = .34$, $p < .01$), Black ($r_s = .38$, $p < .005$) and White ($r_s = .48$, $p < .001$) faces in the FFA. However, there was no correlation between the normalized response and adaptation with Asian ($r_s = .07$, $p = .624$), Black ($r_s = .09$, $p = .517$) or White ($r_s = .01$, $p = .932$) faces in the FFA. There was also no correlation between the normalized response and the spatial pattern of response with Asian ($r_s = .20$, $p = .143$), Black ($r_s = .13$, $p = .332$) or White ($r_s = .15$, $p = .260$) faces in the FFA. These results show there was no link between the normalized response to faces and either the magnitude of adaptation or the spatial pattern of response. However, a link between the magnitude of adaptation and the MVPA was evident in the FFA. Covariation in other face-selective regions is shown in Table 3.3.

Table 3.3 – Covariance in *adaptation, normalized response and spatial pattern of response* across all participants.

		FFA		OFA		STS		AMG	
		r_s	p	r_s	p	r_s	p	r_s	p
Adaptation vs Spatial pattern of response	Asian	.340	.010	.335	.011	-.084	.536	.446	.001
	Black	.376	.004	-.114	.397	.030	.824	.056	.678
	White	.484	.000	.397	.002	-.279	.036	.186	.165
Adaptation vs Normalized response	Asian	.066	.624	.258	.053	-.092	.497	.046	.735
	Black	.088	.517	.188	.161	.141	.294	-.109	.419
	White	.012	.932	.426	.001	.087	.520	.002	.991
Normalized response vs Spatial pattern of response	Asian	.197	.143	.205	.127	.041	.762	.159	.237
	Black	.131	.332	.140	.300	.109	.419	.019	.889
	White	.152	.260	.109	.421	.033	.806	.172	.202

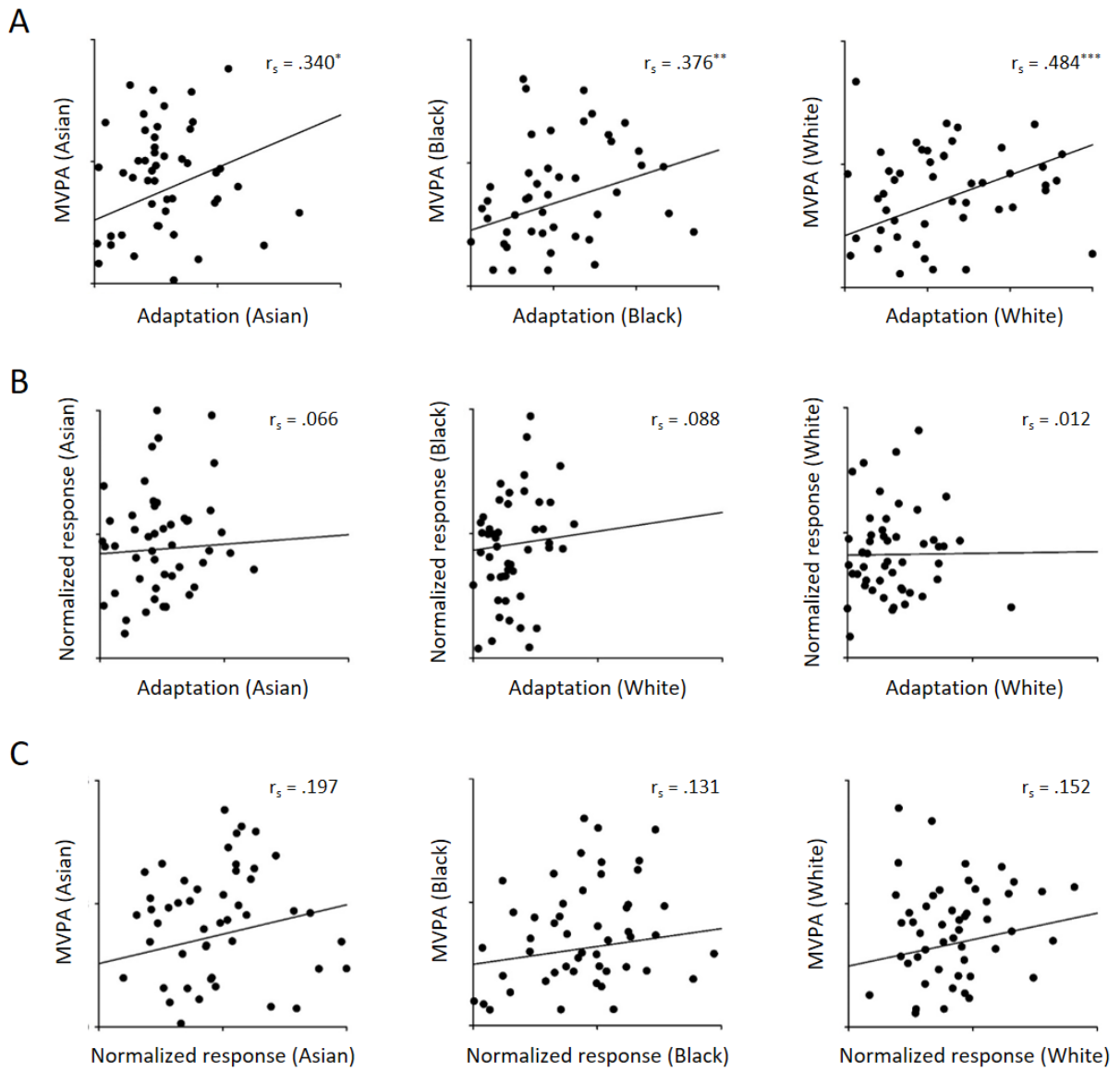


Figure 3.12 (A) Significant covariance were found between Adaptation and spatial patterns of response (MVPA) for same face race in the FFA across all participants. (B) No significant correlation was found between Normalized response and Adaptation. (C) Marginal positive correlation between spatial patterns of response and Normalized response were found.

3.4 Discussion

A range of studies has shown that own-race faces are perceived more accurately than other-race faces (Meissner & Brigham, 2001). To understand the differences in the way own-race and other-race faces are represented in the brain, we first used the fMR-adaptation paradigm (Grill-Spector & Malach, 2001; Andrews & Ewbank, 2004) to ask whether the sensitivity to changes in identity (individuation) is greater with own-race faces. We found significant adaptation (reduced response to repetitions of identity) for Asian, White and Black faces in core face-selective regions, such as the FFA. However, we did not find that the magnitude of adaptation was modified by the race of the participant. These findings also contrast with recent neuroimaging studies that found greater adaptation to own-race compared to other-race faces (Hughes et al., 2019; Reggev et al., 2020). A key difference with these previous studies is our use of a factorial (cross-over) design in which both face race and participants' race are varied simultaneously. This avoids the potential problem that results are due to differences in the stimulus set, rather than an ORE, per se. It is interesting to note that we did find a significant interaction between stimulus set and adaptation in our study. The highest adaptation was to Asian faces, with lower adaptation to White faces and Black faces. So, if our analysis had been restricted to Asian participants it would have shown levels of adaptation that were consistent with the behavioural ORE.

A prominent explanation of the ORE proposes that own-race and other-race faces are processed in different ways. Own-race faces due to their in-group status are processed at an individual level, whereas other-race faces due to their out-group status are processed at a categorical level (Rodin, 1987; Sporer, 2001; Rodes et al., 2009; Hugenberg et al., 2010). Support for this theory comes from studies, which show that other-race faces are more efficiently categorized than own-race faces, whereas own-race faces are more efficiently

individuated (Levin, 1996). A key prediction from this theory is that there should be a more distinct or individual neural response for own-race compared to other-race faces. However, the fact that we did not find differences in the magnitude of adaptation for own-race compared to other-race faces is not consistent with the idea that the ORE is due to greater individuation of own-race faces.

Although participant race did not affect the adaptation to faces, the overall response was greater for own-race compared to other-race faces in the core face regions. For example, in the FFA there was a greater response to Asian faces in Asian compared to White participants, but a greater response to White faces in White compared to Asian participants. This interaction is consistent with the behavioural ORE (Meissner & Brigham, 2001) and previous neuroimaging studies that have reported higher responses to own-race faces. For example, Golby and colleagues (2001) reported that the fusiform gyrus activated more strongly in response to own-race versus other-race faces, with activity in the left fusiform gyrus correlating with the behavioural advantage for own-race faces. Kim et al (2006) reported a stronger response to own-race faces in the fusiform face area (FFA), but this was only evident with unfamiliar faces, demonstrating that the ORE is modulated by familiarity. Feng and colleagues (2011) also found an increased activity to own-race faces in the core regions of the FFA and the occipital face area (OFA), but also in the inferior frontal gyrus and medial prefrontal cortex. Natu et al. (2011) reported an interesting temporal dimension to the ORE in which an initial bias in the FFA to own-race faces reversed to show a bias for other-race faces at later stages of the response.

Previous studies have found a larger response to other-race faces in the amygdala (Cunningham et al., 2004; Lieberman et al., 2005; Hart et al., 2000; Brosch et al., 2013). We only found a trend toward an interaction between face and participant race in the amygdala.

Moreover, this trend was for a larger response to own-race faces. However, the differential response to own-race and other-race faces reported in earlier studies has been shown to be very sensitive to task and paradigm (Kubota et al., 2012; Chekroud et al., 2014). Participants in this study responded to a change in the fixation cross. Our rationale for using this orthogonal task was that we did not want task difficulty to interfere with the neural response. It is possible that our choice of **the** task may explain the absence of an ORE in the amygdala.

Next, we asked whether there were differences in the spatial pattern of response to faces from different races. First, we asked if the spatial pattern of response to faces was more similar to other faces (irrespective of race) compared to scenes. Our results showed distinct face-selective patterns of response in the OFA, FFA and amygdala. Next, we asked if faces from different races give rise to different spatial patterns of response. To do this, we compared the pattern of response to same race faces with the response to different race faces. We found evidence for different patterns of response to faces from different races in the OFA, but not in the FFA (see also Natu et al., 2011). These findings are consistent with the idea that OFA represents an earlier stage of processing in which the structural properties of the face are represented (Haxby et al., 2000). The lack of a difference between same-race and different-race faces in the FFA suggests that race is not represented in the spatial pattern of response in this region (see also Ng et al., 2006).

The critical question is whether own-race faces have a more distinct pattern of response compared to other-race faces. We used a factorial analysis to ask if the response to Asian faces was more distinct in Asian participants and if the response to White faces was more distinct in White participants. We did not find that there was a more distinct response to own-race faces. **This result supports the findings in the behavioural tests that Asian and White participants showed a significantly similar pattern of response on their tasks across all**

face races. A similar spatial pattern of response in the BOLD signal can be seen as the cause of the similar pattern of response in behavioural tasks. Previous MVPA studies have reported mixed findings on whether the spatial pattern of response can differentiate own-race and other-race (Natu et al., 2011; Brosch et al., 2013; Ratner et al., 2013). However, not all studies used a factorial design in which the race of the participants and the faces varied concurrently. Our results show that the spatial pattern of response as revealed by fMRI was not modulated by participant race and shows that the spatial pattern of response to own-race faces is not distinct from the spatial pattern of response to other-race faces.

To determine the extent to which the different univariate and multivariate measures are related, we compared the variation across participants. First, we asked whether the neural response to faces from one race could predict the response of another race. We found that this was not the case for adaptation or the spatial pattern of response. However, we found that the normalized BOLD response to faces from one race predicted the response to faces from a different race. This was evident in all face regions. Next, we asked how the measures from one analysis could predict measures from another analysis. We found that adaptation to faces predicted the spatial pattern of response to faces in the FFA. Despite these analyses measuring seemingly unrelated aspects of the neural response, this was shown independently for Asian, Black and White faces. This link between adaptation and the spatial pattern of response was most consistently found in the FFA compared to the other face-selective regions. The dissociation between the overall response and the adaptation and MVPA measures is interesting in light of the fact that only the normalized response shows an ORE. Future studies that explore the neurophysiological basis of these measures may help understand the processes underlying the ORE.

Finally, we measured the response to objects that are perceived as faces (pareidolia). Although these objects give rise to the perception of a face, we did not expect that they would elicit a difference in response between the participants, as all participants would have a similar experience and perception of objects. Previous studies have found that pareidolic objects not only give rise to the perception of a face, but they also elicit face-like patterns of neural response (Wardle, Taubert, Teichmann, & Baker, 2020; Taubert, Wardle, & Ungerleider, 2020). Here, we found that there was a significant adaptation to pareidolic objects in face-selective regions. Moreover, the spatial pattern of response to pareidolic objects was also different to scenes. However, we found that the spatial pattern of response to pareidolic objects is distinct from the pattern to faces. Together, these findings show that the neural response to pareidolic objects in face-selective regions shows some similarities, but also some differences, to the response to faces.

In conclusion, the results from this study show the overall magnitude of neural response in the FFA to faces from different races was affected by participant race in a way that was consistent with the ORE . However, using an fMR-adaptation paradigm, we found that the sensitivity to different faces was not modulated by the race of the participant in face selective areas. The spatial pattern of response to own-race faces in core face areas was also not modulated by the race of the participant. These findings highlight the importance of using a full cross-over design in neuroimaging studies to investigate group differences in behaviour.

4. NO EVIDENCE FOR AN ORE IN JUDGEMENTS OF DOMINANCE OR TRUSTWORTHINESS

4.1 Introduction

When we encounter unfamiliar people, one of the most salient sources of information about that person is their face. From their face, we can form an impression of their gender, age and ethnicity (Bruce and Young, 2013). We can also make more subjective judgements of their character or traits, such as whether they are trustworthy (Todorov et al., 2015). Despite limited evidence about the accuracy of these first impressions, they are reliable across observers. These judgements can also have important consequences in the real world. For example, impressions of competence from facial photographs of politicians have been shown to predict the outcome of elections (Olivola, Funk, & Todorov, 2014). Recent behavioural models of facial impressions suggest that they are based on three key dimensions: trustworthiness, dominance and attractiveness (Todorov et al., 2015; Sutherland et al., 2013). Trustworthiness and dominance are linked to the evaluation of competence and threat (Fiske et al., 2007), while attractiveness is linked to reward (Sutherland et al., 2013; Rhodes, 2006). As these dimensions can explain a large proportion of the variance across different trait judgements, they have formed an influential theoretical framework in face perception (Todorov et al., 2015).

A potential limitation in our understanding of facial impressions is that the majority of studies involve judgements of White faces with White participants. So, it is not clear how these trait judgements are affected in faces from other races or when faces are viewed by participants of a different race. It is well-established that the perception of own-race faces is better than **of** other-race faces (Malpass and Kravitz, 1969; Meissner & Bringham, 2001).

Although the other-race effect (ORE) has mostly investigated the perception of identity, other studies have shown an ORE for the perception of facial expression (Yuki et al., 2007; Jack, Garrod, Yu, Caldara, & Schyns, 2012; Yan et al., 2016; Jack & Schyns, 2017). The facial cues that are used for trait judgements have been shown to be dependent on invariant aspects of faces such as gender and age, as well as changeable aspects of faces, such as expression (Oosterhof and Todorov, 2008; Sutherland et al., 2013; Vernon et al., 2014). This suggests that our perception of facial first impressions may differ for own-race faces compared to other-races faces.

The perception of facial impressions may also be affected by social categorization and intergroup bias (Cook and Over, 2021). Findings from work on intergroup bias show that individuals attribute positive characteristics to members of their own group, but have a less favourable perception of members from an outgroup (Allport, 1954; Sherif et al., 1961; Tajfel and Turner, 2004; Turner et al., 1987). As social interactions often begin with the face, the categorization of other-race faces as part of the outgroup may lead to negative stereotypes that could have an effect on trait judgements (Fiske et al., 2007; Amodio, 2014). Indeed, it has been argued that the facial properties, such as skin colour, that are important for social categorization may dominate other sources of facial information when trait judgements are made across individuals in the wider population (Cook and Over, 2021).

A number of studies have begun to investigate the effect of race on trait judgements of faces (Zebrowitz et al., 1993, 2010; Stanley et al., 2011; Sutherland et al., 2018; Jones et al., 2021; Xie et al 2019; Oh et al., 2020; Charbonneau et al., 2020; Short et al., 2012). These studies have shown that there are some cross-cultural similarities, but also cross-cultural differences in the way that trait judgements are made. For example, recent studies have explored the extent to which dimensional models of first impressions (Todorov et al., 2015;

Sutherland et al., 2013) might vary across different races. These studies report that there are similarities as well as differences in the models across different cultures (Sutherland et al., 2018; Jones et al., 2021). However, given the variation across faces within a race, it is possible that the level of cross-cultural differences may also be influenced by variance in the images used in different image sets (Xie et al., 2019). For example, it is known that ratings of attractiveness vary dramatically across faces from the same race and indeed from different images of the same person (Jenkins, White, Van Monfort and Burton, 2011).

The aim of this study was to directly compare the reliability of trait judgements using a novel paradigm in which participants compared pairs of faces. This paradigm is commonly used in studies of facial identity, in which participants have to decide whether two faces belong to the same identity. Applying the same image set in chapter 2 will ensure that participants have an ORE in these face trait judgement tasks. The use of a 2AFC design may also provide a more unbiased measure compared to previous studies in which participants are often asked to rate faces on a 7-point scale. In this study, participants were asked to rate which of the two faces is more dominant or trustworthy in different trials. Reliability, which represents how variant the participants responded, was measured for each face pair by measuring how often participants chose the same face. We then asked whether reliability for own-race faces was greater than for other-race faces. A cross-over design was used to measure the performance of East-Asian and White participants when they viewed East-Asian, Black and White faces. Given that own-race faces are perceived more accurately than other-race faces and the effect of social categorization, our prediction was that participants should have lower reliability of trait judgements for other-race faces.

4.2 Methods

4.2.1 Participants

We recruited an opportunity sample of 128 participants (68 Asian: 43 females, mean age: 23.8; 60 White: 51 females, mean age: 18.9) for this study. 62 participants (32 Asian, 30 White) were assigned to the Dominance group and 66 participants (36 Asian, 30 White) were assigned to the Trustworthy group. **The validity of the sample size was confirmed with G*power software. A total sample size of 132 participants would be enough to detect the between-group effect with a power of 0.95 at an alpha level equal to 0.05, 1 non-sphericity and effect size of 0.3 in a 3 (face race) x 2(face traits) x 2(participant race) repeated measures ANOVA.** All Asian and White participants had grown up in East Asian and Western European countries, respectively. For Asian participants, their average time in the UK period was about 12 months (Mean \pm SEM: 12.6 \pm 1.36). All participants gave their written informed consent. The study was approved by the Psychology Ethics Committee at the University of York. Participants were compensated with course credit or a voucher for participation.

4.2.2 Stimuli and Procedure

Images of White faces were taken from the Models Face Matching Test (Dowsett & Burton, 2015). Images of Asian and Black faces were taken from a variety of sources on the internet. There were 180 images for each task, which were arranged in 90 face pairs. **Half of the trials had faces with the same identity and half had faces from different identities. The face expression and selection criteria were the same in chapter one, as the design of this experiment will explore dominance and trustworthiness from two participant groups with the same face images.** The images were cropped to 158 x 222 pixels. At a viewing distance of approximately 57 cm, each image subtended 7.8 x 10.2 degrees of visual angle (see Chapter

2). Participants were assigned to a dominance or trustworthiness group. On each trial, they were asked to determine which face was more dominant or more trustworthy. We decided not to make judgements to test the dimension of youthful/attractiveness because the faces used in this study were taken from male models that had similar ages and levels of attractiveness. The tasks were self-paced and new trials would only appear after a response had been made. Participants performed judgments on Asian, Black and White faces in separate tasks. The order of tests was counterbalanced across participants. The experiment was performed online using Pavlovia.

We measured the reliability of each item in the task. This was done by first calculating the proportion of trials in which either the left or the right image was chosen across each group of participants. A value of 0.5 would indicate that 50% of participants had chosen one face and 50% had chosen the other. This was taken as a baseline from which reliability was calculated. The absolute difference between the proportion selected across a participant group for each trial and 0.5 was calculated. This value was then multiplied by 2. Thus, if on a particular trial one face was perceived to be more dominant in 75% of trials, the reliability would be $(0.75-0.5)*2$. This allowed us to calculate the average reliability across trials for either dominance or trustworthy judgements for Asian or White participants for each of 3 tasks. It also allowed us to correlate reliability values across participant groups and judgements of trustworthiness or dominance with the same images.

4.3 Results

We first asked whether there was an ORE for judgements of trustworthiness or dominance. We calculated the average reliability of judgements across items in each task for each participant group (Asian, White) for each test (Asian, Black, White). Figure 4.1 shows the average reliability of Asian and White participants in the dominance and trustworthy tasks. It is clear from the graphs that average reliability scores were significantly greater than chance (Table 1). This shows that participants were reliably reporting dominance and trustworthiness judgements. A 3 (Face: Asian, Black, White) x 2 (Participant: Asian, White) mixed effects ANOVA was performed separately for the trustworthy and dominance groups to determine the effect of face race and participant race on trait judgements.

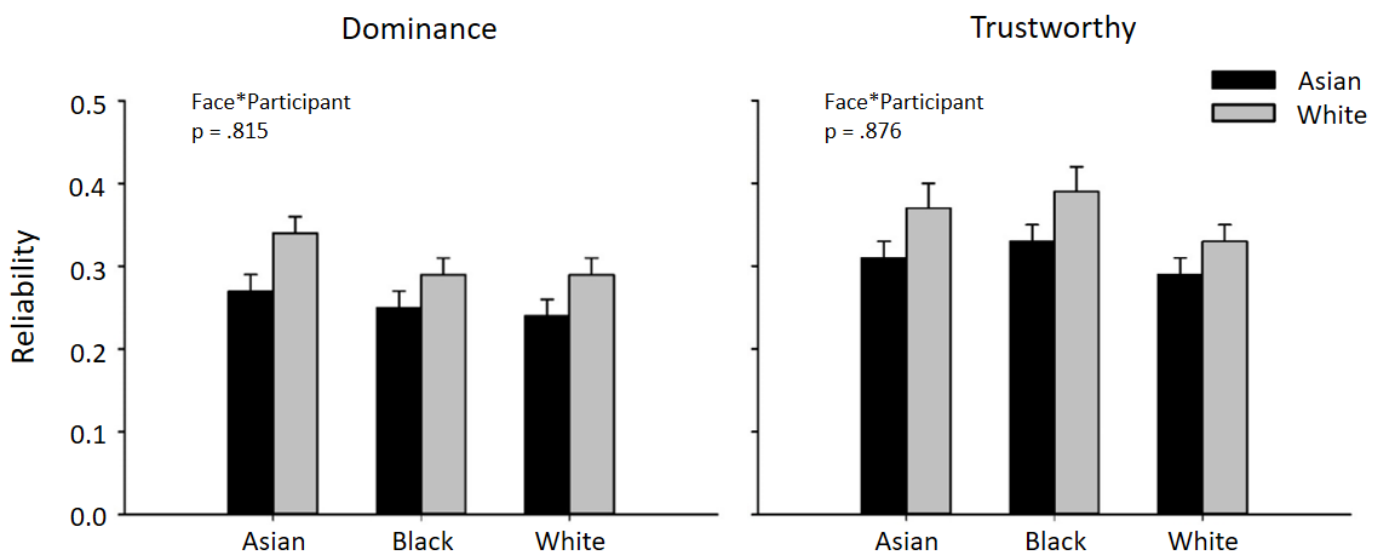


Figure 4.1 Reliability on the dominance and trustworthy task with Asian and White participants viewing Asian, Black and White faces. The data show no significant effect of the participants' race. Error bars show +1 SEM.

Table 4.1 – Comparison of calculated reliability versus chance (50%). All values were significantly above chance indicating that participants were consistent in their judgements of individual items.

		Asian Face		Black Face		White Face	
		t	p	t	p	t	p
Asian	Dominance	15.432	<.001	13.354	<.001	14.195	<.001
	Trustworthy	13.099	<.001	15.260	<.001	13.849	<.001
White	Dominance	15.500	<.001	14.544	<.001	14.872	<.001
	Trustworthy	14.504	<.001	15.144	<.001	14.239	<.001

For dominance judgements, there was a significant effect of Participant ($F(1, 178) = 12.497, p < .001$, Partial Eta Squared = .066), but no effect of Face ($F(2, 356) = 3.036, p = .052$, Partial Eta Squared = .017). The effect of participant was due to higher reliability scores with White participants (mean \pm sem: 0.311 ± 0.021) compared to Asian participants (mean \pm sem: 0.254 ± 0.018). However, there was no interaction between Face and Participant ($F(2, 356) = 0.254 \pm 0.018$). However, there was no interaction between Face and Participant ($F(2, 356) = .193, p = .815$, Partial Eta Squared = .001). This shows that reliability judgements of dominance were not affected by participant race. Therefore, there is no evidence for an ORE for judgements of dominance.

For the trustworthy judgements, there was a significant effect of Participant ($F(1, 178) = 9.491, p < .01$, Partial Eta Squared = .051), but no effect of Face ($F(2, 356) = 1.577, p = .208$, Partial Eta Squared = .009). The effect of participant was due to higher reliability scores with White participants (mean \pm sem: $0.365 \pm .025$) compared to Asian participants (mean \pm sem: 0.308 ± 0.022). However, again there was no interaction between Face and Participant ($F(2, 356) = .133, p = .876$, Partial Eta Squared = .001). This shows that reliability judgements of

dominance were also not affected by participant race. Therefore, these data show no evidence for an ORE for trustworthy judgements.

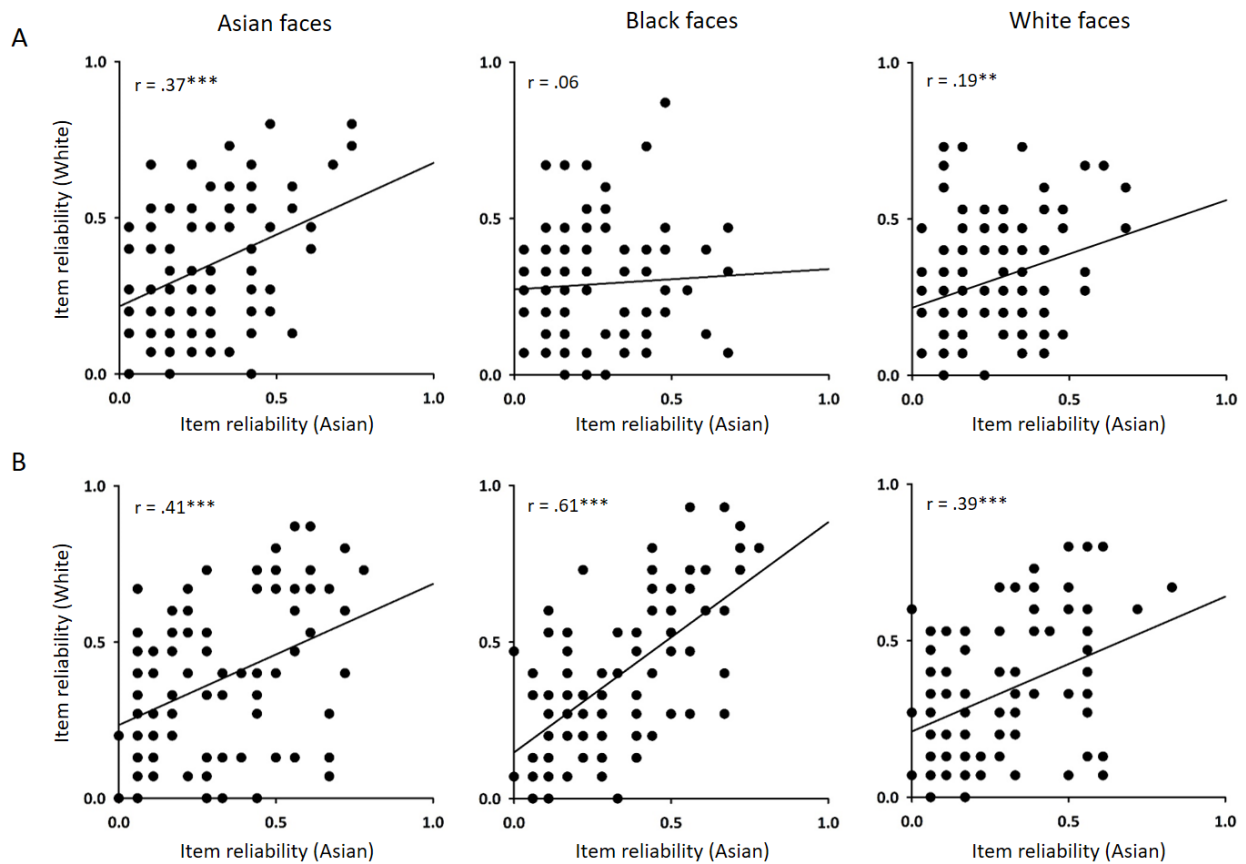


Figure 4.2 Correlation between item reliability of Asian and White participants across Asian, Black and White face for (A) dominance and (B) *trustworthiness*. Significant positive correlations were found for each task for both own-race and other-race faces except black faces in dominance, suggesting a similar pattern of face impression formation for Asian and White participants. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Next, we asked if judgements of dominance or trustworthiness were similar across participants from different races. To do this, we correlated the reliability values of individual items across the different groups of participants (Figure 4.2). For Asian and White faces, there were significant correlations between Asian and White participants for reliability scores on items for dominance (Asian: $r_s = .37$, $p < .001$; White: $r_s = .19$, $p < .01$) and trustworthy judgements (Asian: $r_s = .41$, $p < .001$; White: $r_s = .39$, $p < .001$). For Black faces, there was a significant correlation between White and Asian participants for trustworthy judgements (r_s

= .61, $p < .001$), but not for dominance judgements ($r_s = .06$, $p = .095$). Overall these data show similar patterns of dominance and trustworthy judgements across Asian and White participants.

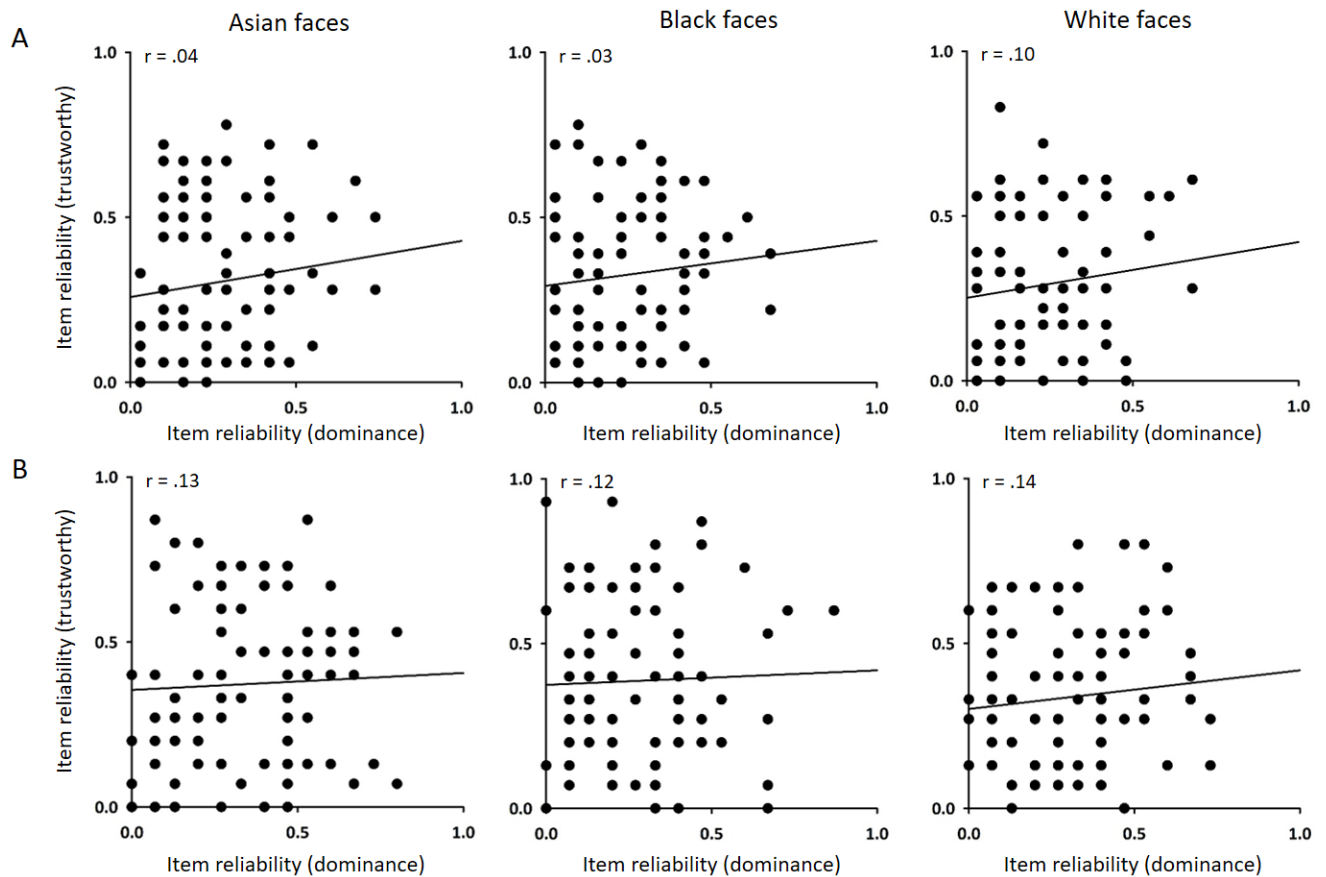


Figure 4.3 Item analysis correlation between dominance and *trustworthiness* across Asian, Black and White faces for (A) Asian and (B) White participants. No significant correlations were found *in all the conditions*.

Next, we asked whether reliability judgements of dominance and trustworthiness were linked (Fig. 4.3). To do this, we correlated the reliability of dominance judgements with the reliability of trustworthy judgements across the same items for Asian (Fig. 4.3A) or White (Fig. 4.3B) participants. We found no correlation between the reliability of trustworthy and dominance judgements, which is consistent with the idea that these judgements are independent.

Finally, we investigated whether the identity of face pairs had any effect on the reliability of judgements of dominance and trustworthiness. Specifically, we asked if judgements on different identity trials were more reliable than for same identity trials. A 3 way (Face: Asian, Black, White) x 2 (Participant: Asian, White) x Identity (Same, Different) ANOVA was performed for Asian and White participants. We found no interaction between identity, Face Race and Participant Race in both Dominance and Trustworthy trials across all the combinations of participant races and face races (See Table 4.2), which indicates the identity of face pairs does not influence the form of face impression for Asian and White participants.

Table 4.2 3-way ANOVA showing *the* interaction between Identity, Face and Participant. There were no significant interactions showing that judgements of dominance or trustworthiness were not affected by whether the faces had the same or a different identity.

		df	F	Sig	η^2
	Identity * Face	2, 528	2.509	.082	.009
Dominance	Identity * Participant	2, 528	1.214	.271	.002
	Identity * Face * Participant	2, 528	2.061	.128	.008
	Identity * Face	2, 528	2.041	.131	.008
Trustworthy	Identity * Participant	2, 528	1.280	.258	.002
	Identity * Face * Participant	2, 528	0.126	.881	.000

4.4 Discussion

The aim of this study was to determine whether there was an other-race effect (ORE) for trait judgements of faces. To address this question, we measured judgements of dominance and trustworthiness judgments from East Asian and White participants while viewing East Asian, Black and White faces. Our results show no evidence for an ORE in first impressions. That is, reliability was not significantly different between own-race and other-race faces. Moreover,

we found that the pattern of response to individual items was similar across participants from different races.

The ORE shows that cultural background can affect the recognition of both the identity and expression of a face. A variety of studies have shown that people are more accurate at recognizing unfamiliar faces from their own ethnic group (Yan, Andrews, Jenkins and Young, 2016; Brigham, Bennett, Meissner & Mitchell, 2007; Meissner and Brigham, 2001; Chance and Goldstein, 1981). A similar own-race advantage has been found in facial expression recognition (Elfenbein & Ambady, 2002; Jack, Caldara & Schyns, 2012; Yan, Andrews & Young, 2016). These findings suggest that we are less able to discriminate faces from other races. In our study, participants made judgements of either dominance or trustworthiness based on pairs of faces. The faces were taken from identity matching tasks in which an other-race effect has been previously reported (Wang, Laming & Andrews, 202?). However, in the current study, participants had to decide which face was the most trustworthy or which face was the most dominant. We found that people did not perform this task idiosyncratically, but showed a bias toward one face or the other. Nevertheless, we did not find that consistency or reliability of this bias was any different for own-race faces or other-races faces.

There is mixed evidence for the role of culture in facial first impressions. Some studies have found significant cross-cultural similarities when people make these trait judgements (Zebrowitz et al., 1993; Cunningham et al., 1995; Walker et al., 2011). For example, Zebrowitz and colleagues (1993) found high levels of intra-observer and inter-observer reliability in trait judgements of faces. However, other studies suggest that there are significant cross-cultural differences (Krys et al., 2013; Zebrowitz et al., 2012; Xie et al., 2019). For example, Xie and colleagues (2019) reported that the perceiver's race and gender explained more of the variance than the face image when making trait judgements. A lack of convergence on the

effect of race or culture on judgements of first impressions is also evident in data-driven models of first impressions. These show evidence for common dimensions across a range of judgements (Sutherland et al., 2018). However, other studies suggest that regional differences are also revealed in these analyses (Jones et al., 2021).

One possible reason for variation across studies could be the significant variation that occurs within faces of the same race. It is possible that the level of cross-cultural differences may be influenced by variance in the faces used in different image sets. In our study, participants judged the same faces using a two-alternative forced choice. The advantage of this approach is that it provides an unbiased measure. Participants do not have to make absolute judgements with reference to an internal representation of the dimension that is being judged, but rather they just have to make a relative judgement. Studies of sensory perception have shown that relative judgements are more accurate and reliable than absolute judgements (c.f. Andrews et al., 2001).

Our findings that there is **no** ORE in the reliability of trait judgements **are** surprising in the context of the effect of race on stereotypical judgements. For example, it is well-established **that** the categorization of people into social groups can lead to the development of stereotypes, in which we perceive members of our own group more positively than members of other groups (Fiske & Neuberg, 1990; Macrae and Bodenhausen, 2000; Amodio, 2014). Individuals are often discriminated against because of their nationality, ethnicity, political ideology and sexual orientation (Paluck, 2016; Cikara & van Bavel, 2014; van Bavel, Packer, & Cunningham, 2008). In many parts of Europe and in the USA, immigrants face rising hostility from the local population and support for explicitly racist political groups is increasing (Hainsworth, 2016). These biases emerge early in development and can be highly resistant to change (Bigler & Liben, 2007; Over, Eggleston, Bell, & Dunham, 2017; Over & McCall, 2018).

Our findings may provide a helpful outlook in attempts to reduce prejudice (Paluck, 2016) by showing that race-based stereotypes do not reflect cross-cultural differences at a perceptual level.

Models of facial impressions suggest that they are based on three key dimensions: trustworthiness, dominance and attractiveness (Todorov et al., 2015; Sutherland et al., 2013). In our study, we were able to partially test this construct by comparing reliability on the same items for judgements of trustworthiness or dominance. Our findings showed that there was no correlation between these judgements. This shows that in our 2AFC paradigm, these trait judgements were being performed independently. We were also able to determine the role of identity in these judgements. In each test, half of the face pairs were from the same identity and half were from a different identity. Nevertheless, we did not find that the identities of the face pairs had any effect on the judgements of first impressions. This provides further support for the idea that information from faces is processed along parallel pathways (Bruce and Young, 2012).

In conclusion, our results show that using a novel 2AFC paradigm that there was no ORE effect for judgements of first impressions. We found that there was no significant effect of participant race in judgements of dominance or trustworthiness. The advantage of the 2AFC paradigm is that it is a relative rather than an absolute measure. Using this approach, we also showed that there was no correlation between judgements of trustworthiness and dominance and these judgements were not influenced by the identities of the faces. Taken together these findings show that stereotypical judgements of other-race individuals do not result from cross-culture differences in perception.

5. VARIATION IN THE SHAPE AND TEXTURE OF FACES FROM DIFFERENT RACES

5.1 Introduction

One possible explanation of the ORE is that faces from different races show different levels of variation in their facial features (the homogeneity hypothesis). This hypothesis suggests that other-race faces have less physiognomic variability compared to own-race faces. This hypothesis has been challenged by studies that have shown that the ORE can be reversed when participant race is changed (see Meissner and Brigham, 2001). For example, Asian and White participants show an opposite ORE with Asian and White faces (see Chapter 3). Other evidence challenging the homogeneity hypothesis comes from studies that have measured variability in facial features across different races. For example, Goldstein (1979) investigated physiognomic variability in faces from different races, using measures such as head height, nose width and interocular distance, and found no evidence of differences in variability.

Although these findings provide no compelling evidence for the homogeneity hypothesis, the difference in recognition of own-race and other-race faces suggests that facial features are likely to vary in different ways in faces from different races (Ellis, Deregowski, & Shepherd, 1975; Shepherd & Deregowski, 1981). Indeed, the fact that we are easily able to perceive the race of faces shows that the facial features of different races are to some extent distinct (Hill, Bruce and Akamatsu, 1995; Bruce & Young, 2012; Yan et al., 2017). Nevertheless, there is relatively little work that has investigated how the visual properties of faces vary across different races beyond obvious differences in hair or skin colour.

A distinction between shape and texture is often used to investigate how variation in the face image contributes to different types of face perception (Bruce & Young, 1998, 2012; Andrews et al., 2016). The shape of faces is based on changes in reflectance due to the shapes

and positions of facial features. The texture of the face results from the pattern of reflectance of light that results from the ambient illumination, face pigmentation, and shape from shading cues due to the 3D structure of the face. A number of studies have investigated the extent to which the shape or texture of faces provides diagnostic information that allows us to discriminate between different social categories such as age and sex. These studies show that both shape and texture information provide important diagnostic information about age and sex and that these cues are actually used perceptually (Burton, Bruce and Dench, 1993; Bruce, Burton, Hanna et al, 1993; Burt and Perrett, 1995).

The physical differences associated with race have been less extensively studied compared to other social categories, such as age or sex. However, one study showed that the faces of different races differ in average shape, as well as in hair and skin colour (Frakas, Katic and Forrest, 2005). To determine whether these visual properties are used in judgements of race, Hill and colleagues (Hill et al., 1995) used image analysis techniques to generate hybrid faces that combine the shape and colour of faces from different races. Consistent with the image variation in faces from different races, their results showed that both shape and colour were important in judgements of face race.

Although our perception of social categories, such as sex and race, appear to depend on variation in both shape and texture, a range of evidence suggests that the texture of the face is more important than shape for the recognition of identity (Hole et al., 2002; Burton, Jenkins, Hancock & White, 2005; Russell et al., 2007; Russell & Sinha, 2007). For example, familiar face recognition is not substantially affected if the surface properties are presented on a standardized shape (Burton et al., 2005), or when the face shape is distorted by stretching the image (Hole et al., 2002). Consistent with the importance of texture, line drawings of faces, which contain shape information, but lack any texture, are not usually

sufficient for recognition (Davies et al., 1978; Leder, 1999), whereas contrast reversed faces that cause large changes in texture but do not affect the shape of the face disrupt recognition (Bruce and Langton, 1994; Russell et al., 2006; Harris, Young and Andrews, 2014).

However, the shape of a face has been suggested to play an important role in face recognition (for reviews see Maurer et al, 2002; McKone & Yovel, 2009; Tanaka and Gordon, 2011; Piepers & Robbins, 2012). Indeed, a number of studies have shown that shape information can be used to discriminate unfamiliar face images (O'Toole et al., 1999; Jiang, Blanz & O'Toole, 2006; Russell et al., 2007; Russell & Sinha, 2007, Caharel et al., 2009; Jiang, Blanz and Rossion, 2011).

A problem in linking image properties of faces with the perception of identity is that as we interact with the natural environment, the shape and texture of a face change dramatically due to changes in lighting, as well as rigid and non-rigid movements of the face. To be useful, the cognitive processes involved in recognition must be able to ignore these changes to reveal an invariant representation that can be useful for recognition (Bruce et al. 1987; Hancock et al. 2000). Principal Components Analysis (PCA) has been used extensively to describe image variation in faces (Turk and Pentland, 1991; O'Toole et al., 1993; Calder et al., 2001; Tredoux et al., 2002; Nestor et al., 2013). PCA can be applied independently to the shape and texture to generate descriptions of the image that are related to perception (Hancock, Burton & Bruce, 1996; Tiddeman et al., 2001; Kramer et al., 2017). However, a problem with PCA is that it is very sensitive to ambient changes in the image (lighting, viewpoint) that may not convey information about identity (Hancock, Bruce & Burton, 1998). More recently, deep convolutional neural networks (DCNNs) have surpassed other computational approaches and are able to recognize face images across a range of natural viewing conditions (O'Toole et al., 2018; Parkhi, Vedaldi and Zisserman, 2015). Although

DCNNs have a structure that is analogous to the human visual system (Krizhevsky et al., 2012), the extent to which it operates in a similar way to the human visual system remains unclear (Kriegeskorte et al., 2015).

The aim of this study was to investigate (1) how shape and texture vary across faces from different races (2) how this information is used for judgements of face identity **when there is a clear other-race effect**. To address this issue, a principal components analysis was used to measure the shape and texture of face images from East Asian, Black and White faces. First, we asked whether similarity in the shape or texture of images was better able to differentiate faces from different races. Next, we asked whether shape and texture information could be used to predict performance in human participants. Finally, we asked whether the performance of a computer vision model of face recognition could also be predicted by behavioural responses on the matching task. **The image analysis focused on comparing differences across race and how these differences in shape and texture predict the behavioural tasks performance on identity discrimination. Detailed comparison within same and different identity was not included in this analysis.**

5.2 Methods

5.2.1 Stimuli

Images were the same as those used in Chapter 2. Images of White faces were taken from the Models Face Matching Task (Dowsett & Burton, 2015). The images for the Asian and Black matching tasks were taken from a variety of sources on the internet, making a total of 540 face images with 180 faces per race **with 45 pairs of the same identity and 45 pairs of different identities**. The images were cropped to 158 x 222 pixels.

5.2.2 Principal Components Analysis (PCA)

Images were rescaled to 380 x 570 pixels and converted to greyscale. The shape of each image was determined by aligning 82 fiducial points to each face (Kramer, Jenkins and Burton, 2016). The texture of each face was generated by warping each image to a standard shape. To ensure the reliability of the measurements, this process was performed independently by two experimenters on all the images. Landmarking was then adjusted based on **the** two experimenters' alignment. A principal components analysis (PCA) was then run on all images independently for shape and texture. The PCA generated a matrix of principal components for the 540 (images) x 539 (principal components, PCs) for both shape and texture. A similarity matrix was then determined by correlating (Pearson's r) the PCs from one image with the PCs from a different image. The analysis was restricted to the first 50 PC components which account for 85% and 92% of the total variance for shape and texture respectively. Correlation values were Fisher transformed before further statistical analysis.

5.2.3 Deep Convolutional Neural Network (DCNN)

We used the VGG-Face DCNN (Parkhi, Vedaldi and Zisserman, 2015), which consists of 13 convolutional layers and 3 fully connected (Fc) layers. The input to the network is an image of size 224 x 224. Each convolutional layer is followed by one or more non-linear layers, such as rectified linear units or max pooling. The first two FC layers have 4096 dimensions and the final FC layer has 2622 dimensions. The DCNN was trained on over 2.6M face images from over 2.6K identities. Face recognition on the Labeled Faces in the Wild dataset (Huang et al., 2008) and YouTube Faces (Wolf et al., 2011) for VGG-Face is 99.9% and 97.4%, respectively.

5.2.4 Behavioural Measurements

Behavioural measurements were taken from Chapter 2. Participants were asked to indicate whether each pair of faces was from the same identity or a different identity. The task was self-paced, but the time spent on each task was recorded. We measured discriminability (d') (Horry, Cheong & Brewer, 2015), by calculating hits (trial: same identity, response: same), misses (trial: same identity, response: different), false positives (trial: different identity, response: same) and correct rejections (trial: different identity, response: different). To further explore the pattern of performance for the two race groups in matching tasks, performance on same-identity and different-identity faces were determined separately for each task and participant group.

5.3 Results

5.3.1 Image differences in faces from different races

To determine whether shape and texture information differs for each race, a PCA was performed on the 540 images (180 from each race) separately for both shape and texture. A

similarity matrix was then calculated by correlating (Pearson's r) the PCs from one image with the PCs from a different image.

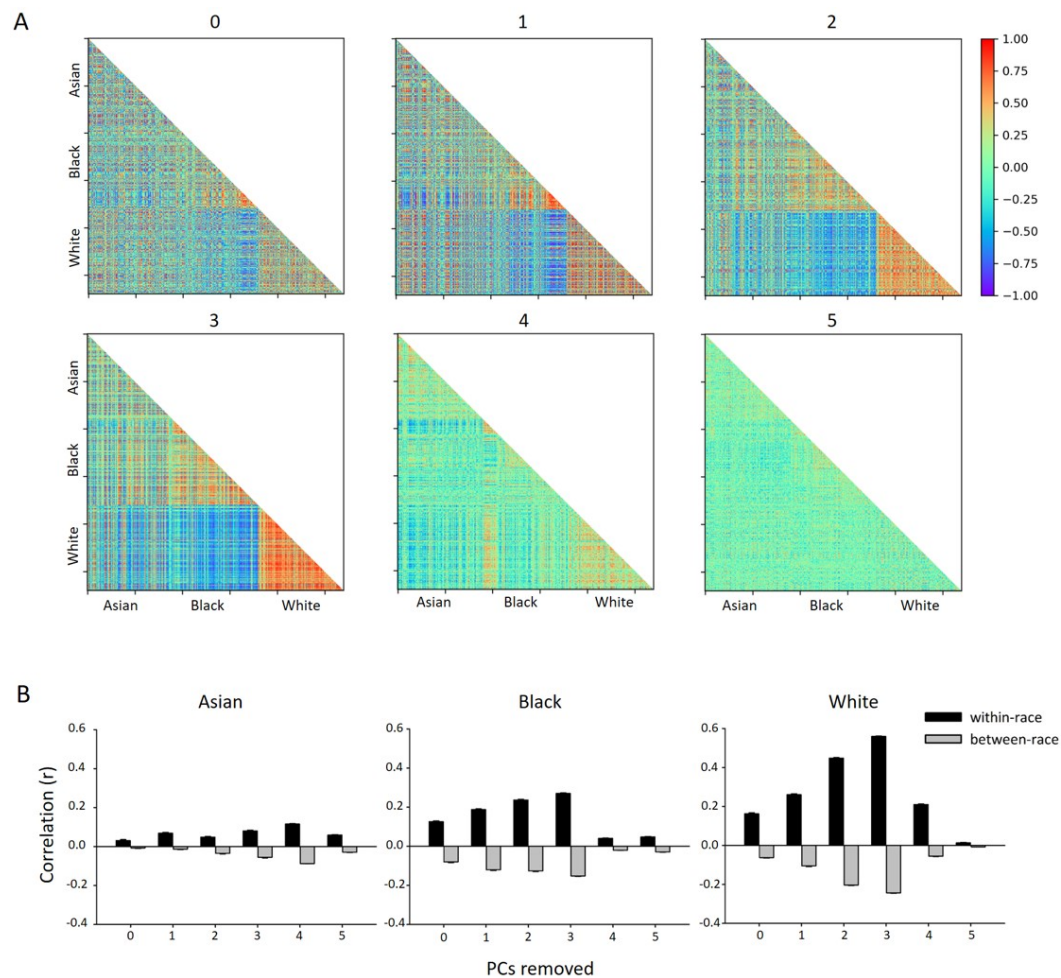


Figure 5.1 (A) Similarity matrices showing the correlation between shape PCs from the 540 different faces images. The similarity matrix was calculated when the first PCs were removed from the correlation between images. The difference between races became more distinct when the 3 PCs were removed. (B) A comparison of averaged within-race similarity and between-race similarity. Errors are SEM.

Figure 5.1A shows the similarity matrices based on the shape of faces from different races. The difference between each matrix is the number of PCs removed from the analysis. For example, 0 shows the shape similarity when all 50 PCs were used in the analysis, 1 indicates the similarity when the first PC was removed, 2 indicates the first and second PCs

were removed, etc. The similarity matrices show that as PCs were removed the shape of faces from different races became more and more distinct. The difference between within-race and between-race values for each PC removed is shown in Figure 5.1B for each race. A statistical analysis of the within versus between race differences in shape is shown in Table 5.1. This shows that the difference between the shape of faces from different races was most evident when the first 3-4 PCs were removed from the analysis.

Table 5.1 Within-race and between-race comparison of shape.

PC	Asian		Black		White	
	t	p	t	p	t	p
0	9.58	.0001	45.68	.0001	50.95	.0001
1	19.63	.0001	68.26	.0001	75.88	.0001
2	18.86	.0001	91.53	.0001	182.97	.0001
3	33.15	.0001	112.33	.0001	242.28	.0001
4	82.01	.0001	24.58	.0001	104.88	.0001
5	43.12	.0001	37.22	.0001	9.11	.0001

Figure 5.2A shows the similarity matrices for texture. In contrast to shape, the within-race compared to **the** between-race difference was greatest when all PCs were used and this gradually decreased as PCs were removed (Table 5.2). Although texture differences were able to differentiate within-race and between-race faces, a comparison with Table 5.1 shows that this was greater for shape.

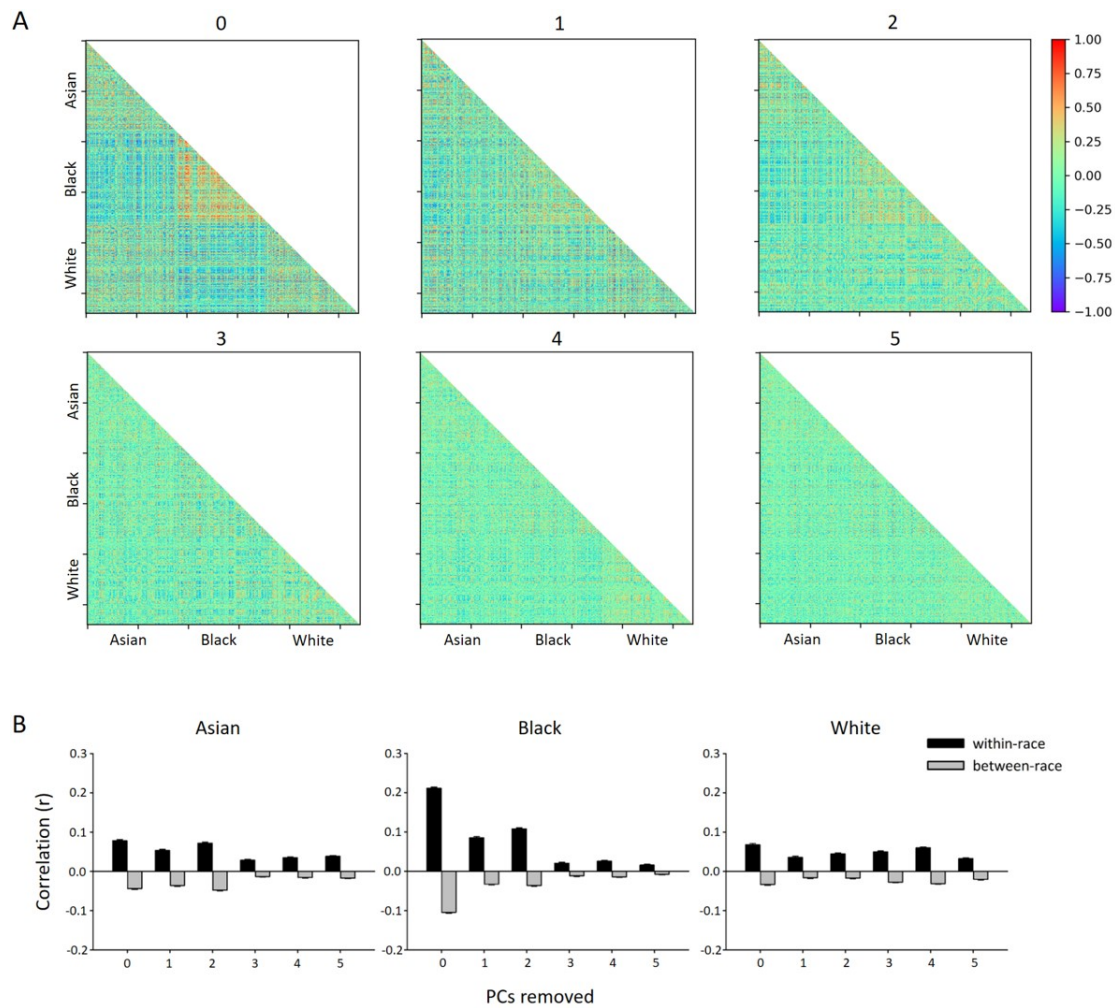


Figure 5.2 (A) A principal components analysis (PCA) of the texture of images from three races (540 images) generates 539 *principal* components (PCs) for each image. After *being* restricted to the 0 – 50 PCs, correlations between the PC of each pair of images were calculated to produce a similarity matrix for texture. (B) A comparison of averaged within-race similarity and between-race similarity. Removing PCs demonstrated the great effect of the first PC *on* the similarity between within- and between-race faces for texture, especially in Black faces.

Table 5.2 – Within-race and between-race comparisons for texture.

PC	Asian		Black		White	
	t	p	t	p	t	p
0	36.94	.0001	96.74	.0001	30.09	.0001
1	27.70	.0001	38.40	.0001	16.00	.0001
2	41.40	.0001	52.79	.0001	24.22	.0001
3	18.96	.0001	12.37	.0001	31.58	.0001
4	23.78	.0001	17.57	.0001	43.51	.0001
5	27.97	.0001	10.68	.0001	26.99	.0001

5.3.2 The role of shape and texture on judgements of identity

Next, we asked whether performance on the face matching task could be predicted by shape and texture of the face images. The 180 images from each race were presented in 90 face pairs (45 same identities, 45 different identity). These images were shown to 70 White and 70 East Asian participants (see Chapter 2). For each face pair, we calculated the proportion of the same identity responses for Asian participants and for White participants and the similarity in shape and texture.

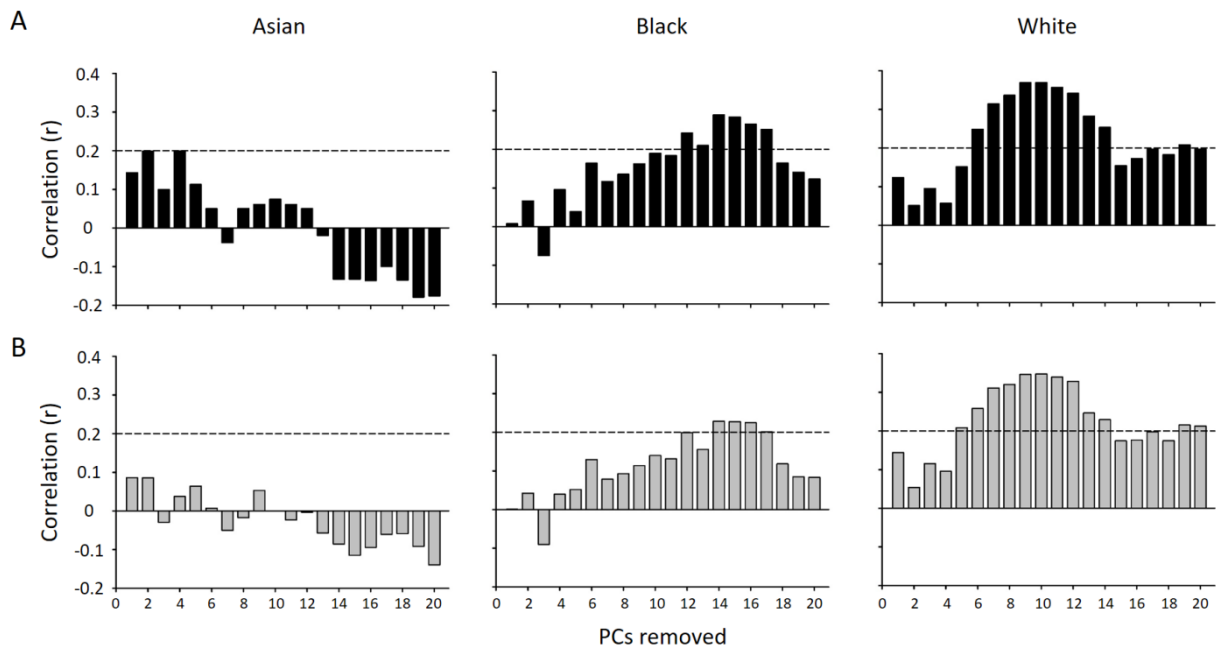


Figure 5.3 (A) The correlation between face matching behavioural task performance (proportion same) and face matching image pairs similarities in shape for each face race of Asian participants, (B) and White participants. The results show that for both Asian and White participants, the correlation between shape and perceived similarity *has* a similar trend across all three face races. As early PCs were removed, both Asian and White participants' performance showed a decline in correlation with Asian faces, and a generally increasing correlation with a peak at 14 PCs removed towards black faces, and a dramatic rise in correlation with White face followed by a slope at 10 PCs removed. The dashed line indicates the critical r -value at $p < 0.05$.

First, we asked whether the shape of the face images could predict behavioural judgements. Fig 5.3 shows the correlation between the average perceptual response (proportion same) across participants and the similarity of the images in each face pair for the 90 trials in each task. A significant correlation between perception and shape similarity only became apparent for Black and White faces when the initial PCs for shape and texture were removed from the analysis. The correlations between shape and perceptual judgements for Asian faces failed to reach significance.

To investigate whether there were any differences between Asian (Fig 5.3A) and White participants (Fig 5.3B), we compared corresponding correlation values for each race

(Diedenhofen & Musch, 2015). There were very few significant differences in the magnitude of the correlations between shape and perception between participants from different races for any of the face races (Table 5.3). A correlation between the data in Fig. 5.3A (Asian participants) and Fig. 5.3B (White participants) showed a very similar pattern for Asian ($r = .910$, $p < .001$), Black ($r = .988$, $p < .001$) and White ($r = .984$, $p < .001$) faces. These findings suggest that Asian and White participants are using shape information in a similar way.

Table 5.3 – Comparison between Asian and White participants correlation values for shape in Figure 5.3

PC	Asian		Black		White	
	z	p	z	p	z	p
0	-.382	.703	-.044	.965	.138	.890
1	-.765	.445	-.159	.874	.018	.986
2	-.852	.394	-.100	.920	.134	.893
3	-1.087	.277	-.373	.709	.256	.798
4	-.322	.747	.087	.931	.387	.699
5	-.283	.777	-.234	.815	.065	.948
6	-.082	.935	-.256	.798	-.021	.983
7	-.448	.654	-.286	.775	-.120	.905
8	-.055	.956	-.330	.741	-.174	.862
9	-.499	.618	-.338	.736	-.164	.869
10	-.556	.578	-.355	.722	-.132	.895
11	-.355	.722	-.297	.766	-.097	.923
12	-.249	.804	-.371	.711	-.258	.767
13	.313	.754	-.429	.668	-.170	.865
14	.116	.908	-.040	.691	.134	.894
15	.279	.781	-.283	.777	.026	.979
16	.259	.796	-.353	.724	.003	.999
17	.505	.613	-.314	.753	-.055	.956
18	.585	.558	-.372	.710	.052	.959
19	.245	.807	-.266	.791	.106	.915

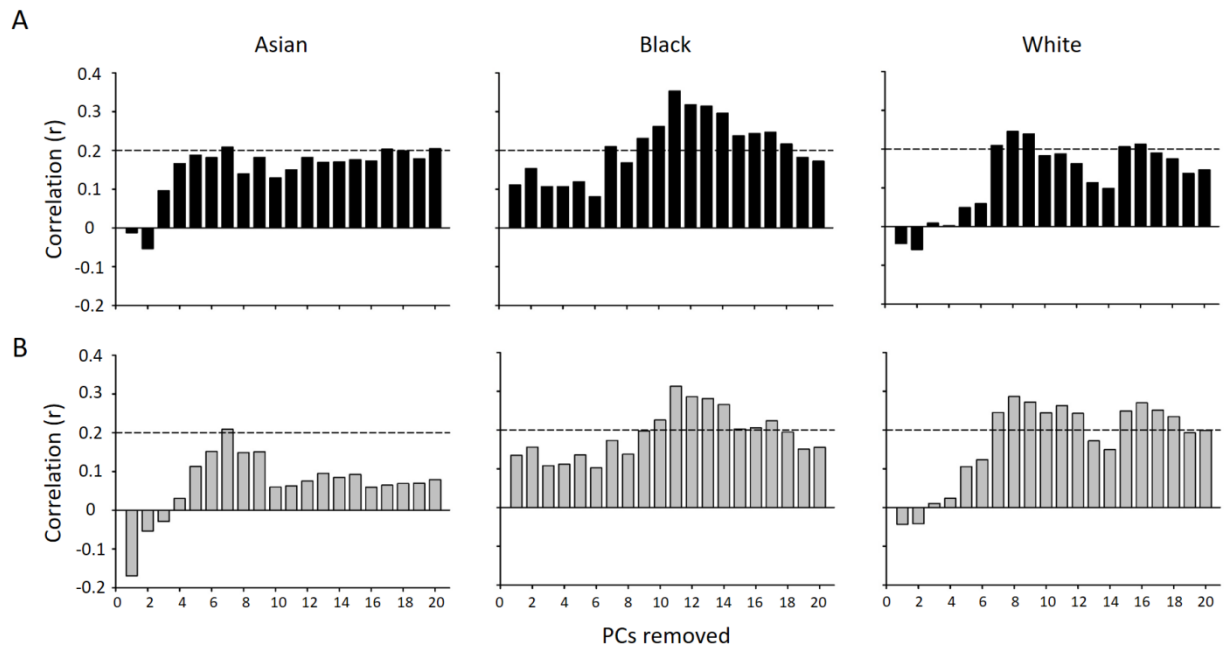


Figure 5.4 (A) The correlation between face matching behavioural task performance (proportion same) and face matching image pairs similarities in texture for each face race of Asian participants, (B) and White participants. The results show that the for both Asian and White participants, the correlation between texture and perceived similarity have a similar trend in black and white faces. There was hardly an effect of removing PCs for the correlations between Asian participants performance and Asian model face texture similarity. The dashed line indicates the critical r value at $p < 0.05$.

Next, we asked whether the similarity in texture could predict behavioural measures (Fig. 5.4). The correlation between the behavioural judgements (proportion same) and the similarity of the images in texture increased when the initial PCs were removed from the analysis.

To investigate whether there were any differences between Asian (Fig. 5.4A) and White (Fig. 5.4B) participants, we compared corresponding correlation values for each participant race. There were very few significant differences in the magnitude of the correlations between texture and perception for any of the face races (Table 5.4). A correlation between the correlations from Asian and White participants did, however, show a very similar pattern for Asian ($r = .791$, $p < .001$), Black ($r = .982$, $p < .001$) and White ($r = .986$, $p < .001$) faces. This

shows that participants from different races are using texture information in a very similar way.

Table 5.4 – Comparison of Asian and White participants correlation values for texture in Figure 5.4.

PC	Asian		Black		White	
	z	p	z	p	z	p
0	-1.045	.296	.161	.872	-.005	.996
1	-.002	.999	.018	.986	.117	.907
2	-.826	.409	.009	.993	.013	.990
3	-.905	.366	.033	.974	.144	.886
4	-.507	.612	.112	.911	.377	.707
5	-.203	.839	.144	.885	.427	.670
6	.002	.999	-.253	.800	.249	.804
7	.062	.950	-.206	.837	.290	.772
8	-.211	.833	-.231	.817	.234	.815
9	-.461	.064	-.254	.800	.423	.673
10	-.058	.559	-.300	.767	.522	.602
11	-.712	.479	-.231	.818	.555	.579
12	-.500	.617	-.236	.813	.396	.692
13	-.576	.565	-.216	.829	.342	.732
14	-.563	.574	-.242	.809	.299	.765
15	-.758	.448	-.266	.790	.406	.685
16	-.931	.352	-.161	.872	.425	.671
17	-.874	.382	-.150	.881	.410	.682
18	-.727	.467	-.212	.832	.382	.703
19	-.845	.398	-.114	.909	.359	.720

5.3.3 DCNN comparison of own-race and other-race faces

Finally, we asked whether the performance of behavioural responses on the matching task could be predicted by the performance of a computer vision model of face recognition. We used a pre-trained DCNN (VGG-Face) to compare the face set within- and between-races. Fig

5.5 shows the similarity matrices from the convolutional and fully-connected layers across all 540 images. This shows that the differences in **the** similarity between faces from different races become most evident in the fully connected layers. The difference between within-race and between-race values for each layer is shown in Table 5.5.

Table 5.5 –Within- and between-race comparison for VGG faces in t-value.

Layers	Asian		Black		White	
	t	p	t	p	t	p
Conv1.1	53.73	0.0001	31.03	0.0001	34.26	0.0001
Conv1.2	53.76	0.0001	21.84	0.0001	37.50	0.0001
Conv2.1	43.28	0.0001	27.13	0.0001	35.00	0.0001
Conv2.2	40.30	0.0001	32.41	0.0001	34.17	0.0001
Conv3.1	36.54	0.0001	32.01	0.0001	43.16	0.0001
Conv3.2	11.45	0.0001	19.74	0.0001	50.61	0.0001
Conv3.3	1.03	0.301	25.28	0.0001	49.80	0.0001
Conv4.1	-3.82	0.0001	26.48	0.0001	50.98	0.0001
Conv4.2	0.32	0.749	24.75	0.0001	45.03	0.0001
Conv4.3	2.16	0.031	27.76	0.0001	41.15	0.0001
Conv5.1	1.02	0.307	27.57	0.0001	53.40	0.0001
Conv5.2	11.89	0.0001	37.77	0.0001	61.18	0.0001
Conv5.3	63.10	0.0001	74.49	0.0001	105.85	0.0001
Fc6	185.18	0.0001	177.87	0.0001	120.28	0.0001
Fc7	200.93	0.0001	129.33	0.0001	94.37	0.0001
Fc8	171.61	0.0001	177.66	0.0001	158.92	0.0001

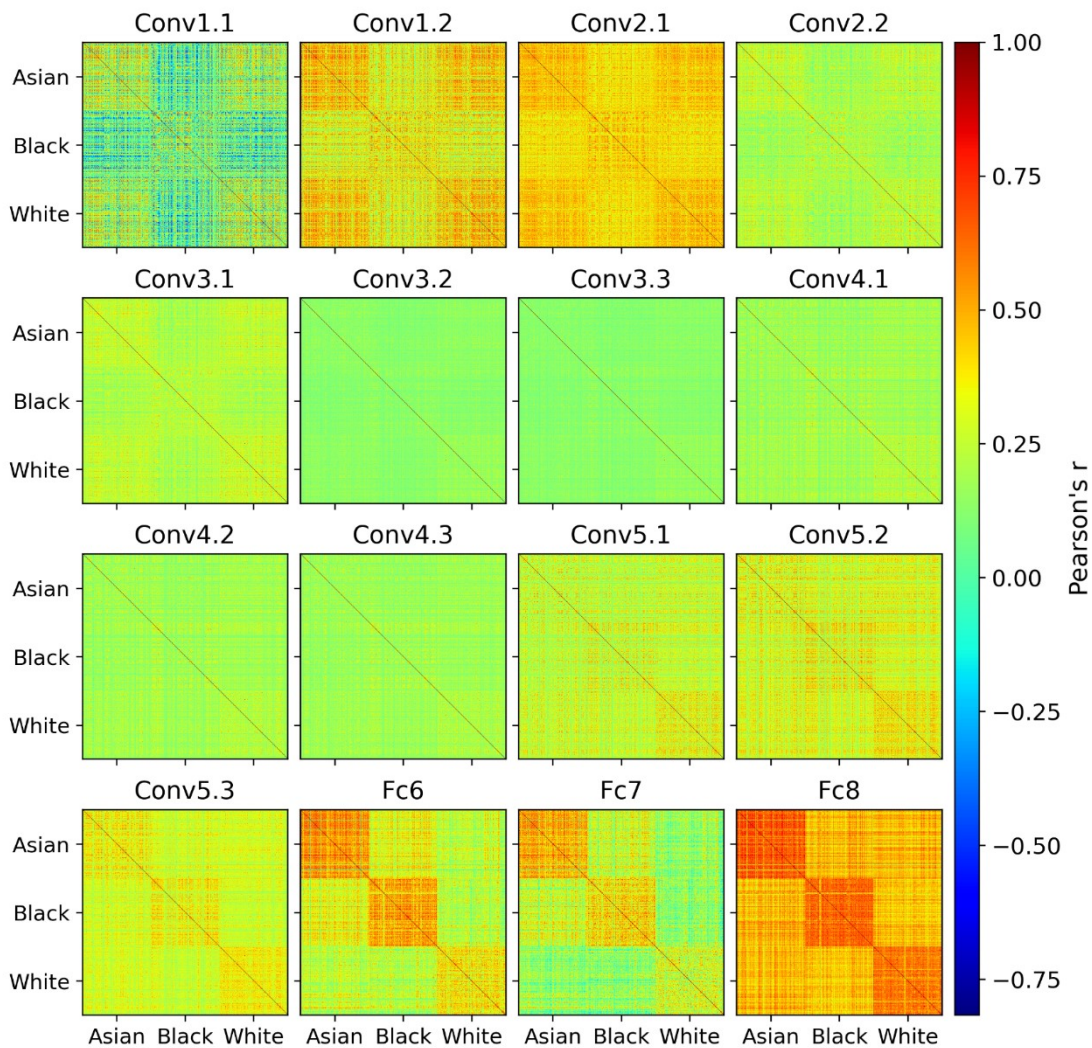


Figure 5.5 Similarity matrices from the images in the face matching task calculated from the 13 convolutional and 3 fully-connected layers of the DCNN.

We then asked how similarity between each face pair in each layer of the DCNN predicted behavioural performance (proportion same). We found that similarity in early convolutional layers of the DCNN did not predict behaviour. However, we found significant correlations in the fully connected layers for all 3 races. Interestingly, the correlation between behaviour and DCNN similarity was greatest for White faces.

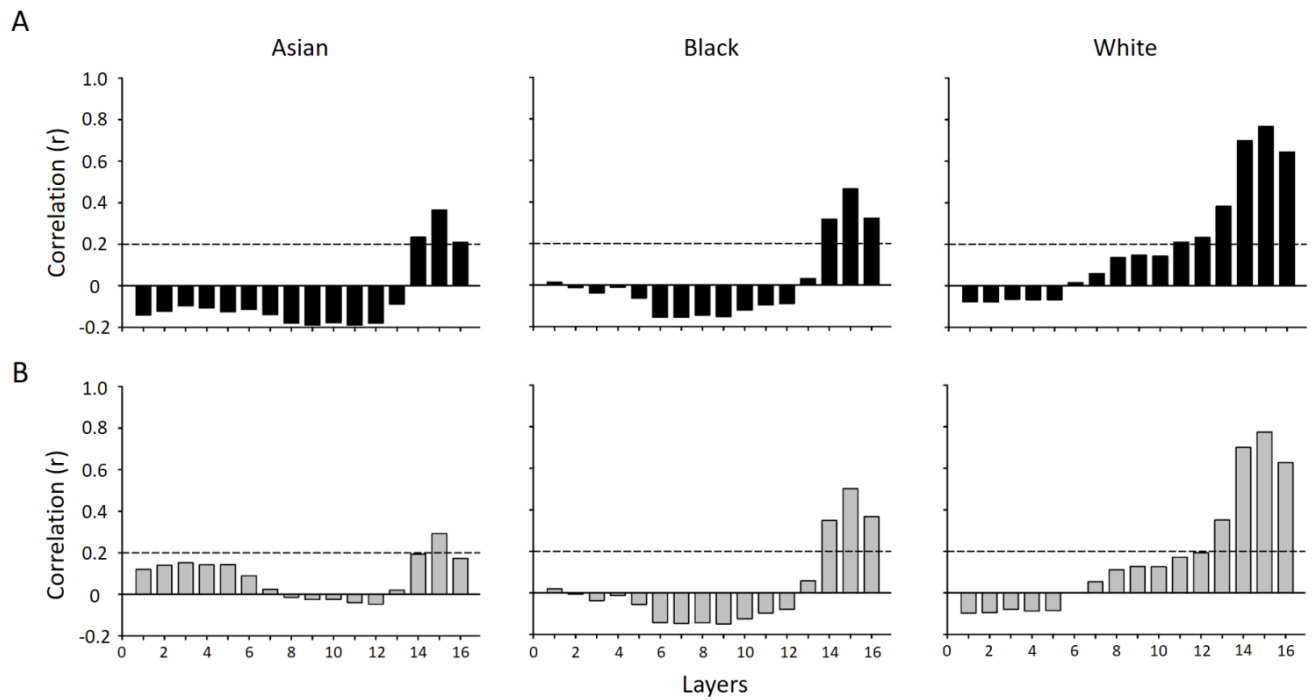


Figure 5.6 (A) The correlation between pairwise image similarity for 16 layers of DCNN and behavioural performance of Asian participants and (B) White participants in proportion same response. The dashed line indicates the critical r -value at $p < 0.05$.

5.4 Discussion

The aims of this study were to determine: (1) how shape and texture vary across faces from different races and (2) how this information is used for judgements of face identity. Our results show that there are differences in the shape and texture of faces of different races. Moreover, differences in shape and texture can be used to predict performance on matching tasks involving identity. The ability of shape and texture to discriminate faces from different races and to predict behaviour increased when low-level image variation due to changes was removed from the analysis.

People belonging to different races have characteristic differences in their faces. Skin and hair pigmentation provides the most obvious differences. Typically, White Europeans have light skin and light hair in the north, darker hair in the south, East Asians have somewhat darker skin and straight black hair and Black people have dark skin and dark curly hair (Bruce and Young, 2013). The faces of different races differ in average shape as well as skin and hair colour (Farkas et al., 2005; Goldstein, 1979). Our results support these findings by showing that both the shape and texture of face images can differentiate between faces of different races. Our results showed that the shape and texture of faces from the same race were on average more similar to each other compared to faces from a different race. The difference between faces from different races was more evident in the shape than the texture of the face. One possible reason for this is that the faces were analyzed in greyscale. So, it is highly likely that if colour had been used texture would have shown a bigger difference between races.

Although these findings show that shape and texture differ between faces of different races, this does not mean that these differences are used perceptually. Previous studies have shown that both shape and texture are important for judgements of the race (Hill et al., 1995).

In this study, we asked whether the difference in shape and texture could be used in judgements of identity in a matching task (see Chapter 3). We found that the similarity in both shape and texture could be used to predict whether participants perceived two faces to have the same identity. Consistent with previous studies, however, we found that texture was a better predictor of behavioral performance (Davies et al., 1978; Leder, 1999; Hole et al., 2002; Burton, Jenkins, Hancock & White, 2005).

As we navigate through the natural environment, the image of a face in the eye changes dramatically due to changes in the lighting direction, as well as with movements of the face. To be useful for recognition, we must ignore these changeable facial properties and generate an invariant representation that can be useful for **personal** identification (Bruce et al. 1987; Hancock et al. 2000). We found that when the first principal components were removed from the analysis, the ability of shape to differentiate between faces from different races increased. Variation in the shape of the face is likely to **be** dominated by changes in the viewpoint of the face, whereas variation in texture is likely to **be** dominated by changes in lighting. Presumably, the removal of these sources of image variation removed this ambient low-level image variation to reveal the image properties that are represented perceptually.

To determine whether the link between the perception of identity and image properties such as shape and texture was more evident for own-race faces, we compared performance on the same faces with Asian and White participants. We found no difference between participants **with** different race faces. On the contrary, we found very similar patterns for Asian and White participants. This result is consistent with **a** recent study **that** found no difference in **the** utilization of shape and texture cues for own- and other-race face learning (Zhou et al., 2021). The fact that own-race and other-race faces are perceived in a similar way again argues against the social cognitive theory of ORE (Goldstein & Chance, 1985;

Rhodes et al., 1989; Chiroro & Valentine, 1995; Nelson et al., 2001; Furl et al., 2002; Sangrioli et al., 2005; Kelly et al., 2005, 2007; Tanaka & Pierce, 2009; Rossion and Michel, 2011).

Finally, we investigate the extent to which a DCNN trained on faces (VGG-Face) was sensitive to faces from different races and its capability in predicting behavioural performance. We found that differences in **the** race were more evident in the fully-connected compared to the convolutional layers of the DCNN. We also found that **the** similarity of faces in the fully-connected, but not the convolutional layers **were** able to predict whether participants perceived the faces to be the same identity. Interestingly, we found that this link between perception and the output of the DCNN was greater for White compared to Black and Asian faces. This is consistent with a number of previous studies that have found a bias toward White faces (Moon & Phillips, 2001; Mandal & Banerjee, 2012; Nagpal et al., 2019), which is likely to reflect the training set of faces used to train the network. This has obvious implications for computer recognition of faces that may be biased against non-White faces. The better recognition **of** white faces was also evident in other face perceptual algorithms such as elastic bunch graph matching and interpersonal image difference classification (Givens et al., 2004). A recent study also found a bias toward Asian faces in a DCNN, **which** could be balanced via providing a matched training dataset with white faces (Tian et al., 2021). This finding suggests the link with **the** perception **of** Asian and Black faces from DCNN could be improved. However, our findings **s** show that a similar pattern was observed for Asian and White participants.

In conclusion, our results show that shape and texture can differentiate between faces **of** different races. We also showed that shape and texture can predict behavioural responses on a face matching task with these faces. The ability to discriminate faces from different races and the link with perception increased when the ambient variation in faces was removed. We

also found that the fully-connected layers of a DCNN trained on faces **were** able to discriminate between faces of different races and predict perception on a matching task. Finally, we found a similar pattern with both Asian and White participants.

6. GENERAL DISCUSSION

6.1 Aims of the Thesis

The other-race effect is the phenomenon that humans recognize faces from their own-race more accurately than those from other races. It has also known as own-race bias, the cross-race effect and own-race advantage (Meissner & Brigham, 2001). Since this effect was first described by Feingold (1914), it has been studied with various methods. A number of theories have been put forward to explain the mechanism underpinning the ORE. One influential theory explains the ORE through a difference in the processing of own-race and other-race faces (Levin, 1996; 2000; Sporer, 2001; Maclin & Malpass, 2001; 2003). Other-race faces due to being in an out-group are processed at a categorical level, whereas own-race faces are part of the in-group and are processed at an individual level (Cloutier & Macrae, 2007; Quinn, Mason & Macrae, 2010). This theory is known as the social cognitive theory of the ORE. The aim of this thesis is to test predictions from the social cognitive theory. A range of approaches **was** used to determine whether own-race and other-race faces engage similar perceptual and neural mechanisms. Specifically, the project explored (1) the co-variation in the recognition of own-race and other-race faces **with two behavioural tests**, (2) the neural patterns of response to own and other race faces, (3) first impressions of own- and other-race faces from Asian and White participants and (4) the variation in shape and texture of faces from different races.

6.2 Findings and Theoretical Implications

In Chapter 2, despite a clear ORE, I found that overall performance on identity tasks (matching and sorting) for own-race faces significantly predicts overall performance on other-race faces

for Asian and White participants. In the matching task, I found performance on own-race faces was positively correlated with matching performance on other-race faces. I also showed that Asian and White participants had a similar pattern of response across trials for the same set of faces. That is, performance in individual trials was similar for participants from different races. In the sorting tasks, and even stronger own-race advantage was observed, but again the performance on own-race predicted the performance on other-race faces. I also found a significant positive correlation between the patterns of response of Asian and White participants in the sorting task. In this project, both Asian and White participants were recruited and tested with the same tasks, which allowed us to measure the ORE effect independent of variation in the stimulus. This covariation in the performance implies that Asian and White participants used similar face processing mechanisms for Asian, Black and White faces, which is consistent with previous findings (Degutis et al., 2013; Megreya et al., 2011; Wan et al., 2017). This argues against the key idea from the social cognitive theory that faces of different races are perceived differently (MacLin & Malpass, 2001; Rodin, 1987; Sporer, 2001; Levin, 1996; Hugenberg, Young, Bernstein & Sacco, 2010; Harrison, Hole & Habibi, 2020).

Another key feature of the social cognitive theory is that people pay less attention to other-race faces due to a lack of motivation compared to own-race faces (Marcon, Susa & Meissner, 2009; Levin & Banaji, 2006; Michel, Corneille & Rossion, 2007). Based on this prediction, they should spend more time on their own-race faces. In this experiment, all the tasks were self-paced, participants can take as long as they need to make their decision, and both the matching and sorting tasks have found no consistent evidence for participants spending more time on own-race faces. On the contrary, it showed a tendency to spend more time on other-race faces in some of the tasks. Taken together, the covariation in performance

on tasks involving own-race and other-race and lack of any bias in task time for own-race faces suggests that the ORE that is clearly shown in this study cannot be accounted for by categorical differences in perceptual processing as suggested by the social cognitive theory.

Next, I explored the neural response to own-race and other-race faces. Asian and White participants viewed own-race and other-race faces while activity was monitored in face-selective ROIs (FFA, OFA, STS, AMG) of their brains. I used an adaptation paradigm to measure whether there is different sensitivity toward own- and other-races in face-selective regions. Firstly, I determined the difference in sensitivity to own-race and other-race faces using fMR-adaptation (Grill-Spector & Malach, 2001; Andrews & Ewbank, 2004). Previous studies have suggested that greater individuation of own-race faces (Levin, 1996; Hugenberg et al., 2010) is consistent with increased adaptation to own-race faces (Hughes et al., 2019; Reggev et al., 2020). However, in this study, I did not find the magnitude of adaptation was greater for own-race compared to other-race faces. A key difference between this study and previous studies was using a full cross over design in which the participants and the faces were both varied. This avoids problems associated with differences in images. It is interesting to note that if we had only used Asian participants, an ORE would have been evident.

A subsequent multivariate analysis of the data also showed that own-race and other-race faces are processed in a similar pathway. For example, evidence for different patterns of response to faces from different races was found in the OFA, but not in the FFA (see also Natu et al., 2011). These findings are consistent with the idea that OFA represents an earlier stage of processing in which the structural properties of the face are represented (Haxby et al., 2000). The lack of a difference between same-race and different-race faces in the FFA suggests that race is not represented in the spatial pattern of response in this region (see also Ng et al., 2006). To take a closer look at whether there is a distinct pattern of response for

own-race faces and other-race faces, I asked if the response to Asian faces was more distinct in Asian participants and if the response to White faces was more distinct in White participants. The results show that **the** spatial pattern of response was not modulated by participant race and the spatial pattern of response to own-race faces is not distinct from the spatial pattern of response to other-race faces.

To further probe our understanding of the ORE, we investigated differences in the way we perceive facial first impressions in faces from different races. It has been proposed that the formation of facial first impressions is highly influenced by the ethnicity of the faces and whether they are own-race or other-race (Elfenbein & Ambady, 2002; Jack, Caldara & Schyns, 2012). However, empirical studies have found significant cross-cultural similarities in trait judgements (Zebrowitz et al., 1993; Cunningham et al., 1995; Walker et al., 2011) as well as cross-cultural differences (Krys et al., 2014; Zebrowitz et al., 2012; Xie et al., 2019). Using the same stimuli from Chapter 2 that demonstrate an ORE for identity, I asked whether judgements of dominance or trustworthiness are also influenced by the race of the participant. I found no evidence for an ORE in the reliability of judgements of first impressions. I also found the pattern of response was similar for own-race and other-race faces. Finally, I found that there was no correlation between **the** judgement of trustworthiness and dominance, consistent with previous studies (Todorov et al., 2015; Sutherland et al., 2013). This suggests that stereotypical judgement of other-race individuals **does** not result from cross-cultural differences in face perception.

In Chapter 5, I explored the extent to which faces from different races differ in image properties, such as shape and texture. Similar to other studies (Hill, Bruce and Akamatsu, 1995; Bruce & Young, 2012; Yan et al., 2017), I found both shape and texture were on average more similar for faces from **the** same race (see also Farkas et al., 2005; Goldstein, 1979; Bruce

and Young, 2013). I then asked how different image properties (shape and texture) are able to differentiate between faces from different races. I found that the difference in shape between faces from different races became greater when the first 3 PCs were removed. However, a similar effect was not evident for texture, in which the removal of PCs did not increase the difference between faces from different races.

An important question is whether differences in the shape and texture of faces influence judgements of identity and is this link more evident for own-race faces? A significant correlation between the shape or texture similarity of faces and participant performance was found. That is, the more similar faces were in shape or texture, the more likely that they would be perceived as belonging to the same identity. This relationship became more evident when the initial PCs (related to ambient variation in the image) were removed. However, this did not vary as a function of participant race. Again, this suggests similar processes are involved in the perception of own-race and other-race faces.

The results in this thesis have provided evidence against the social cognitive theory. However, do these data support alternate theories of the ORE? The perceptual learning or expertise theory proposes that the own-race advantage is the result of greater contact that perceivers have with individuals of their own-race, which trained their sensitivity towards tuned facial features and cues of their own racial group (Byatt & Rhodes, 2004; Brigham & Malpass, 1985; Goldstein & Chance, 1985, Kelly et al., 2007). Unlike the social cognitive theory which proposes different cognitive processes for own-race and other-race faces, the perceptual expertise theory emphasises the importance of experience in the ORE. Support for this theory comes from developmental studies (Chiroro & Valentine, 1995; Sangrigoli et al., 2005; de Heering et al., 2010; Kelly et al., 2005; 2007) and has been attributed to inter-racial contacts (Wright, Boyd, & Tredoux, 2003).

It has been suggested that a key component of the perceptual learning theory is the Multidimensional Face Space Model (MFSM). The MFSM assumes that faces are encoded as dimensions within the multiple dimensions of face space (Valentine, 1991, 2001). This face space will vary as a function of each individual's unique experience of faces across their lifespan. The MFSM has two versions: (1) a prototype or norm-based model, in which faces are encoded as vectors from the single prototype, norm or average face and (2) an exemplar-based model that supposes that all perceived faces are encoded as a single point in the multi-dimension space. Both of them embraced a common uneven distribution of faces within the face space. For the norm-based model, faces with a closer relationship to the prototype would be represented close to the centre of the face space, whereas faces that are less similar to the prototype are presented further away from the centre (Chiroro & Valentine, 1996). For the exemplar-based model, faces with more similar properties are simply represented more closely together (see also Valentine & Endo, 1992).

The behavioural results from chapter 2 and chapter 4 showed very similar patterns of response in Asian and White participants. The strong covariation would be consistent with a similar multidimensional space (common face space) that is used for perception. These results support previous findings that a common system of coding face dimensions is shared for all faces, consistent with the result shown in previous research that participants of different races view own- and other-race faces in a similar way (Jaquet, Rhodes and Hayward, 2007; Hills & Pake, 2013). The results of chapter 5 which showed Asian and White participants have a similar correlation between image properties and behavioural results are also supplementary to the multidimensional scaling analyses that show the same features (e.g. skin color, eye size or nose position) are used for judging own-race and other-race faces (Papesh & Goldinger, 2010).

Furthermore, the fMR-adaptation results found no significant difference in adaptation between own-race and other-race faces for both Asian and White participants. This suggests a similar sensitivity to own-race and other-race faces. The lack of significance in the difference of magnitude of adaptation between own- and other-race faces is consistent with the norm-based face space accounted study that found similar adaptation from stimuli sets of face and anti-face (Leopold et al., 2001), as the anti-face can be regarded as an other-race face for its completely reversed shape and texture properties. Meanwhile, from previous studies of facial adaptation in face-space, the re-centralization of the perceptual space nearer to the adaptor stimulus was verified during the formation of face adaptation (Webster & Macleod, 2011; Webster & MacLin, 1999). From this aspect, it would be logical to predict the spatial patterns of neural responses to faces should be influenced by the re-normalization process during the formation of adaptation (Clifford, Wenderoth and Spehar, 2000). In this study, the significant correlation that was found between the magnitude of adaptation and the spatial pattern of the response, this significant correlation may also provide clues to the dynamic sensory system of mapping adapted faces onto patterns of fixed neuronal responses, which consequently develop into perceptual expertise towards featured faces (Carbon & Diyte, 2012; Valentine, Lewis & Hills., 2016), yet this interesting process will have to wait for further exploration. To sum up, this thesis applied crossover design in both behavioural and neural imaging experiments to comprehensively monitor the other-race effect in perceptual and neural level, the result provides evidence against the idea of social cognitive account that own-race faces and other-race faces are processed differently in the brain. This suggests that further research on the ORE should focus more on how perceptual expertise influences the ORE and how differences in the processing of own-race and other-race faces are represented in the brain.

6.3 Limitations

The Asian participants of this experiment were all recruited from the University of York and had some experience in recognizing White faces. Although I did find a robust other-race effect with our Asian participants recruited in the UK, it is possible that participants with less experience of recognizing other-race faces may exhibit larger ORE. In addition, the Asian and White participants were not the same in the behavioural and neural studies. It would have been better to have the same participants doing both studies so that we would have been able to correlate the behavioural and neural measures across individuals. Nevertheless, due to the large amount of the sample size and the alteration of students, which composed the majority of the sample, it was practically impossible to re-recruit the same people for both experiments. However, the cross-over design (Asian and White participants viewing Asian and White faces) was an important aspect of the design and allowed for more definitive to be made about the mechanisms underlying the ORE.

There was a potential limitation in the trait judgement. There are currently three key dimensions that were thought to form the face impression (Todorov et al., 2015; Sutherland et al., 2013). We have included two of them (dominance and trustworthiness), but have not used attractiveness. This is because the faces were of a similar age and attractiveness. So, we suspected that this would not vary across images. However, previous reports suggest that Chinese and British may exhibit cultural differences in perceiving attractiveness (Sutherland et al., 2018). Future experiments could test the reliability of this variable to explore whether there is an ORE.

6.4 Conclusions

This thesis aimed to investigate how own-race and other-race faces are represented in the brain by looking at the key distinction in theories of the ORE that whether the process involves the experience enhanced perceptual encoding of own-race faces in a similar pathway or social categorization of other-race faces via a different pathway. I found: (1) a similar pattern of behavioural face recognition performance on individual items for own-race and other-race faces; (2) a similar neural sensitivity to own-race and other-race faces that was not modified by the race of the participants; (3) a similar pattern of trait judgements for own-race and other-race; and (4) a similar ability to predict recognition performance from the image properties of own-race and other-race faces. These findings all indicate that own-race faces and other-race faces are processed in a similar way in the brain for both Asian and White participants.

References

- Allport, F. H. (1954). The structuring of events: outline of a general theory with applications to psychology. *Psychological Review*, *61*(5), 281–303.
- Amodio, D. M. (2014). The neuroscience of prejudice and stereotyping. *Nature Reviews Neuroscience*, Vol. 15, pp. 670–682. <https://doi.org/10.1038/nrn3800>
- Andrews, T. J., & Ewbank, M. P. (2004). Distinct representations for facial identity and changeable aspects of faces in the human temporal lobe. *NeuroImage*, *23*(3), 905–913.
- Andrews, T. J., Baseler, H., Jenkins, R., Burton, A. M., & Young, A. W. (2016). Contributions of feature shapes and surface cues to the recognition and neural representation of facial identity. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *83*, 280–291.
- Andrews, T. J., Davies-Thompson, J., Kingstone, A., & Young, A. W. (2010). Internal and external features of the face are represented holistically in face-selective regions of visual cortex. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *30*(9), 3544–3552.
- Andrews, T. J., Glennerster, A., & Parker, A. J. (2001). Stereoacuity thresholds in the presence of a reference surface. *Vision Research*, *41*(23), 3051–3061.
- Anthony, T., Copper, C., & Mullen, B. (1992). Cross-Racial Facial Identification: A Social Cognitive Integration. *Personality & Social Psychology Bulletin*, *18*(3), 296–301.
- Bate, S., Bennetts, R., Hasshim, N., Portch, E., Murray, E., Burns, E., & Dudfield, G. (2019). The limits of super recognition: An other-ethnicity effect in individuals with extraordinary face recognition skills. *Journal of Experimental Psychology. Human Perception and Performance*, *45*(3), 363–377.
- Bernstein, M. J., Young, S. G., & Hugenberg, K. (2007). The cross-category effect: mere social categorization is sufficient to elicit an own-group bias in face recognition. *Psychological Science*, *18*(8), 706–712.

- Brewer, M. B. (1988). A dual process model of impression formation. In T. K. Srull & R. S. Wyer, Jr. (Eds.), *A dual process model of impression formation* (pp. 1–36). Lawrence Erlbaum Associates, Inc
- Bigler, R. S., & Liben, L. S. (2007). Developmental Intergroup Theory: Explaining and Reducing Children’s Social Stereotyping and Prejudice. *Current Directions in Psychological Science*, *16*(3), 162–166.
- Bothwell, R. K., Brigham, J. C., & Malpass, R. S. (1989). Cross-Racial Identification. *Personality & Social Psychology Bulletin*, *15*(1), 19–25.
- Brigham, J. C., Bennett, L. B., Meissner, C. A., Mitchell, T. L., Lindsay, R. C. L., Ross, D. F., Read, J. D., & Tolia, M. P. (2014). The influence of race on eyewitness memory. *Memory for People*, *2*, 257–282.
- Brigham, J. C., & Malpass, R. S. (1985). The Role of Experience and Contact in the Recognition of Faces Of Own- and Other-Race Persons. In *Journal of Social Issues* (Vol. 41, Issue 3, pp. 139–155). <https://doi.org/10.1111/j.1540-4560.1985.tb01133.x>
- Brosch, T., Bar-David, E., & Phelps, E. A. (2013). Implicit race bias decreases the similarity of neural representations of black and white faces. *Psychological Science*, *24*(2), 160–166.
- Bruce, V. (1982). Changing faces: visual and non-visual coding processes in face recognition. *British Journal of Psychology*, *73*(Pt 1), 105–116.
- Bruce, V. (1994). Stability from variation: The case of face recognition the MD Vernon memorial lecture. *The Quarterly Journal of Experimental Psychology*, *47*(1), 5–28.
- Bruce, V., & Langton, S. (1994). The Use of Pigmentation and Shading Information in Recognising the Sex and Identities of Faces. *Perception*, *23*(7), 803–822.
- Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology*, *77* (Pt 3), 305–327.
- Bruce, V., & Young, A. (1998). In the eye of the beholder: The science of face perception. Oxford: Oxford University Press.

- Bruce, V., & Young, A. (2012). *Face perception*. Hove, East Sussex: Psychology Press.
- Bruce, V., & Young, A. (2013). *Face perception*. Psychology Press.
- Bruce, V., & Young, A. W. (1998). A theoretical perspective for understanding face recognition. In *Face and Mind* (pp. 96–130). <https://doi.org/10.1093/acprof:oso/9780198524205.003.0003>
- Bruce, V., Healey, P., Burton, M., Doyle, T., Coombes, A., & Linney, A. (2013). Recognising Facial Surfaces. In *Perception* (Vol. 42, Issue 11, pp. 1200–1214). <https://doi.org/10.1068/p200755n>
- Bruce, V., Valentine, T., & Baddeley, A. (1987). The basis of the 3/4 view advantage in face recognition. *Applied Cognitive Psychology*, 1(2), 109–120.
- Burt, D. M., & Perrett, D. I. (1995). Perception of age in adult Caucasian male faces: computer graphic manipulation of shape and colour information. *Proceedings. Biological Sciences / The Royal Society*, 259(1355), 137–143.
- Burton, A. M. (2013). Why has research in face recognition progressed so slowly? The importance of variability. *Quarterly Journal of Experimental Psychology*, 66, 1467-1485.
- Burton, A. M., Bruce, V., & Hancock, P. J. B. (1999). From Pixels to People: A Model of Familiar Face Recognition. *Cognitive Science*, 23(1), 1–31.
- Burton, A. M., Jenkins, R., Hancock, P. J. B., & White, D. (2005). Robust representations for face recognition: the power of averages. *Cognitive Psychology*, 51(3), 256–284.
- Burton, A. M., Kramer, R. S. S., Ritchie, K. L., & Jenkins, R. (2016). Identity from variation: Representations of faces derived from multiple instances. *Cognitive Science*, 40(1), 202–223.
- Burton, A. M., Mike Burton, A., Bruce, V., & Dench, N. (1993). What's the Difference between Men and Women? Evidence from Facial Measurement. In *Perception* (Vol. 22, Issue 2, pp. 153–176). <https://doi.org/10.1068/p220153>
- Byatt, G., & Rhodes, G. (2004). Identification of own-race and other-race faces: implications for the representation of race in face space. *Psychonomic Bulletin & Review*, 11(4), 735–741.
- Caharel, S., Jiang, F., Blanz, V., & Rossion, B. (2009). Recognizing an individual face: 3D shape contributes earlier than 2D surface reflectance information. *NeuroImage*, 47(4), 1809–1818.

- Calder, A. J., Burton, A. M., Miller, P., Young, A. W., & Akamatsu, S. (2001). A principal component analysis of facial expressions. *Vision Research*, 41(9), 1179–1208.
- Calder, A. J., & Young, A. W. (2005). Understanding the recognition of facial identity and facial expression. *Nature Reviews. Neuroscience*, 6(8), 641–651.
- Castillo, R. (2013). *How many Africans are there in Guangzhou, China? If you really want to know you must read this!* AfricansInChina.Net. <https://africansinchina.net/2013/09/30/how-many-africans-are-there-in-guangzhou-if-you-really-want-to-know-you-must-read-this/>
- Carbon, C.-C., & Ditye, T. (2012). Face adaptation effects show strong and long-lasting transfer from lab to more ecological contexts. *Frontiers in Psychology*, 3, 3.
- Chance, J. E., & Goldstein, A. G. (1981). Depth of Processing in Response to Own- and Other-Race Faces. *Personality & Social Psychology Bulletin*, 7(3), 475–480.
- Chance, J. E., Turner, A. L., & Goldstein, A. G. (1982). Development of differential recognition for own- and other-race faces. *The Journal of Psychology*, 112(1st Half), 29–37.
- Charbonneau, I., Robinson, K., Blais, C., & Fiset, D. (2020). Implicit race attitudes modulate visual information extraction for trustworthiness judgments. *PloS One*, 15(9), e0239305.
- Chekroud, A. M., Everett, J. A. C., Bridge, H., & Hewstone, M. (2014). A review of neuroimaging studies of race-related prejudice: does amygdala response reflect threat? *Frontiers in Human Neuroscience*, 8, 179.
- Chen, M., & Bargh, J. A. (1997). Nonconscious Behavioral Confirmation Processes: The Self-Fulfilling Consequences of Automatic Stereotype Activation. *Journal of Experimental Social Psychology*, Vol. 33, pp. 541–560. <https://doi.org/10.1006/jesp.1997.1329>
- Chiroro, P., & Valentine, T. (1995). An Investigation of the Contact Hypothesis of the Own-race Bias in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, 48(4), 879–894.
- Cikara, M., & Van Bavel, J. J. (2014). The Neuroscience of Intergroup Relations. In *Perspectives on Psychological Science* (Vol. 9, Issue 3, pp. 245–274). <https://doi.org/10.1177/1745691614527464>

- Clifford, C. W., Wenderoth, P., & Spehar, B. (2000). A functional angle on some after-effects in cortical vision. *Proceedings. Biological Sciences / The Royal Society*, 267(1454), 1705–1710.
- Cloutier, J., & Macrae, C. N. (2007). Who or what are you?: Facial orientation and person construal. *European Journal of Social Psychology*, 37(6), 1298–1309.
- Cook, R., & Over, H. (n.d.). Why is the literature on first impressions so focused on White faces? *Royal Society Open Science*, 8(9), 211146.
- Corenblum, B., & Meissner, C. A. (2006). Recognition of faces of ingroup and outgroup children and adults. *Journal of Experimental Child Psychology*, 93(3), 187–206.
- Cross, J. F., Cross, J., & Daly, J. (1971). Sex, race, age, and beauty as factors in recognition of faces. *Perception & Psychophysics*, 10(6), 393–396.
- Cui, Z., Zhao, Y., Guo, J., Du, H., & Zhang, J. (2020). Typical and Reverse Other-Race Effect on Tibetan Students' Emotional Face Recognition. *2020 15th IEEE International Conference on Automatic Face and Gesture Recognition (FG 2020)*, 754–760.
- Cunningham, M. R., Roberts, A. R., Barbee, A. P., Druen, P. B., & Wu, C.-H. (1995). “Their ideas of beauty are, on the whole, the same as ours”: Consistency and variability in the cross-cultural perception of female physical attractiveness. *Journal of Personality and Social Psychology*, 68(2), 261–279.
- Cunningham, W. A., Johnson, M. K., Raye, C. L., Chris Gatenby, J., Gore, J. C., & Banaji, M. R. (2004). Separable neural components in the processing of black and white faces. *Psychological Science*, 15(12), 806–813.
- Davies, G. M., Ellis, H., & Shepherd, J. (1978). Face identification: The influence of delay upon accuracy of Photofit construction. *Journal of Police Science and Administration*, 6(1), 35–42.
- Davies-Thompson, J., & Andrews, T. J. (2012). Intra- and interhemispheric connectivity between face-selective regions in the human brain. *Journal of Neurophysiology*, 108(11), 3087–3095.
- Degutis, J., Mercado, R. J., Wilmer, J., & Rosenblatt, A. (2013). Individual differences in holistic processing predict the own-race advantage in recognition memory. *PloS One*, 8(4), e58253.

- de Heering, A., & Rossion, B. (2015). Rapid categorization of natural face images in the infant right hemisphere. *eLife*, *4*, e06564.
- Diedenhofen, B., & Musch, J. (2015). cocor: a comprehensive solution for the statistical comparison of correlations. *PLoS One*, *10*(3), e0121945.
- Dowsett, A. J., & Burton, A. M. (2015). Unfamiliar face matching: Pairs out-perform individuals and provide a route to training. *British Journal of Psychology*, *106*(3), 433–445.
- Elfenbein, H. A., & Ambady, N. (2002). Is there an in-group advantage in emotion recognition? [Review of *Is there an in-group advantage in emotion recognition?*]. *Psychological Bulletin*, *128*(2), 243–249.
- Ellis, H. D., Deregowski, J. B., & Shepherd, J. W. (1975). Description of White and Black Faces by White and Black Subjects. *International Journal of Psychology: Journal International de Psychologie*, *10*(2), 119–123.
- Estudillo, A. J., Lee, J. K. W., Mennie, N., & Burns, E. (2020). No evidence of other-race effect for Chinese faces in Malaysian non-Chinese population. *Applied Cognitive Psychology*, *34*(1), 270–276.
- Ewbank, M. P., & Andrews, T. J. (2008). Differential sensitivity for viewpoint between familiar and unfamiliar faces in human visual cortex. *NeuroImage*, *40*(4), 1857–1870.
- Farkas, L. G., Katic, M. J., & Forrest, C. R. (2005). Anthropometric proportion indices in the craniofacial regions of 73 patients with forms of isolated coronal synostosis. *Annals of Plastic Surgery*, *55*(5), 495–499.
- Fairhall, S. L., & Ishai, A. (2007). Effective connectivity within the distributed cortical network for face perception. *Cerebral Cortex*, *17*(10), 2400–2406.
- Feingold, G. A. (1914). The Influence of Environment on Identification of Persons and Things. *Journal of the American Institute of Criminal Law and Criminology*, *5*(1), 39.

- Feng, L., Liu, J., Wang, Z., Li, J., Li, L., Ge, L., Tian, J., & Lee, K. (2011). The other face of the other-race effect: an fMRI investigation of the other-race face categorization advantage. *Neuropsychologia*, *49*(13), 3739–3749.
- Fiske, S. T., & Neuberg, S. L. (1990). A Continuum of Impression Formation, from Category-Based to Individuating Processes: Influences of Information and Motivation on Attention and Interpretation. In *Advances in Experimental Social Psychology* (pp. 1–74). [https://doi.org/10.1016/s0065-2601\(08\)60317-2](https://doi.org/10.1016/s0065-2601(08)60317-2)
- Fiske, S. T., Cuddy, A. J. C., & Glick, P. (2007). Universal dimensions of social cognition: warmth and competence. *Trends in Cognitive Sciences*, *11*(2), 77–83.
- Freeman, J. B., & Ambady, N. (2011). Hand movements reveal the time-course of shape and pigmentation processing in face categorization. *Psychonomic Bulletin & Review*, *18*(4), 705–712.
- Fu, G., Hu, C. S., Wang, Q., Quinn, P. C., & Lee, K. (2012). Adults scan own- and other-race faces differently. *PloS One*, *7*(6), e37688.
- Furl, N., Phillips, P. J., & O'Toole, A. J. (2002). Face recognition algorithms and the other-race effect: computational mechanisms for a developmental contact hypothesis. *Cognitive Science*, *26*(6), 797–815.
- Givens, G., Beveridge, J. R., Draper, B. A., Grother, P., & Phillips, P. J. (2004). How features of the human face affect recognition: a statistical comparison of three face recognition algorithms. *Proceedings of the 2004 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2004. CVPR 2004.*, *2*, II – II.
- Golby, A. J., Gabrieli, J. D., Chiao, J. Y., & Eberhardt, J. L. (2001). Differential responses in the fusiform region to same-race and other-race faces. *Nature Neuroscience*, *4*(8), 845–850.
- Goldstein, A. G. (1979). Race-related variation of facial features: Anthropometric data I. *Bulletin of the Psychonomic Society*, *13*(3), 187–190.

- Goldstein, A. G., & Chance, J. E. (1980). Memory for Faces and Schema Theory. *The Journal of Psychology, 105*(1), 47–59.
- Goldstein, A. G., & Chance, J. E. (1985). Effects of training on Japanese face recognition: Reduction of the other-race effect. *Bulletin of the Psychonomic Society, 23*(3), 211–214.
- Grill-Spector, K., & Malach, R. (2001). fMR-adaptation: a tool for studying the functional properties of human cortical neurons. *Acta Psychologica, 107*(1-3), 293–321.
- Grill-Spector, K., Kushnir, T., Edelman, S., Avidan, G., Itzchak, Y., & Malach, R. (1999). Differential processing of objects under various viewing conditions in the human lateral occipital complex. *Neuron, 24*(1), 187–203.
- Gross, T. F. (2009). Own-Ethnicity Bias in the Recognition of Black, East Asian, Hispanic, and White Faces. *Basic and Applied Social Psychology, 31*(2), 128–135.
- Hainsworth, P. (2016). *The Politics of the Extreme Right: From the Margins to the Mainstream*. Bloomsbury Publishing.
- Hancock, K. J., & Rhodes, G. (2008). Contact, configural coding and the other-race effect in face recognition. *British Journal of Psychology, 99*(1), 45–56.
- Hancock, P. J., Bruce, V., & Burton, M. A. (1998). A comparison of two computer-based face identification systems with human perceptions of faces. *Vision Research, 38*(15-16), 2277–2288.
- Hancock, P. J., Bruce, V., & Burton, A. M. (2000). Recognition of unfamiliar faces. *Trends in Cognitive Sciences, 4*(9), 330–337.
- Hancock, P. J., Bruce, V., & Burton, A. M. (2000). Recognition of unfamiliar faces. *Trends in Cognitive Sciences, 4*(9), 330–337.
- Hancock, P. J., Burton, A. M., & Bruce, V. (1996). Face processing: human perception and principal components analysis. *Memory & Cognition, 24*(1), 21–40.

- Hanke, M., Halchenko, Y. O., Sederberg, P. B., Hanson, S. J., Haxby, J. V., & Pollmann, S. (2009). PyMVPA: A python toolbox for multivariate pattern analysis of fMRI data. *Neuroinformatics*, 7(1), 37–53.
- Harris, R. J., Young, A. W., & Andrews, T. J. (2012). The role of the pSTS in the pre-categorical coding of emotional expression. In *Journal of Vision* (Vol. 12, Issue 9, pp. 783–783). <https://doi.org/10.1167/12.9.783>
- Harris, R. J., Young, A. W., & Andrews, T. J. (2014). Brain regions involved in processing facial identity and expression are differentially selective for surface and edge information. *NeuroImage*, 97, 217–223.
- Harrison, V., Hole, G., & Habibi, R. (2020). Are You In or Are You Out? The Importance of Group Saliency in Own-Group Biases in Face Recognition. *Perception*, 49(6), 672–687.
- Hart, A. J., Whalen, P. J., Shin, L. M., McInerney, S. C., Fischer, H., & Rauch, S. L. (2000). Differential response in the human amygdala to racial outgroup vs ingroup face stimuli. *Neuroreport*, 11(11), 2351–2355.
- Haxby, J. V., Gobbini, M. I., Furey, M. L., Ishai, A., Schouten, J. L., & Pietrini, P. (2001). Distributed and overlapping representations of faces and objects in ventral temporal cortex. *Science*, 293(5539), 2425–2430.
- Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences*, 4(6), 223–233.
- Herrmann, M. J., Ehlis, A.-C., Ellgring, H., & Fallgatter, A. J. (2005). Early stages (P100) of face perception in humans as measured with event-related potentials (ERPs). *Journal of Neural Transmission*, 112(8), 1073–1081.
- Hill, H., Bruce, V., & Akamatsu, S. (1995). Perceiving the sex and race of faces: the role of shape and colour. *Proceedings. Biological Sciences / The Royal Society*, 261(1362), 367–373.
- Hills, P. J., & Lewis, M. B. (2006). Reducing the own-race bias in face recognition by shifting attention. *Quarterly Journal of Experimental Psychology*, 59(6), 996–1002.

- Hills, P. J., & Pake, J. M. (2013). Eye-tracking the own-race bias in face recognition: revealing the perceptual and socio-cognitive mechanisms. *Cognition*, *129*(3), 586–597.
- Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience*, *3*(1), 80–84.
- Hole, G. J., George, P. A., Eaves, K., & Rasek, A. (2002). Effects of geometric distortions on face-recognition performance. *Perception*, *31*(10), 1221–1240.
- Horry, R., Cheong, W., & Brewer, N. (2015). The other-race effect in perception and recognition: insights from the complete composite task. *Journal of Experimental Psychology. Human Perception and Performance*, *41*(2), 508–524.
- Huang, G. B., Mattar, M., Berg, T., & Learned-Miller, E. (2008). Labeled faces in the wild: A database for studying face recognition in unconstrained environments. *Workshop on Faces in Real-Life Images: Detection, Alignment, and Recognition*. <https://hal.inria.fr/inria-00321923/>
- Hugenberg, K., Young, S. G., Bernstein, M. J., & Sacco, D. F. (2010). The categorization-individuation model: an integrative account of the other-race recognition deficit. *Psychological Review*, *117*(4), 1168–1187.
- Hughes, M. J. (2019). *The Social Consequences of Facial Disfigurement*. <https://doi.org/10.4324/9780429433269>
- Ito, T. A., Thompson, E., & Cacioppo, J. T. (2004). Tracking the timecourse of social perception: the effects of racial cues on event-related brain potentials. *Personality & Social Psychology Bulletin*, *30*(10), 1267–1280.
- Ito, T. A., & Urland, G. R. (2003). Race and gender on the brain: electrocortical measures of attention to the race and gender of multiply categorizable individuals. *Journal of Personality and Social Psychology*, *85*(4), 616–626.
- Ishai, A. (2008). Let's face it: it's a cortical network. *NeuroImage*. <https://www.sciencedirect.com/science/article/pii/S1053811907009883>

- Jack, R. E., & Schyns, P. G. (2017). Toward a Social Psychophysics of Face Communication. *Annual Review of Psychology*, *68*, 269–297.
- Jack, R. E., Caldara, R., & Schyns, P. G. (2012). Internal representations reveal cultural diversity in expectations of facial expressions of emotion. *Journal of Experimental Psychology. General*, *141*(1), 19–25.
- Jack, R. E., Garrod, O. G. B., Yu, H., Caldara, R., & Schyns, P. G. (2012). Facial expressions of emotion are not culturally universal. In *Proceedings of the National Academy of Sciences* (Vol. 109, Issue 19, pp. 7241–7244). <https://doi.org/10.1073/pnas.1200155109>
- Jaquet, E., Rhodes, G., & Hayward, W. G. (2007). Opposite Aftereffects for Chinese and Caucasian Faces are Selective for Social Category Information and not Just Physical Face Differences. In *Quarterly Journal of Experimental Psychology* (Vol. 60, Issue 11, pp. 1457–1467). <https://doi.org/10.1080/17470210701467870>
- Jenkins, R., & Burton, A. M. (2011). Stable face representations. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *366*(1571), 1671–1683.
- Jenkins, R., White, D., Van Montfort, X., & Burton, A. M. (2011). Variability in photos of the same face. *Cognition*, *121*(3), 313–323.
- Jenkins, R., White, D., Van Montfort, X., & Mike Burton, A. (2011). Variability in photos of the same face. *Cognition*, *121*(3), 313–323.
- Jiang, F., Blanz, V., & O’Toole, A. J. (2006). Probing the Visual Representation of Faces With Adaptation. In *Psychological Science* (Vol. 17, Issue 6, pp. 493–500). <https://doi.org/10.1111/j.1467-9280.2006.01734.x>
- Jiang, F., Blanz, V., & Rossion, B. (2011). Holistic processing of shape cues in face identification: Evidence from face inversion, composite faces, and acquired prosopagnosia. *Visual Cognition*, *19*(8), 1003–1034.

- Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for face perception. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *17*(11), 4302–4311.
- Kelly, D. J., Liu, S., Ge, L., Quinn, P. C., Slater, A. M., Lee, K., Liu, Q., & Pascalis, O. (2007). Cross-Race Preferences for Same-Race Faces Extend Beyond the African Versus Caucasian Contrast in 3-Month-Old Infants. *Infancy: The Official Journal of the International Society on Infant Studies*, *11*(1), 87–95.
- Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Gibson, A., Smith, M., Ge, L., & Pascalis, O. (2005). Three-month-olds, but not newborns, prefer own-race faces. *Developmental Science*, *8*(6), F31–F36.
- Kim, J. S., Yoon, H. W., Kim, B. S., Jeun, S. S., Jung, S. L., & Choe, B. Y. (2006). Racial distinction of the unknown facial identity recognition mechanism by event-related fMRI. *Neuroscience Letters*, *397*(3), 279–284.
- Kramer, R. S. S., Jenkins, R., & Burton, A. M. (2016). InterFace: A software package for face image warping, averaging, and principal components analysis. *Behavior Research Methods* *6*: 2002–2011.
- Kramer, R. S. S., Jenkins, R., Young, A. W., & Burton, A. M. (2017). Natural variability is essential to learning new faces. *Visual Cognition*, *25*(4-6), 470–476.
- Kramer, R. S. S., Young, A. W., & Burton, A. M. (2018). Understanding face familiarity. *Cognition*, *172*, 46–58.
- Kriegeskorte, N. (2015). Deep Neural Networks: A New Framework for Modeling Biological Vision and Brain Information Processing. *Annual Review of Vision Science*, *1*, 417–446.
- Kriegeskorte, N., Formisano, E., Sorger, B., & Goebel, R. (2007). Individual faces elicit distinct response patterns in human anterior temporal cortex. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(51), 20600–20605.
- Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. *Advances in Neural Information Processing Systems*, *25*, 1097–1105.

- Krys, K., Hansen, K., Xing, C., Szarota, P., & Yang, M.-M. (2014). Do Only Fools Smile at Strangers? Cultural Differences in Social Perception of Intelligence of Smiling Individuals. *Journal of Cross-Cultural Psychology, 45*(2), 314–321.
- Kubota, J. T., Banaji, M. R., & Phelps, E. A. (2012). The neuroscience of race. *Nature Neuroscience, 15*(7), 940–948.
- Laurence, S., Zhou, X., & Mondloch, C. J. (2016). The flip side of the other-race coin: They all look different to me. In *British Journal of Psychology* (Vol. 107, Issue 2, pp. 374–388). <https://doi.org/10.1111/bjop.12147>
- Leder, H. (1999). Matching person identity from facial line drawings. *Perception, 28*(9), 1171–1175.
- Leopold, D. A., O'Toole, A. J., Vetter, T., & Blanz, V. (2001). Prototype-referenced shape encoding revealed by high-level aftereffects. In *Nature Neuroscience* (Vol. 4, Issue 1, pp. 89–94). <https://doi.org/10.1038/82947>
- Levin, D. T. (1996). Classifying faces by race: The structure of face categories. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 22*(6), 1364.
- Levin, D. T. (2000). Race as a visual feature: using visual search and perceptual discrimination tasks to understand face categories and the cross-race recognition deficit. *Journal of Experimental Psychology. General, 129*(4), 559–574.
- Levin, D. T., & Banaji, M. R. (2006). Distortions in the perceived lightness of faces: the role of race categories. *Journal of Experimental Psychology. General, 135*(4), 501–512.
- Lieberman, M. D., Hariri, A., Jarcho, J. M., Eisenberger, N. I., & Bookheimer, S. Y. (2005). An fMRI investigation of race-related amygdala activity in African-American and Caucasian-American individuals. *Nature Neuroscience, 8*(6), 720–722.
- Lindsay, D. S., Jack, P. C., Jr, & Christian, M. A. (1991). Other-race face perception. *The Journal of Applied Psychology, 76*(4), 587–589.
- Linville, P. W., & Jones, E. E. (1980). Polarized appraisals of out-group members. *Journal of Personality and Social Psychology, 38*(5), 689.

- Linville, P. W., Fischer, G. W., & Salovey, P. (1989). Perceived distributions of the characteristics of in-group and out-group members: empirical evidence and a computer simulation. *Journal of Personality and Social Psychology*, 57(2), 165–188.
- Luce, T. S. (1974). BLACKS, WHITES AND YELLOWS THEY ALL LOOK ALIKE TO ME. *Psychology Today*, 8(6), 105.
- MacLin, O. H., & Malpass, R. S. (2001). Racial categorization of faces: The ambiguous race face effect. *Psychology, Public Policy, and Law: An Official Law Review of the University of Arizona College of Law and the University of Miami School of Law*, 7(1), 98.
- MacLin, O. H., & Malpass, R. S. (2003). The ambiguous-race face illusion. *Perception*, 32(2), 249–252.
- MacLin, O. H., MacLin, M. K., Peterson, D., Chowdhry, O., & Joshi, P. (2009). Social psychophysics: Using psychophysics to answer “social” questions with PsychoPro. *Behavior Research Methods*, 41(3), 623–632.
- Macrae, C. N., & Bodenhausen, G. V. (2000). Social cognition: thinking categorically about others. *Annual Review of Psychology*, 51, 93–120.
- Marcon, J. L., Susa, K. J., & Meissner, C. A. (2009). Assessing the influence of recollection and familiarity in memory for own- versus other-race faces. In *Psychonomic Bulletin & Review* (Vol. 16, Issue 1, pp. 99–103). <https://doi.org/10.3758/pbr.16.1.99>
- Malina, A. C., Bowers, D. A., Millis, S. R., & Uekert, S. (1998). Internal consistency of the Warrington Recognition Memory Test. *Perceptual and Motor Skills*, 86(3 Pt 2), 1320–1322.
- Malpass, R. S. (1974). Racial Bias in Eyewitness Identification? *Proceedings of the Division of Personality and Society Psychology*, 1(1), 42–44.
- Malpass, R. S., & Kravitz, J. (1969). Recognition for faces of own and other race. *Journal of Personality and Social Psychology*, 13(4), 330–334.
- Mandal, S. N., & Banerjee, K. (2012). Performance Analysis for Detection and Location of Human Faces in Digital Image With Different Color Spaces for Different Image Formats. In *International*

- Journal of Image, Graphics and Signal Processing* (Vol. 4, Issue 7, pp. 15–25).
<https://doi.org/10.5815/ijigsp.2012.07.02>
- Maurer, D., Grand, R. L., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences*, 6(6), 255–260.
- McKone, E., & Yovel, G. (2009). Why does picture-plane inversion sometimes dissociate perception of features and spacing in faces, and sometimes not? Toward a new theory of holistic processing. In *Psychonomic Bulletin & Review* (Vol. 16, Issue 5, pp. 778–797).
<https://doi.org/10.3758/pbr.16.5.778>
- Megreya, A. M., White, D., & Burton, A. M. (2011). The other-race effect does not rely on memory: Evidence from a matching task. *Quarterly Journal of Experimental Psychology*, 64(8), 1473–1483.
- Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy, and Law: An Official Law Review of the University of Arizona College of Law and the University of Miami School of Law*, 7(1), 3–35.
- Michel, C., Corneille, O., & Rossion, B. (2007). Race categorization modulates holistic face encoding. *Cognitive Science*, 31(5), 911–924.
- Michel, C., Rossion, B., Bühlhoff, I., Hayward, W. G., & Vuong, Q. C. (2013). The contribution of shape and surface information in the other-race face effect. *Visual Cognition*, 21(9-10), 1202–1223.
- Moon, H., & Phillips, P. J. (2001). Computational and performance aspects of PCA-based face-recognition algorithms. *Perception*, 30(3), 303–321.
- Morris, J. S., Frith, C. D., Perrett, D. I., Rowland, D., Young, A. W., Calder, A. J., & Dolan, R. J. (1996). A differential neural response in the human amygdala to fearful and happy facial expressions. *Nature*, 383(6603), 812–815.
- Nagpal, S., Singh, M., Singh, R., & Vatsa, M. (2019). Deep Learning for Face Recognition: Pride or Prejudiced? In *arXiv [cs.CV]*. arXiv. <http://arxiv.org/abs/1904.01219>

- Natu, V. S., Jiang, F., Narvekar, A., Keshvari, S., Blanz, V., & O'Toole, A. J. (2010). Dissociable neural patterns of facial identity across changes in viewpoint. *Journal of Cognitive Neuroscience*, *22*(7), 1570–1582.
- Natu, V., Raboy, D., & O'Toole, A. J. (2011). Neural correlates of own- and other-race face perception: spatial and temporal response differences. *NeuroImage*, *54*(3), 2547–2555.
- Nelson, C. A. (2001). The development and neural bases of face recognition. *Infant and Child Development*, *10*(1-2), 3–18.
- Nestor, A., Plaut, D. C., & Behrmann, M. (2013). Face-space architectures: evidence for the use of independent color-based features. *Psychological Science*, *24*(7), 1294–1300.
- Ng, M., Ciaramitaro, V. M., Anstis, S., Boynton, G. M., & Fine, I. (2006). Selectivity for the configural cues that identify the gender, ethnicity, and identity of faces in human cortex. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(51), 19552–19557.
- O'Toole, A. J., Abdi, H., Deffenbacher, K. A., & Valentin, D. (1993). Low-dimensional representation of faces in higher dimensions of the face space. *JOSA A*, *10*(3), 405–411.
- O'Toole, A. J., Castillo, C. D., Parde, C. J., Hill, M. Q., & Chellappa, R. (2018). Face Space Representations in Deep Convolutional Neural Networks. *Trends in Cognitive Sciences*, *22*(9), 794–809.
- O'Toole, A. J., Jiang, F., Abdi, H., & Haxby, J. V. (2005). Partially distributed representations of objects and faces in ventral temporal cortex. *Journal of Cognitive Neuroscience*, *17*(4), 580–590.
- O'Toole, A. J., Price, T., Vetter, T., Bartlett, J. C., & Blanz, V. (1999). 3D shape and 2D surface textures of human faces: the role of “averages” in attractiveness and age. *Image and Vision Computing*, *18*(1), 9–19.
- Oh, D., Dotsch, R., Porter, J., & Todorov, A. (2020). Gender biases in impressions from faces: Empirical studies and computational models. *Journal of Experimental Psychology. General*, *149*(2), 323–342.
- Olivola, C. Y., Funk, F., & Todorov, A. (2014). Social attributions from faces bias human choices. *Trends in Cognitive Sciences*, *18*(11), 566–570.

- ONS. (2011). *Ethnic group*. <https://webarchive.nationalarchives.gov.uk/20160106185816/http://www.ons.gov.uk/ons/guide-method/measuring-equality/equality/ethnic-nat-identity-religion/ethnic-group/index.html>
- Oosterhof, N. N., & Todorov, A. (2008). The functional basis of face evaluation. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(32), 11087–11092.
- Ostrom, T. M., Carpenter, S. L., Sedikides, C., & Li, F. (1993). Differential processing of in-group and out-group information. *Journal of Personality and Social Psychology*, *64*(1), 21.
- Over, H., & McCall, C. (2018). Becoming us and them: Social learning and intergroup bias. *Social and Personality Psychology Compass*, *12*(4), e12384.
- Over, H., Eggleston, A., Bell, J., & Dunham, Y. (2018). Young children seek out biased information about social groups. *Developmental Science*, *21*(3), e12580.
- Palmeri, T. J., & Gauthier, I. (2004). Visual object understanding. *Nature Reviews Neuroscience*, *5*, 291–303. <https://doi.org/10.1038/nrn1364>
- Paluck, E. L. (2016). How to overcome prejudice. *Science*. <https://science.sciencemag.org/content/352/6282/147.summary>
- Parkhi, O. M., Vedaldi, A., & Zisserman, A. (2015). *Deep face recognition*. <https://ora.ox.ac.uk/objects/uuid:a5f2e93f-2768-45bb-8508-74747f85cad1>
- Papesh, M. H., & Goldinger, S. D. (2010). A multidimensional scaling analysis of own- and cross-race face spaces. *Cognition*, *116*(2), 283–288.
- Peirce, J. W. (2007). PsychoPy—Psychophysics software in Python. *Journal of Neuroscience Methods*, *162*(1), 8–13.
- Phelps, E. A., Delgado, M. R., Nearing, K. I., & LeDoux, J. E. (2004). Extinction learning in humans: role of the amygdala and vmPFC. *Neuron*, *43*(6), 897–905.
- Phelps, E. A., O'Connor, K. J., Cunningham, W. A., Funayama, E. S., Gatenby, J. C., Gore, J. C., & Banaji, M. R. (2000). Performance on indirect measures of race evaluation predicts amygdala activation. *Journal of Cognitive Neuroscience*, *12*(5), 729–738.

- Piepers, D. W., & Robbins, R. A. (2012). A review and clarification of the terms “holistic,” “configural,” and “relational” in the face perception literature. *Frontiers in Psychology, 3*, 559.
- Platz, S. J., & Hosch, H. M. (1988). Cross-Racial/Ethnic Eyewitness Identification: A Field Study 1. *Journal of Applied Social Psychology, 18*(11), 972–984.
- Quattrone, G. A., & Jones, E. E. (1980). The perception of variability within in-groups and out-groups: Implications for the law of small numbers. *Journal of Personality and Social Psychology, 38*(1), 141.
- Quinn, K. A., Mason, M. F., & Macrae, C. N. (2010). When Arnold is “The Terminator”, We No Longer See Him as a Man. *Experimental Psychology, 57*(1), 27–35.
- Ran, G., Zhang, Q., Chen, X., & Pan, Y. (2014). The effects of prediction on the perception for own-race and other-race faces. *PloS One, 9*(11), e114011.
- Ratner, K. G., Kaul, C., & Van Bavel, J. J. (2013). Is race erased? Decoding race from patterns of neural activity when skin color is not diagnostic of group boundaries. *Social Cognitive and Affective Neuroscience, 8*(7), 750–755.
- Reggev, N., Brodie, K., Cikara, M., & Mitchell, J. P. (2020). Human Face-Selective Cortex Does Not Distinguish between Members of a Racial Outgroup. *eNeuro, 7*(3).
<https://doi.org/10.1523/ENEURO.0431-19.2020>
- Rhodes, G., Hayward, W. G., & Winkler, C. (2006). Expert face coding: configural and component coding of own-race and other-race faces. *Psychonomic Bulletin & Review, 13*(3), 499–505.
- Rhodes, G., Locke, V., Ewing, L., & Evangelista, E. (2009). Race coding and the other-race effect in face recognition. *Perception, 38*(2), 232–241.
- Rhodes, G., Tan, S., Brake, S., & Taylor, K. (1989). Expertise and configural coding in face recognition. *British Journal of Psychology, 80* (Pt 3), 313–331.
- Rice, G. E., Watson, D. M., Hartley, T., & Andrews, T. J. (2014). Low-level image properties of visual objects predict patterns of neural response across category-selective regions of the ventral visual pathway. *Journal of Neuroscience, 34*(26), 8837–8844.

- Robertson, D. J., Black, J., Chamberlain, B., Megreya, A. M., & Davis, J. P. (2020). Super-Recognisers show an advantage for other race face identification. *Applied Cognitive Psychology, 34*(1), 205–216.
- Rodin, M. J. (1987). Who Is Memorable to Whom: A Study of Cognitive Disregard. *Social Cognition, 5*(2), 144–165.
- Rossion, B., Michel, C., & Others. (2011). An experience-based holistic account of the other-race face effect. *The Oxford Handbook of Face Perception, 215–244*.
- Rule, N. O., Ambady, N., Adams, R. B., Jr, & Macrae, C. N. (2007). Us and them: memory advantages in perceptually ambiguous groups. *Psychonomic Bulletin & Review, 14*(4), 687–692.
- Russell, R., & Sinha, P. (2007). Real-world face recognition: The importance of surface reflectance properties. *Perception, 36*(9), 1368–1374.
- Russell, R., Sinha, P., Biederman, I., & Nederhouser, M. (2006). Is pigmentation important for face recognition? Evidence from contrast negation. *Perception, 35*(6), 749–759.
- Sangrigoli, S., Pallier, C., Argenti, A.-M., Ventureyra, V. A. G., & de Schonen, S. (2005). Reversibility of the other-race effect in face recognition during childhood. *Psychological Science, 16*(6), 440–444.
- Sankar, A., Costafreda, S. G., Marangell, L. B., & Fu, C. H. Y. (2018). Other race effect on amygdala response during affective facial processing in major depression. *Neuroscience Letters, 662*, 381–384.
- Shapiro, P. N., & Penrod, S. (1986). Meta-analysis of facial identification studies. *Psychological Bulletin, 100*(2), 139.
- Shepherd, J. W., & Deregowski, J. B. (1981). Races and faces - a comparison of the responses of Africans and Europeans to faces of the same and different races. *The British Journal of Social Psychology / the British Psychological Society, 20*(2), 125–133.

- Sherif, M., Harvey, O. J., White, B. J., Hood, W. R., & Sherif, C. W. (1961). Intergroup conflict and cooperation: the robbers cave experiment Norman. *OK University Book Exchange*.
<http://www.dominiopublico.gov.br/download/texto/ps000162.pdf>
- Short, L. A., Mondloch, C. J., McCormick, C. M., Carré, J. M., Ma, R., Fu, G., & Lee, K. (2012). Detection of Propensity for Aggression based on Facial Structure Irrespective of Face Race. *Evolution and Human Behavior: Official Journal of the Human Behavior and Evolution Society*, 33(2), 121–129.
- Slone, A. E., Brigham, J. C., & Meissner, C. A. (2000). Social and Cognitive Factors Affecting the Own-Race Bias in Whites. *Basic and Applied Social Psychology*, 22(2), 71–84.
- Soukup, V. M., Bimbela, A., & Schiess, M. C. (1999). Recognition Memory for Faces: Reliability and Validity of the Warrington Recognition Memory Test (RMT) in a Neurological Sample. *Journal of Clinical Psychology in Medical Settings*, 6(3), 287–293.
- Sporer, S. L. (2001). Recognizing faces of other ethnic groups: An integration of theories. *Psychology, Public Policy, and Law: An Official Law Review of the University of Arizona College of Law and the University of Miami School of Law*, 7(1), 36.
- Stanley, D. A., Sokol-Hessner, P., Banaji, M. R., & Phelps, E. A. (2011). Implicit race attitudes predict trustworthiness judgments and economic trust decisions. *Proceedings of the National Academy of Sciences of the United States of America*, 108(19), 7710–7715.
- Stahl, J., Wiese, H., & Schweinberger, S. R. (2008). Expertise and own-race bias in face processing: an event-related potential study. *Neuroreport*, 19(5), 583–587.
- Stahl, J., Wiese, H., & Schweinberger, S. R. (2010). Learning task affects ERP-correlates of the own-race bias, but not recognition memory performance. *Neuropsychologia*, 48(7), 2027–2040.
- Stelter, M., & Degner, J. (2018). Investigating the other-race effect in working memory. *British Journal of Psychology*, 109(4), 777–798.
- Sutherland, C. A. M., Liu, X., Zhang, L., Chu, Y., Oldmeadow, J. A., & Young, A. W. (2018). Facial First Impressions Across Culture: Data-Driven Modeling of Chinese and British Perceivers'

- Unconstrained Facial Impressions. In *Personality and Social Psychology Bulletin* (Vol. 44, Issue 4, pp. 521–537). <https://doi.org/10.1177/0146167217744194>
- Sutherland, C. A. M., Oldmeadow, J. A., Santos, I. M., Towler, J., Michael Burt, D., & Young, A. W. (2013). Social inferences from faces: ambient images generate a three-dimensional model. *Cognition*, *127*(1), 105–118.
- Tajfel, H., & Turner, J. C. (2004). The Social Identity Theory of Intergroup Behavior. In *Political Psychology* (pp. 276–293). <https://doi.org/10.4324/9780203505984-16>
- Tajfel, H., Billig, M. G., Bundy, R. P., & Flament, C. (1971). Social categorization and intergroup behaviour. *European Journal of Social Psychology*, *1*(2), 149–178.
- Tanaka, J. W., & Gordon, I. (2011). Features, configuration, and holistic face processing. *The Oxford Handbook of Face Perception*, 177–194.
- Tanaka, J. W., & Pierce, L. J. (2009). The neural plasticity of other-race face recognition. *Cognitive, Affective & Behavioral Neuroscience*, *9*(1), 122–131.
- Taubert, J., Wardle, S. G., & Ungerleider, L. G. (2020). What does a “face cell” want?’. *Progress in Neurobiology*, *195*, 101880.
- Telzer, E. H., Flannery, J., Shapiro, M., Humphreys, K. L., Goff, B., Gabard-Durman, L., Tottenham, N. (2013). Early experience shapes amygdala sensitivity to race: an international adoption design. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *33*(33), 13484–13488.
- Tian, J., Xie, H., Hu, S., & Liu, J. (2021). Multidimensional Face Representation in a Deep Convolutional Neural Network Reveals the Mechanism Underlying AI Racism. *Frontiers in Computational Neuroscience*, *15*, 620281.
- Tiddeman, B., Burt, M., & Perrett, D. (2001). Prototyping and transforming facial textures for perception research. *IEEE Computer Graphics and Applications*, *21*(5), 42–50.

- Todorov, A., Olivola, C. Y., Dotsch, R., & Mende-Siedlecki, P. (2015). Social attributions from faces: determinants, consequences, accuracy, and functional significance. *Annual Review of Psychology*, *66*, 519–545.
- Tredoux, C. (2002). A direct measure of facial similarity and its relation to human similarity perceptions. In *Journal of Experimental Psychology: Applied* (Vol. 8, Issue 3, pp. 180–193). <https://doi.org/10.1037/1076-898x.8.3.180>
- Turk, M., & Pentland, A. (1991). Face recognition using eigenfaces. *Proceedings. 1991 IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, 586–587.
- Turk, M., & Pentland, A. (1991). Eigenfaces for recognition. *Journal of Cognitive Neuroscience*, *3*(1), 71–86.
- Turner, J. C., Hogg, M. A., Oakes, P. J., Reicher, S. D., & Wetherell, M. S. (1987). *Rediscovering the social group: A self-categorization theory*. 239. <https://psycnet.apa.org/fulltext/1987-98657-000.pdf>
- Tüttenberg, S. C., & Wiese, H. (2021). Recognising other-race faces is more effortful: The effect of individuation instructions on encoding-related ERP Dm effects. In *Biological Psychology* (Vol. 158, p. 107992). <https://doi.org/10.1016/j.biopsycho.2020.107992>
- Valentine, T., & Endo, M. (1992). Towards an exemplar model of face processing: the effects of race and distinctiveness. *The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology*, *44*(4), 671–703.
- Valentine, T., Lewis, M. B., & Hills, P. J. (2016). Face-space: A unifying concept in face recognition research. *Quarterly Journal of Experimental Psychology*, *69*(10), 1996–2019.
- Van Bavel, J. J., Packer, D. J., & Cunningham, W. A. (2008). The neural substrates of in-group bias: a functional magnetic resonance imaging investigation. *Psychological Science*, *19*(11), 1131–1139.
- Vernon, R. J. W., Sutherland, C. A. M., Young, A. W., & Hartley, T. (2014). Modeling first impressions from highly variable facial images. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(32), E3353–E3361.

- Vizioli, L., Rousselet, G. A., & Caldara, R. (2010). Neural repetition suppression to identity is abolished by other-race faces. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(46), 20081–20086.
- Walker, M., Jiang, F., Vetter, T., & Sczesny, S. (2011). Universals and Cultural Differences in Forming Personality Trait Judgments From Faces. In *Social Psychological and Personality Science* (Vol. 2, Issue 6, pp. 609–617). <https://doi.org/10.1177/1948550611402519>
- Walker, P. M., & Hewstone, M. (2006). A perceptual discrimination investigation of the own-race effect and intergroup experience. *Applied Cognitive Psychology*, *20*(4), 461–475.
- Walker, P. M., Silvert, L., Hewstone, M., & Nobre, A. C. (2008). Social contact and other-race face processing in the human brain. *Social Cognitive and Affective Neuroscience*, *3*(1), 16–25.
- Wan, L., Crookes, K., Dawel, A., Pidcock, M., Hall, A., & McKone, E. (2017). Face-blind for other-race faces: Individual differences in other-race recognition impairments. *Journal of Experimental Psychology. General*, *146*(1), 102–122.
- Wardle, S. G., Taubert, J., Teichmann, L., & Baker, C. I. (2020). Rapid and dynamic processing of face pareidolia in the human brain. *Nature Communications*, *11*(1), 4518.
- Warrington, E. K. (1984). *Recognition memory test*. Western Psychological Services.
- Webster, M. A., & MacLeod, D. I. A. (2011). Visual adaptation and face perception. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *366*(1571), 1702–1725.
- Webster, M. A., & MacLin, O. H. (1999). Figural aftereffects in the perception of faces. *Psychonomic Bulletin & Review*, *6*(4), 647–653.
- Weibert, K., & Andrews, T. J. (2015). Activity in the right fusiform face area predicts the behavioural advantage for the perception of familiar faces. *Neuropsychologia*, *75*, 588–596.
- Wiese, H., Kaufmann, J. M., & Schweinberger, S. R. (2014). The neural signature of the own-race bias: evidence from event-related potentials. *Cerebral Cortex*, *24*(3), 826–835.

- Winston, J. S., Henson, R. N. A., Fine-Goulden, M. R., & Dolan, R. J. (2004). fMRI-adaptation reveals dissociable neural representations of identity and expression in face perception. *Journal of Neurophysiology*, *92*(3), 1830–1839.
- Wolf, L., Hassner, T., & Maoz, I. (2011). Face recognition in unconstrained videos with matched background similarity. In *CVPR 2011*. <https://doi.org/10.1109/cvpr.2011.5995566>
- Wright, D. B., Boyd, C. E., & Tredoux, C. G. (2001). A field study of own-race bias in South Africa and England. *Psychology, Public Policy, and Law: An Official Law Review of the University of Arizona College of Law and the University of Miami School of Law*, *7*(1), 119.
- Wright, D. B., Boyd, C. E., & Tredoux, C. G. (2003). Inter-racial contact and the own-race bias for face recognition in South Africa and England. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, *17*(3), 365–373.
- Xiao, J., Hays, J., Ehinger, K. A., Oliva, A., & Torralba, A. (2010). SUN database: Large-scale scene recognition from abbey to zoo. *2010 IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, 3485–3492.
- Xie, S. Y., Flake, J. K., & Hehman, E. (2019). Perceiver and target characteristics contribute to impression formation differently across race and gender. *Journal of Personality and Social Psychology*, *117*(2), 364–385.
- Yan, X., Andrews, T. J., & Young, A. W. (2016). Cultural similarities and differences in perceiving and recognizing facial expressions of basic emotions. *Journal of Experimental Psychology. Human Perception and Performance*, *42*(3), 423–440.
- Yan, X., Andrews, T. J., Jenkins, R., & Young, A. W. (2016). Cross-cultural differences and similarities underlying other-race effects for facial identity and expression. *Quarterly Journal of Experimental Psychology*, *69*(7), 1247–1254
- Yan, X., Young, A. W., & Andrews, T. J. (2017). The automaticity of face perception is influenced by familiarity. *Attention, Perception & Psychophysics*, *79*(7), 2202–2211.

- Young, A. W., & Burton, A. M. (2017). Recognizing Faces. *Current Directions in Psychological Science*, 26(3), 212–217.
- Young, A. W., & Burton, A. M. (2018). Are We Face Experts? *Trends in Cognitive Sciences*, 22(2), 100–110.
- Young, S. G., Hugenberg, K., Bernstein, M. J., & Sacco, D. F. (2009). Interracial contexts debilitate same-race face recognition. *Journal of Experimental Social Psychology*, 45(5), 1123–1126.
- Yuki, M., Maddux, W. W., & Masuda, T. (2007). Are the windows to the soul the same in the East and West? Cultural differences in using the eyes and mouth as cues to recognize emotions in Japan and the United States. *Journal of Experimental Social Psychology*, 43(2), 303–311.
- Zebrowitz, L. A., Matthew Bronstad, P., & Montepare, J. M. (2010). An Ecological Theory of Face Perception. In *The Science of Social Vision* (pp. 3–30). <https://doi.org/10.1093/acprof:oso/9780195333176.003.0002>
- Zebrowitz, L. A., Montepare, J. M., & Lee, H. K. (1993). They don't all look alike: Individual impressions of other racial groups. *Journal of Personality and Social Psychology*, 65(1), 85–101.
- Zebrowitz, L. A., Wang, R., Bronstad, P. M., Eisenberg, D., Undurraga, E., Reyes-García, V., & Godoy, R. (2012). First impressions from faces among U.s. and culturally isolated Tsimane' people in the Bolivian Rainforest. *Journal of Cross-Cultural Psychology*, 43(1), 119–134.
- Zhao, L., & Bentin, S. (2008). Own- and other-race categorization of faces by race, gender, and age. *Psychonomic Bulletin & Review*, 15, 1093–1099. <https://doi.org/10.3758/PBR.15.6.1093>
- Zhou, X., Itz, M. L., Vogt, S., Kaufmann, J. M., Schweinberger, S. R., & Mondloch, C. J. (2021). Similar use of shape and texture cues for own- and other-race faces during face learning and recognition. *Vision Research*, 188, 32–41.