Recognizing Own- and Other-race Faces: Cognitive Mechanisms Underlying the Other-Race Effect

by
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Abstract

Other-race faces are discriminated and recognized less accurately than own-race faces. The other-race effect (ORE) emerges during infancy and is robust across different participant populations and a variety of methodologies (Meissner & Brigham, 2001). Decades of research has been successful in characterizing the roots of the ORE, however certain aspects regarding the nature of own- and other-race face representations remain unspecified. The present dissertation attempts to find the commonalities and differences in the processing of own- vs. other-race faces so as to develop an integrative understanding of the ORE in face recognition.

In Study 1, I demonstrated that the ORE is attributable to an impaired ability to recognize other-race faces despite variability in appearance. In Study 2, I further examined whether this ability is influenced by familiarity. The ORE disappears for familiar faces, suggesting a fundamental difference in the familiar and unfamiliar other-race face recognition. Study 3 was designed to directly test whether the ORE is attributable to a less refined representation of other-race faces in face space. Adults are more sensitive to deviations from normality in own- than other-race faces, and between-rater variability in attractiveness rating of individual faces is higher for other- than own-race faces. In Study 4, I investigated whether the ORE is driven by the different use of shape and texture cues. Despite an overall ORE, the transition from idiosyncratic shape to texture cues was comparable for own- and other-race faces, suggesting that the different utilization of shape and texture cues does not contribute to the ORE. In Study 5, applying a novel continuous-response paradigm, I investigated how the representations of own- and other-race face are stored in visual working memory (VWM). Following ample encoding time, the ORE is attributable to differences in the probability of a face being maintained in VWM. Reducing encoding time caused a loss of precision of VWM for other- but not own-race faces. Collectively, the results of this dissertation help elucidate the nature of representations of own- and other-race faces and clarify the role of perceptual experience in shaping our ability to recognize own- and other-race faces.

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CHAPTER 1

General Introduction

1.1 The Other-Race Effect: A Definition

Adults possess a remarkable ability to recognize individual faces, despite the fact that all faces share the same configural template (i.e., two eyes located above the nose and mouth). However, such face expertise is limited to face categories with which people have abundant perceptual experience (e.g., upright faces, own-race faces). One of the most replicated phenomena in face perception is that perceivers tend to discriminate and recognize faces of the race with which they are most familiar (typically one's own race) more accurately than the faces of the race with which they are less familiar. This is the so-called other-race effect (ORE), which has also been called the "own-race bias" and "cross-race effect" (Byatt & Rhodes, 2004; Ng & Lindsay, 1994; see Meissner & Brigham, 2001 for a review).

The other-race effect was first reported in 1914 by Feingold, who claimed 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 whole. Thus, to the uninitiated American all Asiatics look alike, while to the Asiatics, all White men look alike" (Feingold, 1914; p.50). The first empirical evidence supporting the ORE derives from a study conducted by Malpass and Kravitz in 1969. These researchers found that both Caucasian and African American adults were more accurate when identifying previously learned own- than other-race faces (Malpass & Kravitz, 1969). Since then, the robustness of the ORE has been confirmed by a great volume of research testing participants from different ethnic groups and with faces from different races (e.g., West

Caucaisan and Hispanic faces; see Tanaka & Pierce, 2009; Turkish and German faces; Sporer, 2002; Anglo-American, African-American, and Mexican-American faces; see Platz & Hosch, 1998 for a field study; East Asian faces, Valentine & Endo, 1992; Ng & Lindsay, 1994; Zhang, Zhou, Pu, & Hayward, 2011). Given that the effect is found across participant groups and face categories, the ORE is unlikely due to the differences in either stimulus sets or observer characteristics. Furthermore, Goldstein compared the physiognomic variability among Japanese, white and black faces and found no evidence for racial differences in facial heterogeneity (Goldstein, 1979), suggesting that the ORE is not due to the fact that faces of one ethnic group are inherently more difficult to recognize and memorize than the faces from another ethnic group (also see Baytt & Rhodes, 2004).

Importantly, Bothwell and colleagues conducted a meta-analysis based on 14 studies involving both black and white participants (n = 1435; Bothwell, Brigham, & Malpass, 1989). They also found a consistent ORE; around 80% of the black and white subjects exhibited better recognition of own- than other-race faces. Meissner and Brigham (2001) also confirmed the reliability of the ORE in their meta-analysis, involving 39 research studies and nearly 5000 participants. They reported that the chance of a mistaken identification is 1.56 greater for an other-race identity than that of an own-race identity (Meissner & Brigham, 2001). They suggested that the ORE is associated with greater error when identify a previously seen other-race face as familiar (hit) and greater error when identify a previously unseen other-race face as novel (correct rejection).

In addition to the behavioral studies described above, a great volume of neurophysiological studies and neuroimaging studies have been conducted to explore the time-course and the anatomical basis of the other-race effect. Several EEG studies have reported smaller amplitudes of N170 and P200 for other- than own-race faces (Ito & Urland, 2005; Jonathan, Freeman, & Holcomb, 2009; Vizioli, Foreman, Rousselet, & Caldara, 2009; Vizioli, Rousselet, Foreman, & Caldara, 2009; but see Balas & Nelson, 2010; Stahl, Wiese & Schweinberger, 2008; Tanaka & Pierce, 2009). N170 and P200 are ERP components that peak over tempero-occipital brain regions about 170ms and 200ms after stimulus onset, are larger for faces than most other stimulus categories, and are thought to reflect structural encoding and holistic processing of faces (see Rossion, 2014 for a review). These findings therefore suggest that the ORE is at least partially attributable to the impairments in the formation of sensory representations of other- than own-face faces (structural encoding) and in the integration of facial features into a whole when encoding other- than own-race faces.

Neuroimaging studies are conducted to explore the localization of activity associated with the processing of own- versus other-race faces. Some fMRI studies have reported greater activation of fusiform gyrus (FFA) and occipital face area (OFA) for own- and other-race faces (Feng et al., 2011; Golby, Gabrieli, Chiao, & Eberhardt., 2001; Kim et al., 2006; Natu, Raboy, & O'Toole, 2010; also see Natu & O'Toole, 2013 for a review, but see Kanwisher et al., 1997). OFA has been found to be sensitive to face parts and configuration. FFA has been reported to be involved in the processing of faces at a subordinate level rather than at a basic-level and activation of the FFA reflects differential visual expertise (Natu & O'toole, 2013; Tarr & Gauthier, 2000). For example, FFA can be greatly activated when bird and car experts judge whether the two birds in a pair belong to the same species, or whether the two cars in a pair belong to same model but different years (Gauthier et al., 2000). Greater activation of these brain areas for own- vs. other-race faces would suggest that the ORE is associated with impaired sensitivity to the structure of facial features in other-race faces, likely a directly result of limited perceptual experience with these faces (Natu & O'toole, 2013; Feng et al., 2011).

1.2 Measurement of Other-Race Effect

A variety of methodologies have been used to investigate the ORE. These tasks are designed to characterize the perceptual and mnemonic differences in the processing of own- and other-race faces. For example, the old/new face recognition task and Cambridge face memory tasks are designed to measure perceivers' ability to store and recall representations of own- and other-race faces. Other tasks, such as Glasgow face-matching task and the 1-in-10 line-up task, are designed to measure perceivers' ability to perpetually discriminate among own- and other-race faces. Some other tasks are designed to determine the mechanisms underlying differential discrimination and recognition; these tasks test people's sensitivity to the shape of facial features and feature spacing (e.g., Jane/Ling task; Scrambled/blurred task), as well as holistic processing of own- and other-race faces (e.g., Composite face task; Part/Whole task).

Extensive evidence has suggested that the ORE is not merely a memory phenomenon; it also exists at a perceptual level. Perceivers tend to show deficits in the encoding, storage, and/or retrieval of the other-race face representations from memory, however, their performance is also impaired in perceptual discrimination tasks, where the memory demands are largely eliminated or reduced. This section will review the most typical five measures that are used in the ORE literature: old/new face recognition task, which measures perceivers' memory for faces; 1-to-10 face matching task, which tests the perceptual discrimination of faces; the composite face task, which measures the holistic processing of faces; and the scrambled/blurred task and Jane/Ling task, which test perceivers' sensitivity to the appearance of individual facial features and the spacing among facial features in own- and other-race faces.

1.2.1 Old/new face recognition task

One of the classic measures of own- and other-race face memory is the old/new face recognition task (e.g., Golby, Gabrieli, Chiao & Eberhardt, 2001; MacLin & Malpass, 2001; Meissner & Brigham, 2001; Wright, Boyd & Tredoux, 2003). In this task, participants are typically instructed to memorize a set of own- and other-race faces, followed by a forced-choice recognition test in which the learned faces are intermixed with novel faces; participants are asked to indicate whether each face is an 'old' face (seen during the learning phase) or a 'new' face (not seen during the learning phase).

Participants' responses can be therefore categorized into four types: *hits*, defined as the proportion of trials in which previously learned faces are correctly identified as 'old'; *misses*, defined as the proportion of trials in which previously learned faces are incorrectly identified as 'new'; *correct rejections*, defined as the proportion of trials in which previously unseen faces are correctly identified as 'new'; and false alarms, which is the proportion of trials in which previously unseen faces are incorrectly identified as 'old'. Using signal detection theory, d-prime, which takes into account both hits and false alarms, can be calculated to represent overall recognition accuracy. Using this paradigm, researchers have consistently found that when asked to recall the learned own- and other-race faces from memory, perceivers typically make fewer hits and more false alarms for other- than own-race faces (see Meissner & Brigham, 2001 for a review), reflecting impairments in the encoding, storage and/or retrieval of other-race face representations from memory (Meissner & Brigham, 2001; Young, Hugenberg, Bernstein, & Sacco, 2012). Although the old/new face recognition task has been widely used to test people's memory for own- and other-race faces, its' real-world applicability is criticised by some researchers (Lindsay & Well, 1983) as it is unlikely in the real world that perceivers learn a set of faces sequentially and then recall these faces from their memory. Some other more applied tasks, such as the identity task, requiring participants to locate a target face in an identity line-up from memory (Meissner, Tredoux, Parker & MacLin, 2005; Jackiw, Arbuthnott, Pfeifer, Marcon & Meissner, 2008; Evans, Marcon & Meissner, 2009), have also been used in the face perception literature, but will not be discussed in detail here.

1.2.2 Face matching task

In addition to face memory tasks, researchers have also developed various matching tasks to measure people's perceptual discrimination of own- and other-race faces. One of the classic tasks is the face-matching task (also see Glasgow face matching task; Megreya & Burton, 2007; Megreya, White, & Burton, 2011). The face-matching task has different formats that vary in their difficulty (e.g., simultaneous face matching, sequential face matching, 1-to-1 face matching, 1-to-10 face matching), but all are designed to minimize the memory demands so as to test whether there is differential discrimination of own- and other-race faces at the perceptual level.

In the classic 1-to-10 face matching task (e.g., Megreya, White, & Burton, 2011), participants are shown a target face and an array of 10 test faces; their task is to determine whether the target is present among the test faces and, if so, to identity the person. In the half of the trials, the target faces are present in the test array, and in the other half, the target faces are absent. For the target-present trials, there are three possible responses: *hit*, defined as correctly reporting that the target is 'present', and correctly identifying the target; *misses*, defined as incorrectly reporting that the target is 'absent'; and *misidentification*, defined as incorrectly identify a distractor. For the target-absent trials, there are two possible responses: *correct rejections*, defined as correctly reporting that the target is 'absent'; and *false alarms*, defined as incorrectly reporting that target is 'present' and identifying a foil. Overall accuracy is typically calculated based on hits and correct rejections. It has been consistently found that participants' matching performance is significantly impaired for other- relative to own-race faces (Levin, 2000; Megreya & Havard, 2011; Megreya, White, & Burton, 2011; Sporer, Trinkl, & Guberova, 2007). Megreya and colleagues used upright and inverted target own- and other-race faces in their study and found a stronger inversion effect for own- than other-race faces, suggesting that the ORE is also associated with more configural processing of own- than other-race faces (inversion especially disrupts the accurate extraction of special relations among facial features, Maurer, Le Grand, & Mondloch, 2002). Collectively, these studies show poor discrimination and recognition of other-race faces; the studies to follow look at potential underlying processes.

1.2.3 Composite face task

Several lines of studies have suggested that other-race faces are processed less holistically than own-race face, which may underlie the recognition and discrimination deficits for other-race faces (e.g., Michel, Corneille, & Rossion, 2007; Michel, Rossion, Han, Chung, & Caldara, 2006; Tanaka, Kiefer, & Bukach, 2003). This conclusion has been made based on tasks measuring people’s ability to extract the relationship between facial features, and to integrate the facial features into a gestalt (i.e., holistic processing; see Maurer, Le Grand, & Mondloch, 2002). One of the classic measures is the composite face task.

In this task (see Figure 1.1), participants are shown a target face and then a composite face comprised of the same upper half paired with a different bottom half or a composite face comprised of a different upper and a different bottom half than the target face. Participants are asked to indicate whether the top halves of the two faces are identical or different. On the half of the trials, the top and the bottom half are aligned while on the other half of the trials, they are misaligned (a manipulation that disrupts holistic processing). When the two halves are aligned, participants are inclined to respond ‘different’ because the face is processed as a whole and therefore perception of the top half is influenced by the bottom half. When the two halves are misaligned, the top and bottom halves are processed independently and accuracy improves. Some studies suggest that the difference in accuracy between misaligned and aligned conditions is bigger for own- than other-race faces (Michel, Corneille, & Rossion, 2007; Michel, Rossion, Han, Chung, & Caldara, 2006; but see Mondloch et al., 2010), suggesting that other-race faces are processed less holistically than own-race faces.

1.2.4 Scrambled/blurred task and Jane/Ling task

The scrambled/blurred task and Jane/Ling task are designed to measure perceivers' sensitivity to the appearance of individual facial features as well as the spacing among facial features. In the scrambled/blurred task, participants study a set of original faces, and then make old/new judgments about scrambled and blurred faces. While configural information is largely eliminated in scrambled faces, featural information is largely eliminated in blurred faces. Researchers found that accuracy is typically higher in both blurred and scrambled face pairs for own- than for other-race faces, suggesting that perceivers are less sensitive to facial features and their second-order configuration in other-race faces than own-race faces (e.g., Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010; Rhodes et al., 2009). In the Jane/Ling task, memory demands are minimized by having participants make same/different judgements about pairs of faces that differ in the spacing among featural features (spacing set) or the shape of individual features (featural set). In the featural set, individual facial features of a target identity (e.g., eyes and mouth) are replaced by the facial features of another sex-matched identity, while retaining the original spatial configuration of features. In the spacing set, the individual facial features of the target identity remain unchanged, however, the spacing among them is changed (e.g., moving two eyes up or down 1.3 standard deviations). Consistent with the scrambled/blurred task, accuracy on both the spacing and featural set is higher for own- than for other-race faces, indicating that perceivers are less sensitive to facial features and their configuration in other- than own-race faces (Mondloch et al., 2010).

In summary relative to own-race faces, perceivers process other-race faces less holistically, are less sensitive to differences in features and their spacing, are less able to discriminate between faces in simultaneous/sequential matching tasks, and less able to store and recall other-race faces from memory.

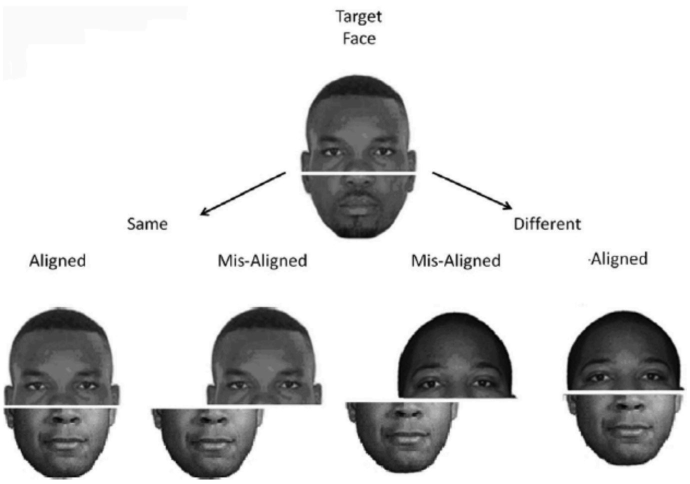

Figure 1.1. An example of faces stimuli used for composite face task; Retrieved from Young, S. G., Hugenberg, K., Bernstein, M. J., & Sacco, D. F. (2012). Perception and motivation in face recognition a critical review of theories of the cross-race effect. *Personality and Social Psychology Review*, *16*(2), 116-142.

1.3 Theoretical Accounts of Other-Race Effect

Despite the many years of research on the other-race effect, the underlying mechanisms of the ORE are still under debate. A number of theoretical explanations for the ORE have been proposed. This section will review the two major theoretical accounts of the other-race effect: the perceptual expertise hypothesis, and the social cognitive hypothesis.

1.3.1 Perceptual expertise hypothesis

A core assumption of the perceptual expertise hypothesis is that a lack of perceptual experience with other-race faces leads to reduced sensitivity to differences among other-race faces in shape and spacing of facial features (Mondloch et al., 2010), and consequently leads to a deficient encoding and processing of other-race faces (Michel, Caldara, & Rossion, 2006; Tanaka, Kiefer, & Bukach, 2004). These differences together fundamentally shape the way in which own- and other-race faces are mentally represented, which has been conceptualized in Valentine's influential multidimensional face space model (Valentine, 1911).

Extensive evidence has been provided to support this hypothesis. This evidence can be generally categorized into two streams. One stream comprises developmental studies that examine how the asymmetrical perceptual experience with faces of racial in-group and out-group members gained through development differently shapes perceivers' ability to recognize own- and other-race faces; these studies have suggested that the other-race effect is a direct product of perceptual narrowing (see the following section). Another stream comprises studies that examine how acquired perceptual expertise with other-race faces through specialized training modulates the magnitude of the other-race effect. In this section, I will firstly review the studies supporting the perceptual expertise hypothesis based on each of the two streams and then explain the ORE in the context of the influential multidimensional face space model and norm-based coding model.

1.3.1.1 The role of perceptual experience

Many developmental studies suggest that the ORE is a result of perceptual narrowing, which refers to the phenomenon that the perceptual system is broad from birth, but narrows as a function of experience (Maurer & Merker, 2013; Kelly et al., 2005; 2007; Pascalis et al., 2005). Just as experience tunes our sensitivity to musical rhythms (Hannon & Trehub, 2005) and speech sounds (Kuhl, Tsao, & Liu, 2003), so too does it tune our sensitivity to facial cues to identity (Pascalis et al., 2005). More specifically, researchers proposed that infants are born with a broad face-processing system, allowing them to discriminate faces from different ethnic groups. This broad system gradually becomes tuned to faces from the infant's own ethnic group, as a result of repeated exposure to these faces and not to faces from a different ethnic group (Anzures et al., 2013; Kelly et al., 2005; 2007).

In line with this hypothesis, Kelly and colleagues (2007) found that 3-month-old Caucasian infants are capable of discriminating faces both from their own ethnic group (Caucasian faces) and from three other ethnic groups (Middle Eastern, Chinese, and African faces). By 6 months of age Caucasian infants lose their ability to discriminate African and Middle Eastern faces and by 9 months, they can only discriminate faces from their own ethnic group (Caucasian faces). Several studies suggest that the fine-tuning of the perceptual system is highly experience-dependent. African infants living in a predominantly Caucasian environment showed similar preference for black and white faces (Bar-Haim, Ziv, Lamy, & Hodes, 2006). Training Caucasian infants with East Asian faces between 6 and 9 months (70 minutes of visual experience with photos of Asian individuals) tends to postpone the emergence of the other-race effect (Heron-Delaney et al., 2011). A similar pattern was observed in the discrimination of monkey faces in infants; between 6 and 9 months of age, infants gradually lose their ability to discriminate different monkey faces. Most notably, extensive perceptual training tends to postpone this loss of ability (Pascalis et al., 2005). Moreover, Anzures et al (2012) found that after receiving approximately 100- 105 minutes' video training with Asian faces, 8 to 10 months old Caucasian infants who previously could not discriminate between novel and familiarized Asian faces started to show above-chance recognition of novel Asian faces. These developmental studies together highlighted that face-processing expertise still remains plastic and it is continuously shaped by early perceptual experience.

Consistent with evidence that experience drives perceptual narrowing during infancy, it has been found that the magnitude of the other-race effect in adults is modulated by the extent of interracial contact. For example, Chiroro and colleagues found that the other-race effect is reduced in both Caucasian and African Americans who report having a high degree of contact with other-race identities relative to individuals who reported having little contact with other-race identities (Chiroro & Valentine, 1995). Consistent with this finding, considerable research has confirmed a positive relationship between participants' self-reported interracial contact and their performance for other-race faces in both discrimination (Brigham et al., 1982) and in recognition tasks (Wiese, Kaufmann, & Schweinberger, 2014; Zhao, Hayward, & Bulthoff, 2014). The ORE is also less evident in children who live in more integrated neighborhoods than in children who live in segregated neighborhoods (Feinman & Entwisle, 1976). Furthermore, the other-race effect is absent (de Heering, Liedekerke, Deboni, & Rossion, 2010) and even reversed following cross-race adoption before the age of nine years (Sangrigoli et al., 2005). Taken together, these studies show that perceptual experience plays a critical role in shaping our ability to recognize own- and other-race faces.

In addition, some researchers argue that the magnitude of the ORE can be reduced by specific training with other-race faces. Although the stability and effectiveness of training as well as whether the training can be generalized to novel other-race faces is still debatable, initial evidence suggests that specific types of training might reduce the other-race effect. For example, Dunning et al found that basketball fans outperform basketball novices in recognizing black faces (Dunning, Li, & Malpass, 1998), likely a result of extensive exposure to black faces, given that the majority of professional basketball players are black. Malpass and colleagues found that recognition of other-race faces can be improved by feedback training (Malpass, Lavigueur, & Weldon, 1973) and by asking participants to learn which face was paired with which number (faces paired with digits task; Elliott, Wills, & Goldstein, 1973). In contrast to these findings, other laboratory training has produced modest results (McGugin, Tanaka, Lebrecht, Tarr & Gauthier, 2011; Tanaka & Pierce, 2009). For example, in the Tanaka and Pierce study, Caucasian participants were trained to discriminate Caucasian and African American's faces either at an individual level (e.g., Joe, Bob) or at a categorical level (African American, Caucasians). Although participants' recognition performance benefited more from the subordinate-level training than the categorical-level training, such training does not reduce the magnitude of ORE, suggesting a comparable training effect for own- and other-race faces (Tanaka & Pierce, 2009).

Collectively, this evidence highlights that discrimination and recognition of own- and other-race faces is highly experience-dependent. The developmental and perceptual asymmetries in the experience with own- and other-race faces likely fundamentally modulate the way in which own-and other-race faces are processed and subsequently recognized.

1.3.1.2 Multidimensional face space model and norm-based coding

Some researchers argue that the asymmetrical perceptual experience with own and other-race faces influences how own and other-race faces are mentally represented. The other-race effect is attributable to less refined representations of other- than own-race faces in a multidimensional face space. This could be explained in the context of Valentine's multidimensional face space model (Valentine, 1991).

According to Valentine, individual faces are represented as unique points in a multidimensional face space. The dimensions underlying this face space represent the specific feature properties that are used to define individual faces (e.g., length of the nose, the distance between two eyes). The location of each face is determined by its values on the dimensions underlying face space, along which faces vary. The average face (norm/prototype), which has the average value on each dimension and represents the average of all faces preciously encountered, is located in the center of the face space. Given that the dimensions of face space are shaped by experience such that they maximally differentiate faces from categories with which adults have abundant experience, different degrees of contacts make own-race faces distributed in the central region of face space and other-race faces tightly clustered together in the periphery (see Figure 1.2; Valentine, 1991; also see O'Toole & Natu, 2013). The dense clustering of other-race faces is responsible for the increased errors in the discrimination of other-race faces (Valentine, 1991). Papesh and Goldinger (2010) asked Caucasian participants to rate the similarity of white and black computerized faces; the faces in the two sets were identical and varied only in skin tone. Based on a multidimensional scaling method, they found that the inter-face distance for other-race faces is smaller than that of own-race faces, suggesting a more tightly clustered representation of other- than own-race faces. A similar pattern was found in another study using natural Caucasian and Asian faces (Byatt & Rhodes, 2004). These studies provide initial support for the multidimensional face space model and its explanatory power for the other-race effect.

Valentine has identified two conceptual sub-models in the multidimensional face space framework. One is the norm-based coding model and the other is the exemplar-based coding model. The norm-based coding model suggests that faces are encoded with respect to their deviations from the average face (norm/prototype; Valentine, 1991). In contrast, the exemplar-based coding model suggests faces are encoded with regarded to absolute value of each dimension in the face space (Valentine, 1991). Although both models posit the existence of the face norm, exemplar-based coding model predicts that the face norm/prototype has no special significance. There has been prolonged debate regarding which model better captures how faces are represented in face space (Goldstein & Chance, 1980; Diamond & Garey, 1986; Rhodes, 1996; Leopold, O'Toole, Vetter, & Blanz, 2001). However, recent evidence from adaptation after-effects studies are in favor

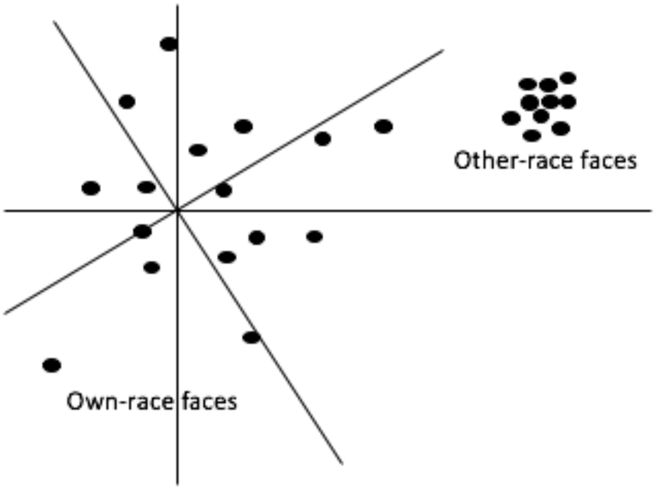

Figure 1.2. Representations of own- and other-race faces in the multidimensional face space. Each dot represents a face and each vector represents a dimension along which face can vary in the face space. Note that the different exemplar density is shown for the own- and other-race faces. The original multidimensional face space model is from Valentine (1991).

of the norm-based coding model (Jaquet, Rhodes & Hayward, 2007; Short, Hatry, & Mondloch, 2011). Hill et al (2006) trained white participants to attend to some feature dimensions (lips, mouth, and nose) that are used more frequently by black participants and tested the size of the ORE. They found that such training improved white participants' recognition of black faces, therefore reduced the ORE. These results suggest that selectively attending to meaningful dimensions of other-race faces facilitates the establishment of a fine-tuned representation of these faces. In addition, Jaquet et al (2008) adapted Caucasian and Chinese participants to distorted faces of both race in opposite directions simultaneously (e.g., Caucasian expanded and Chinese compressed faces) and found that participants' perception of face normality simultaneously altered in opposite directions for own- and other-race faces. They therefore proposed that faces from different race groups are coded by dissociable norms (Jaquet, Rhodes, Hayward, 2008).

Although the multidimensional face space and norm-based coding model have been successful in characterizing some critical effects, including the other-race effect in face perception, this account has been questioned, largely because the nature of the underlying dimensions of face space are not clearly specified. They might be features and their spacing (e.g., nose length, distance between the eyes,) or more abstract dimensions (e.g., eigenfaces; Hancock, Burton, & Bruce, 1996). Furthermore, it does not explain how representations of a particular face can be activated by multiple instances.

Extensions of Valentine's model (Voronoi regions and attractor fields model; Lewis & Johnston, 1999; Tanaka, Giles, Kremen & Simon, 1998; also see Tanaka & Corneille, 2007) posit that faces are not represented as points, but instead are represented as a Vironoi region or attractor field, which reflect the range of inputs that are perceived as belonging to a given identity, allowing recognition despite changes in appearance (e.g., in expressions, viewing angles, makeup). These models will be discussed in details in the context of the Study 1 and Study 2 of my dissertation (see Chapter 2 and 3).

Taken together, with the aforementioned evidence, the ORE can be regarded as a perceptual and memory deficit for other-race faces that is attributable to a less refined representation of other-race faces, reduced sensitivity to the shape and spacing of facial features in other-race faces, as well as a less efficient processing of other-race faces. Differential perceptual experience plays a pivotal role in the development of the other-race effect.

1.3.2 Social cognitive hypothesis

Although the perceptual hypothesis offers an elegant explanation of the ORE, more recently, an alternate social cognitive theory (Hugenberg, Young, & Bernstein, 2010) of the ORE has been proposed. This theory suggests that differential perceiver motivation and social categorization of own- and other-race faces leads to a qualitatively different way of attending to racial in-group and out-group members. Own-race faces are recognized more accurately than other-race faces because they are typically categorized as belonging to social in-group members. This shared in-group membership signals that own-race faces are important to individuate. Individuation of own-race members requires one to attend to facial characteristics that are identity-diagnostic (e.g., configural information) rather than category-diagnostic (e.g., skin tone), leading to a more accurate identification and discrimination of own- than other-race faces. In contrast, other-race faces are processed at the categorical level, reducing attention to individuating features.

Following this logic, the social cognitive model posits that if the social categorization (in-group / out-group membership) is the key underlying the ORE, merely manipulating the non-race social membership while holding the racial group membership constant (e.g., viewing own-race faces) would modulate the recognition of social in-group and out-group faces. This argument has been supported by several studies. For example, Bernstein et al (2007) found that holding the perceptual experience with target faces constant (all target faces were own-race faces), merely categorizing faces as belonging to an in-group facilitates their recognition, relative to faces categorized as belonging to an out-group (in- and group membership were manipulated based on university affiliation/personality; see also Short & Mondloch, 2010). Consistent with this finding, Hugenberg and Corneille (2009) found that own-race faces categorized as in-group members are processed more holistically than own-race faces categorized as out-group members. In addition, it has been found motivating perceivers to individuate racial outgroup members facilitates their recognition of these other-race faces (Hugenberg, Miller, & Claypool, 2007).

The social cognitive model of the ORE has been supported by empirical evidence suggesting that manipulation of non-identity specific information is sufficient to modulate the amplitude of the ORE (Bernstein, Young, & Hugenberg, 2007). For example, Hehman et al. (2012) found that when both own- and other-race faces are categorized as belonging to the in-group members, these faces are recognized with a similar accuracy, leading to an elimination of other-race effect, and suggesting that the ORE is at least partially attributable to different social cognitive mechanisms.

The perceptual expertise hypothesis and social cognitive models emphasize on different mechanisms, and both provide explanations for the cause of other-race effect. Increasing evidence suggests that social categorization can modulate the perceptual and cognitive mechanisms underlying the ORE. For example, Cassidy, Quinn and Humphreys (2011) found that other-race in-group faces are processed more configurally than own-race out-group faces. Their work highlights the role of both perceptual expertise and social group status of faces in shaping people's encoding of own- and other-race faces and suggests that perceptual expertise hypothesis and social cognitive hypothesis are not mutually exclusive and they jointly contribute to the other-race effect.

1.4 The Current Research

The current research was designed to examine the role of perceptual experience in shaping adults' ability to recognize own- versus other-race faces and to clarify some specific perceptual and cognitive mechanisms underlying the other-race effect. My first objective was to further characterize the ORE by highlighting a previously ignored aspect –one's ability to recognize identity in 'ambient images' that capture natural variability in appearance—and to directly contrast recognition of familiar vs. unfamiliar faces (Chapters 2 and 3). I then provide the first direct examination of the hypothesis that the mental representation of other-race faces is less well-refined than that of own-race faces (Chapter 4). Following that, I investigated whether impaired encoding and learning of other-race faces is attributable to differential utilization of shape and texture—two facial cues to identity. Finally, applying a novel continuous response paradigm, I explored how representations of own- and other-race faces are stored in and recalled from visual working memory. Characterizing these differences or commonalities in the processing of own- vs. other-race faces, my dissertation attempts to develop an integrative understanding of the ORE in face recognition.

For over one hundred years, the other-race effect has been framed as problem of discriminating among other-race identities (i.e., telling faces apart). The conclusion that "they all look the same to me" is based on studies measuring the perception/memory of highly controlled stimuli, typically involving only one or two images of each identity. Indeed, almost every study examining identity matching and recognition, holistic processing, and sensitivity to features and their spacing was based on representing each identity with a single image.

Thus, despite many years of research on the other-race effect, our understanding of a key aspect of own- and other-race face recognition, namely how do we identify own- and other-race faces despite a wide range of natural variations in their appearance (e.g., changes in expression, viewing angles, lighting conditions), is surprisingly limited. Successfully identifying faces despite changes in their appearance is not only a prevalent and challenge task in our daily life; it is also the very purpose of face recognition. Relying on a single image for each identity conflates face recognition with image recognition (Burton, 2013). It might be the case that the challenge of recognizing other-race identities is underestimated, given that pictorial cues (e.g., illuminance, shadows) to identity are less reliable when an identities' appearance changes. Therefore, in my dissertation, I attempted to first fill in the gap in the other-race effect literature by investigating this neglected challenge in face recognition. Specifically, in Study 1 (Chapter 2), I examined how a wide range of natural variations in appearance influences people's recognition of unfamiliar own- and other-race identities. Applying a sorting task developed by Jenkins et al (Jenkins, White, Montfort, & Burton, 2011), I tested both Caucasian and Asian adults' ability to recognize own- and other-race identities (unfamiliar celebrities as well as non-celebrities) in ambient images. They were asked to sort 20 images of each of two unfamiliar identities, such that each pile contained all of the images of one person. I found that participants make nearly twice as many piles (i.e., perceived twice as many identities) when sorting other- compared to own-race faces, suggesting within-person variability affects identity perception for other-race faces more than own-race faces—at least when faces are unfamiliar.

In addition, considerable studies examining own-race face recognition have suggested that whereas representations of unfamiliar own-race faces can be greatly influenced by the variations in appearance, representations of familiar own-race faces are resistant to these variations (e.g., Jenkins, White, Montfort, & Burton, 2011), highlighting a fundamental difference in familiar and unfamiliar own-race face recognition. Following this logic, In Study 2 (Chapter 3), I then examined how the ability to recognize own- and other-race faces across natural variations in appearance is modulated by the familiarity of faces. Particularly, I asked whether perceivers also build up reliable representations of familiar other-race faces that allow for accurate recognition despite a wide range of natural variation in appearance. Using a sorting task, Chinese adults were asked to sort familiar own- and other-race faces, and unfamiliar own- and other-race faces. I replicated the findings of Study 1 in sorting unfamiliar faces. Notably, I found that the other-race effect disappears when sorting familiar faces, suggesting that when a specific other-race identity becomes familiar, perceivers can form an abstract representation allowing recognition across natural variation in appearance. Establishing these fundamental questions is important for us to gain a more comprehensive understanding of the mechanisms of the other-race effect, and is particularly helpful to clarify some questions regarding how own- and other-race faces are represented in the face space.

Having discovered that the starting point for face learning differs for own- vs. other-race faces (i.e., that perceivers are less tolerant to the within-person variability in appearance for other than own-race faces; Chapter 2) but that adults can form robust representations of individual identities regardless of face race (Chapter 3), I next conducted three lines of research to investigate why it might be harder to match identity in unfamiliar other-race faces relative to unfamiliar own-race faces (Chapter 4) and the extent to which differential use of cues to identity (Chapter 5) and differences in the capacity and precision of visual working memory for other- compared to own-race faces (Chapter 6) might contribute to differences in the familiarization process.

Thus, the second question that my research attempts to address is how different perceptual experience with own-and other-race faces shapes the way in which own- and other-race faces are mentally represented in multi-dimensional face space. Although past studies have suggested that adults possess separable norms coding for own- and other-race faces (Jaquet, Rhodes, & Hayward, 2008; Little, DeBruine, Jones, & Waitt, 2008), no direct evidence was provided to demonstrate whether the norm and face space are less well differentiated for other-race faces. To address this question, in Study 3, I tested both Caucasian and Asian participants' sensitivity to how faces deviate from an average face when judging own- and other-race faces. To do so I took two approaches. First I directly asked participants to judge which of two faces was more normal. Second, I asked adults to rate the attractiveness of own- and other-race faces. I found that adults are less sensitive to deviations from normality in other- than own-race faces, and that between-rater variability in attractiveness ratings of individual faces was higher for other- than own-race faces. These findings suggest that dimensions of face space are optimized for own- rather than other-race faces, and the other-race effect is attributable to the inefficiency in the use of norm-based coding for other-race faces.

Study 4 was designed to examine whether impairments in encoding novel other-race faces (as reflected in poor sorting of other-race faces in Study 1 and reduced sensitivity to normality for other-race faces in Study 3) and in the recognition of newly learned other-race faces (i.e., in old/new recognition tasks; Golby, Gabrieli, Chiao & Eberhardt, 2001; MacLin & Malpass, 2001; Wright, Boyd & Tredoux, 2003) are driven by the inefficiency with which different types of facial cues are used. Recent studies have highlighted that shape and texture cues are used differently in the encoding of unfamiliar/novel faces and in the recognition of familiar/learned faces. Whereas shape information is particularly important for the initial encoding of unfamiliar faces, texture information is more important for recognizing familiar/learned faces (Itz, Schweinberger, Schulz, & Kaufmann, 2014); furthermore the shift from shape to texture cues is associated with recognition accuracy (Kaufmann, Schulz, & Schweinberger, 2013). No study has investigated whether the different utilization of shape and texture cues underlies the impairments in encoding and learning other-race faces. To address this question, in Study 4, I directly tested this hypothesis using two opposite approaches. I selectively caricatured or reduced the shape or texture information (replacing the shape or texture cues of original faces by the average shape or texture). Across two approaches, I found that despite an overall other-race effect, the transition from shape to texture cues is comparable for own- and other-race faces, suggesting that although other-race faces are learned less efficiently, the use of shape and texture cues in the learning is not qualitatively different for own- and other-race faces. My research therefore identified commonalities regarding the cues used during own- and other-race face learning.

Although it was well established that the other-race effect is partially driven by impairments in recalling representations of other-race faces from memory, little is known about the nature of the representations of own- and other-race faces. Traditional measures only provide a single binary measure of perceivers' memory performance (e.g., correct/incorrect answer in the old/new face recognition task) therefore failing to capture potential variation in the quality of face representations. Applying a novel continuous-response paradigm, in the final study of my dissertation, I independently measured the number of own- and other-race face representations stored in visual working memory (VWM) and the precision with which they were stored. Participants reported target own- or other-race faces on a circular face space that smoothly varied along the dimension of identity. Using statistical mixture modeling, I found that following ample encoding time, the ORE is attributable to differences in the probability of a face being maintained in VWM. Reducing encoding time caused a loss of precision of VWM for other- but not own-race faces. This study provides direct evidence that the ORE is driven by the inefficiency with which other-race faces are rapidly encoded in VWM. I proposed that impaired VWM performance for other-race faces, evident in the failure to rapidly establish high-precision representations for those faces, is likely carried forward into long-term memory. These impairments likely cascade to cause greater recognition errors for other-race faces, an effect that has been consistently found in tasks that require the retrieval of face representations from long-term memory.

Collectively, the results of the five studies in this dissertation help us to better understand how representations of own- and other-race faces are encoded and represented, and what factors fundamentally modulate the other-race effect. The ORE is not only limited to the impaired discrimination of individual other-race faces, but is also manifested by impairments in the establishment of stable representations of other-race faces across variability in appearance. However, such ability is greatly modulated by perceivers' familiarity with the faces. The other-race effect is attributable to less refined dimensions of face space for other-race faces, and by the failure to rapidly consolidate other-race faces into coherent and stable representations in visual working memory. Moreover, despite these differences underlying own- and other-race faces recognition, there are some commonalities between the processing of own- and other-race faces. Ultimately, perceivers can build up reliable representations of familiar other-race faces that are as stable as the representations of familiar own-race faces. Despite being less efficient in learning other-race faces, the reliance on efficient facial cues in the face learning is comparable for own- and other-race faces.

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CHAPTER 2

Study 1: The flip side of the other-race coin: They all look *different* to me[1]

2.1 Introduction

People are worse at recognizing and discriminating other-race faces than own-race faces (see Bothwell, Brigham & Malpass, 1989; Meissner & Brigham, 2001 for reviews)[2]. This other-race effect (ORE) is robust across a range of methodologies: recognition tests, in which participants' ability to discriminate between previously seen faces and novel faces is measured (e.g., Golby, Gabrieli, Chiao & Eberhardt, 2001; MacLin & Malpass, 2001; Wright, Boyd & Tredoux, 2003); identity tasks in which participants locate a target face in an identity line-up from memory (e.g., Meissner, Tredoux, Parker & MacLin, 2005; Jackiw, Arbuthnott, Pfeifer, Marcon & Meissner, 2008; Evans, Marcon & Meissner, 2009); discrimination tasks that involve making same/different judgments about pairs of faces (e.g., Walker & Tanaka, 2003; Mondloch et al., 2010); and sequential matching tasks (e.g., Lindsay, Jack & Christian, 1991; Tanaka, Kiefer & Buklach, 2004; Rhodes, Hayward & Winkler, 2006).

In addition to providing insights about the role of experience in the development of perceptual expertise (see Tanaka, Heptonstall & Hegan, 2013; Kelly et al., 2007), this phenomenon has important practical implications. Difficulty in recognizing other-race individuals leads to embarrassment when adults fail to recognize familiar individuals in social or professional contexts, and has led to numerous false incarcerations based on

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[1] This chapter is based on the published article: Laurence, S., Zhou, X., & Mondloch, C. J. (2016). The flip side of the other-race coin: They all look different to me. *British Journal of Psychology*, *107*(2), 374-388. doi: 10.1111/bjop.12147

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

erroneous eyewitness testimony (reviewed in Hugenberg, Young, Bernstein & Sacco, 2010). Understanding the mechanisms underlying the effect is essential. The ORE has been framed as a problem with individuating (discriminating between) other-race faces, consistent with Feingold's claim that "to the uninitiated American, all Asiatics looks alike, while to the Asiatic, all White men look alike" (1914, p50; see also Meissner & Brigham, 2001; Vizioli, Rousselet & Caldara, 2010; but see Goldstein, 1979). When asked to recall faces from memory, participants typically make fewer hits (correctly identifying a previously seen face as familiar) and more false alarms (incorrectly identifying a novel face as familiar) for other-race faces, compared to own-race faces (Meissner & Brigham, 2001). Collectively, this leads to lower accuracy (d') for other-race faces. A higher false alarm rate suggests that one component of the other-race effect is that other-race faces have higher perceived similarity than own-race faces, resulting from their being densely clustered in multi-dimesional face space (e.g., Young, Hugenberg, Bernstein, Sacco, 2012). Consistent with this hypothesis, other-race faces are judged to look more similar to each other than are own-race faces when presented in pairs (Byatt & Rhodes, 2004; Papesh & Goldinger, 2010). In fact, a number of journal articles investigating the ORE even have the phrase "they/we all look the same" in their titles (Johnson & Fredrickson, 2005; Ackerman et al., 2006; Wilson & Hugenberg, 2010).

Poor discrimination and recognition of other-race faces is predicted by Valentine's model (Valentine, 1991), according to which each individual identity is represented as a unique point in a multidimensional face space. The location of each identity is determined by its values on the dimensions underlying face space, along which faces vary (e.g., distance between the eyes, nose length). The dimensions of face space are refined through perceptual experience to represent the facial properties that are optimal for discriminating identities from highly familiar categories (see O'Toole & Natu, 2013 for a discussion); own-race faces are distributed in the central region of face space whereas other-race faces are tightly clustered together in the periphery (Valentine, 1991, also see Figure 2.1a). This dense clustering of other-race faces is responsible for increased errors when discriminating between other-race identities.

Extensions of Valentine's model take into account an aspect of face recognition that has largely been ignored in the literature (see Burton, 2013)—the fact that representations of each identity can be activated by multiple images; we need, for example, to recognize our neighbor when she dons a pair of sunglasses or applies makeup prior to going out. Voronoi regions (Lewis & Johnston, 1999) and attractor fields (Tanaka, Giles, Kremen & Simon, 1998; also see Tanaka & Corneille, 2007) around each point in face space reflect the range of inputs that are perceived as belonging to a given identity, allowing recognition despite changes in appearance (e.g., in expression, makeup, hairstyle, illumination, or orientation). The size of an identity's attractor field is determined by the density of nearby representations (i.e., by its location in face space) and determines the range of acceptable inputs. Because the dimensions of face space are optimized for own-race faces, own-race faces will, on average, have larger inter-face distances than other-race faces, which are clustered together in the periphery of face space. Such models imply that own-race face have larger attractor fields (or Voronoi regions) than other-race faces (see Figure 2.1).

In the vast majority of studies investigating the ORE an individual's face is only represented by a single photograph (e.g., Mondloch et al., 2010; Wilson & Hugenberg, 2010; Hancock & Rhodes, 2008) or by a pair of pictures that vary in expression (e.g., Vizioli et al., 2010; Ackerman et al., 2006; Chiroro & Valentine, 1995), viewpoint (e.g., Ellis & Deregowski, 1981; Sporer, Trinkl & Guberova, 2007; Sporer & Horry, 2011) or the camera with which the pictures were taken (e.g., Megreya, White & Burton, 2011; but see Meissner, Susa & Ross, 2013 who varied expression and camera). The ability to recognize that multiple images of another-race face belong to the same person (i.e., the implication of other-race faces having smaller attractor fields) has been ignored.

This is an important oversight: Within-person variability can have a profound effect on one's perception of identity. Even for own-race faces, photos of the same person can be perceived as belonging to different individuals, unless that person is familiar. Jenkins, White, Montfort & Burton (2011) collected 20 photographs of each of two Dutch celebrities. Participants were asked to sort the faces such that all of the photos of the same person were grouped together. Their results were striking: When the faces were familiar (in the Netherlands) most participants correctly sorted the photographs into two identities. However, UK participants who were unfamiliar with the faces perceived more identities (i.e., sorted faces into more piles; Median = 7.5) than the two identities that were present. These findings highlight the difficultly of recognizing unfamiliar identities across natural variation in images.

In the current study we hypothesized that participants would perceive even more identities when completing the sorting task with unfamiliar other-race faces. At first glance, this prediction is counterintuitive; if other-race faces all "look the same" one might expect participants to make fewer piles when sorting other-race faces. However, smaller attractor fields for other-race compared to own-race identities were expected to

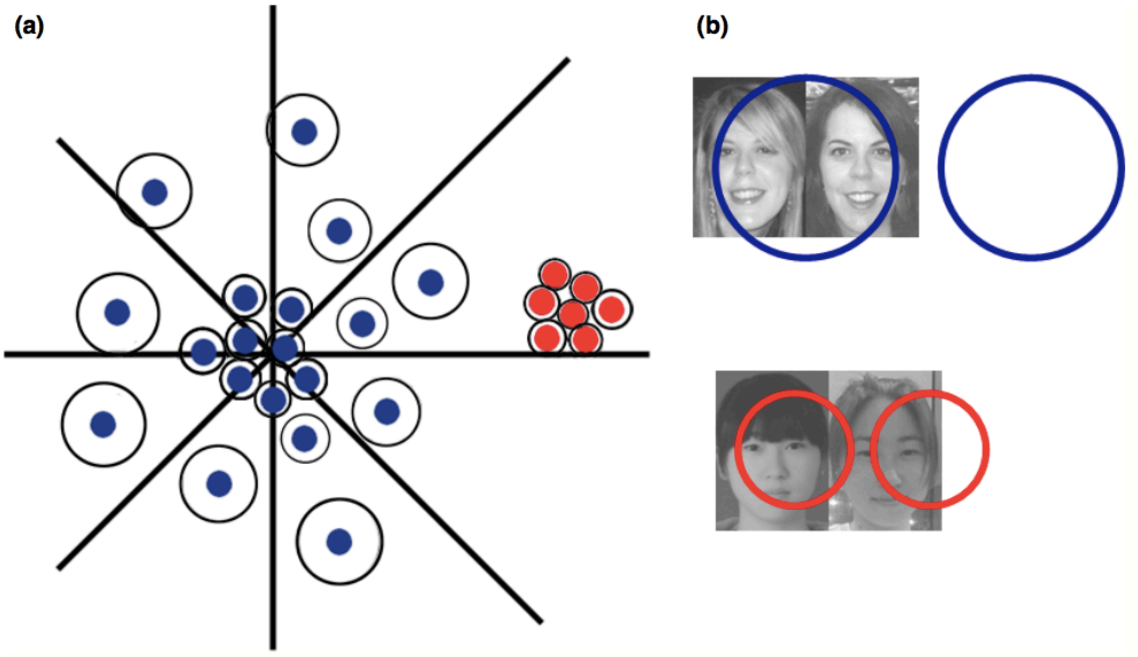

Figure 2.1. (a) A representation of Valentine's (1991) face space, in which each dot represents an individual identity and the circles around each dot represent the attractor fields. Own-race faces (blue dots) fall in the centre of face space and have relatively large attractor fields, whereas other-race faces (red dots) are tightly clustered together in the periphery of face space with relatively small attractor fields. (b) Each circle represents an identity and its associated attractor field in face space. Top row: Own-race faces are further apart and the attractor field is bigger. Two pictures of the same Caucasian identity both fall within the same attractor field; therefore, they are perceived as belonging to the same person. Bottom row: Other-race faces are closer together and the size of the attractor field is smaller. Two pictures of the same East Asian identity overlap with two attractor fields; therefore, they are perceived as belonging to two distinct identities.

make recognition of other-race faces across a wide range of natural variation especially hard because even trivial changes might result in an image crossing the boundaries of the identity's relatively small attractor field, resulting in an activation of neighboring identities (see Figure 2.1b).

To test this hypothesis, in two experiments we asked participants to sort 40 photographs into piles such that each pile contained all of the photographs of one person. All identities were unfamiliar to all participants. Participants were not told that the correct solution was two piles of 20 pictures. In Experiment 1 Caucasian participants sorted photographs of either two Caucasian celebrities or two East Asian celebrities; to control for stimulus effects Chinese participants also sorted the Caucasian photographs. The Caucasian celebrities were from a different country than the participants and thus unfamiliar. In Experiment 2 participants sorted non-celebrity faces and we used a complete design such that both Caucasian and Chinese participants sorted own- and other-race faces. We hypothesized that participants would make more piles (i.e., perceive more identities) when sorting unfamiliar other-race faces than unfamiliar own-race faces.

We also recorded misidentification errors, defined as sorting the two different identities into the same pile. Based on Jenkins et al. (2011) we anticipated very few misidentification errors when participants sorted own-race faces. However, given the predominant view that other-race faces are perceived as more similar than own-race faces, we predicted more misidentification errors for other-race faces than own-race faces.

2.2 Experiment 1

2.2.1 Method

2.2.1.1 Participants

Seventy-five participants were included in the final analysis: 25 were East Asian students at Zhejiang Normal University, China (15 female; Mean age = 20.92; SD = 2.74) and 50 were Caucasian students at Brock University, Canada (45 female; Mean age = 19.48; SD = 1.23). All East Asian and 25 Caucasian participants (21 female) completed the task with Caucasian faces and the other 25 Caucasian participants (24 female) did so with East Asian faces. We aimed to have 25 participants in each condition who were wholly unfamiliar with the identities contained in the sorting card task so we excluded an additional 17 participants who believed they were familiar with the faces. In fact, none of the excluded participants accurately identified the identities contained in the task; all of the identities were misidentified (e.g., as belonging to an American singer or a Japanese actress).

2.2.1.2 Stimuli

Twenty images of each of two female UK celebrities (Holly Willoughby and Fearne Cotton) and two female Chinese celebrities (Bingbing Fan and Zhiling Lin) were taken from the Internet via a Google image search. The celebrities were chosen because they were well known in their country of origin, unfamiliar to the participants we tested in other countries and, within each country of origin, physically similar (e.g., hair color, age etc.). For each person we selected the first 20 images in which their face was bigger than 150 pixels in height, displayed in frontal aspect, and not occluded in any way. This resulted in a total of 80 images (20 per identity). The images were cropped so that only the head was displayed (much like a passport photograph) and were changed to grayscale. They were then printed on cards that were 38 x 50 mm in size. A representation of the variability among photographs is shown in Figure 2.2.

2.2.1.3 Procedure

The task procedure was also based on Jenkins et al. (2011). Participants were presented with the following written instructions: "*In front of you is a deck of 40 face photos. Your task is to sort the photos by identity, so that photos of the same face are grouped together. There is no time limit on this task and you are free to create as many or as few groups as you wish.*" After each participant had completed the card-sorting task they were asked to indicate whether they were familiar with any of the faces. If participants indicated that a face(s) was familiar they were then asked to provide a name(s) or any information about that person (e.g., where they had seen that person). Upon completion, participants answered questions assessing their contact with other-race identities (e.g., Caucasian participants' contact with East Asian identities). For example, they were asked how many of their top 10 friends were of East Asian/Caucasian ethnicity, and how much current and previous experience they had with individuals of East Asian ethnicity.

2.2.2 Results and Discussion

2.2.2.1 Number of Perceived Identities

Overall, participants reported very little contact with other-race identities. All participants reported having less than three other-race friends. Seventy-two percent of Caucasian and 92% of East Asian participants reported having zero other-race friends.

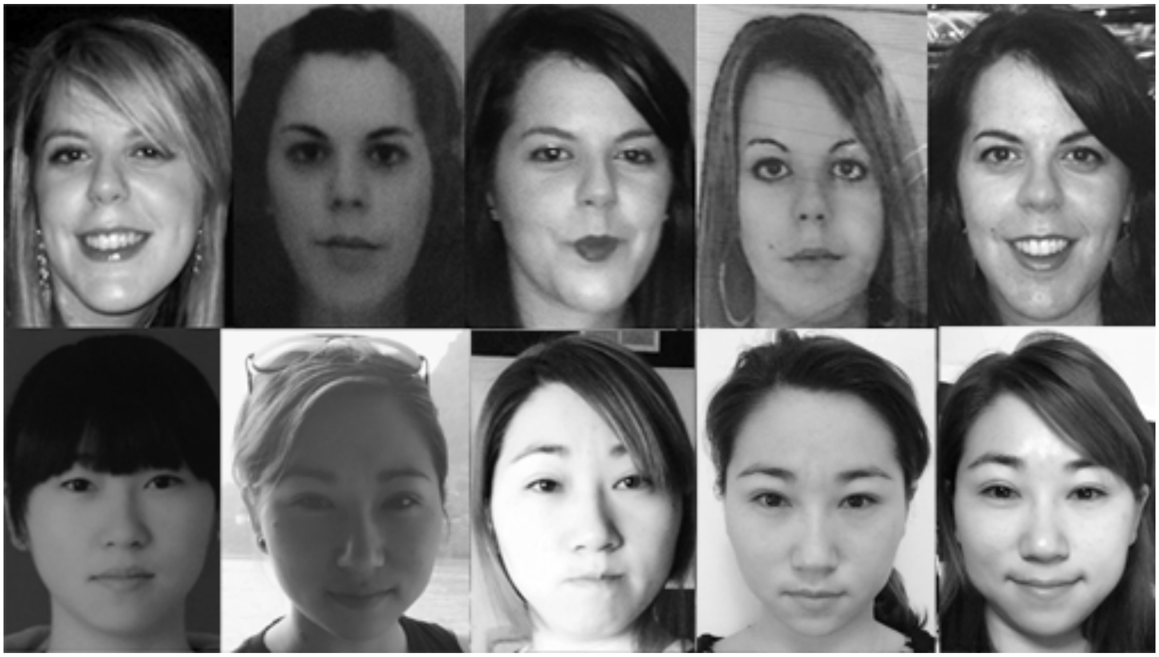

Figure 2.2. Five pictures of two identities, Sarah Laurence (top) and Xiaomei Zhou (bottom). We are unable to show the photographs from our experiment for copyright reasons.

Variance differed across groups so we analyzed the data using non-parametric tests. One-Sample Wilcoxon Signed-Rank Tests revealed that in all three groups the median number of perceived identities was significantly greater than the two identities that were present (Caucasian participants sorting Caucasian photos: *Mdn* = 4, *Z* = 120, *p* = .001; Caucasian participants sorting East Asian photos: *Mdn* = 9, *Z* = 325, *p* < .001; East Asian participants sorting Caucasian photos: *Mdn* = 13, *Z* = 324, *p* < .001).

Participants perceived more identities (i.e., made more piles) when sorting other-race faces compared to own-race faces. As shown in Figure 2.3, Caucasian participants sorted own-race photos into a mean of 4.8 identities (*SD* = 3.51; Median = 4; Mode = 2; Range = 2-16). In contrast, they sorted other-race photos into a mean of 11 identities (*SD* = 6.43; Median = 9; Mode = 7; Range = 4-31) and East Asian participants sorted the Caucasian photos into a mean of 13.6 identities (*SD* = 7.16; Median = 13; Mode = 13; Range = 1-31). Mann-Whitney *U* tests showed that Caucasian participants perceived significantly more identities when sorting the East Asian photos than the Caucasian photos, *U* (25, 25) = 93, *p* < .001, two-tailed, *r* = .61. Likewise, East Asian participants perceived significantly more identities in the Caucasian photographs than did the Caucasian participants, *U* (25, 25) = 76.5, *p* < .001, two-tailed, *r* = .65. The two groups sorting other-race faces made a similar number of piles.

2.2.2.2 Misidentification Errors

We analyzed misidentification errors in two ways. First, we compared the number of piles containing two identities when participants sorted own- versus other-race faces. Second, we compared the number of participants who made at least one misidentification error when sorting own- versus other-race faces. For Caucasian participants, the number of misidentification errors was higher when participants sorted other-race faces (see Table 2.1). Mann-Whitney *U* tests confirmed that the number of misidentification errors (number of piles with two identities) was higher when Caucasian participants sorted other-race faces ($M = 3.0$) than own-race faces ($M = 1.8$), U (25, 25) = 192.50, $p = .02$, two-tailed, $r = .33$. This is a significant finding because making more piles for other-race faces (see above) reduces the number of faces in each pile and, consequently, reduces the chance probability of misidentification errors. However, there was no significant difference in the number of misidentification errors for East Asian and Caucasian participants sorting the Caucasian photographs, U (25, 25) = 265.5, $p = 0.35$, two-tailed, $r = .13$, suggesting that the effect observed among Caucasian participants could be a stimulus effect.

For Caucasian participants there was a significant association between the race of the faces they were sorting and the number of people who made at least one misidentification error, χ^2 (1) = 5.71, $p = .02$, $\phi = .11$; whereas 92% of Caucasian participants made at least one misidentification error for other-race faces only 64% made at least one for own-race faces. However, for Caucasian photographs, there was no significant association between the race of participant (East Asian versus Caucasian) and the number who made at least one misidentification error, χ^2 (1) = 2.60, $p = .11$, $\phi = .05$. Eighty-four percent of Chinese participants made at least one misidentification error. Taken together our results provide no support for misidentification errors being more likely when sorting other-race faces.

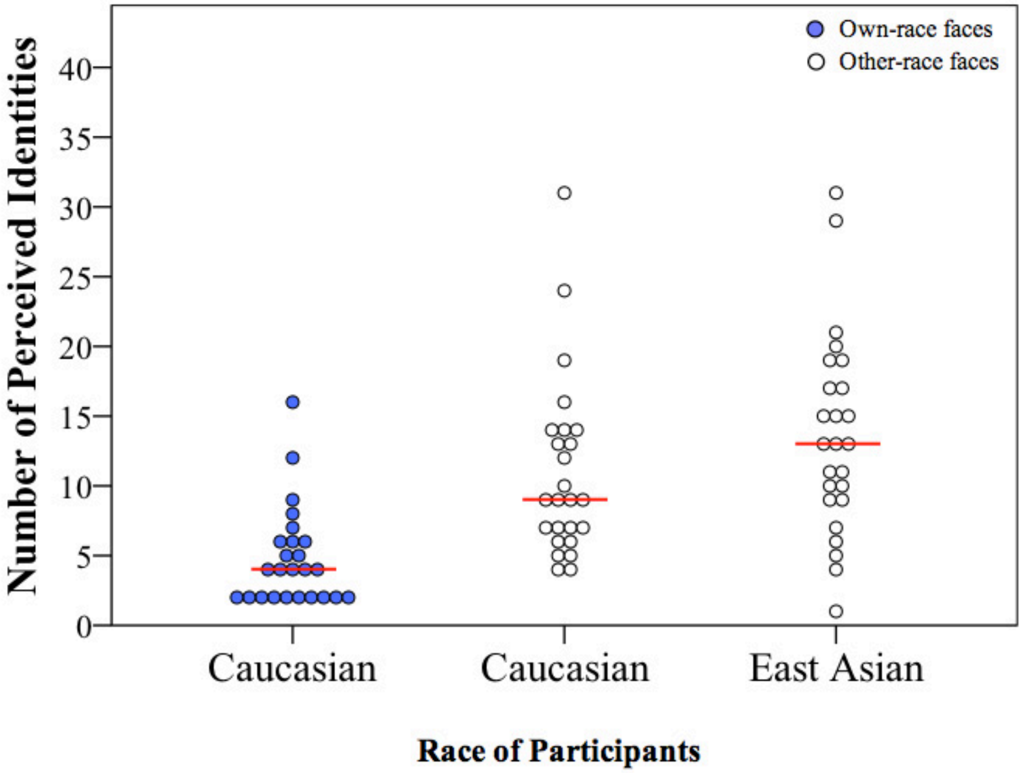

Figure 2.3. The number of perceived identities for Caucasian and East Asian participants sorting Caucasian or East Asian faces. Each dot represents the number of perceived identities for an individual participant. The red line represents the median number of perceived identities.

Table 2.1

Descriptive Statistics for the Number of Misidentification Errors in Experiment 1 and 2.

	M	*SD*	Range	Median	Mode
Experiment 1					
CA sorting Own	1.8	1.88	0-6	1	0
CA sorting Other	3.0	1.70	0-6	3	3
EA sorting Other	2.2	2.02	0-6	1	1
Experiment 2					
CA sorting Own	1.4	1.43	0-5	1	0
CA sorting Other	1.6	1.67	0-5	1	0
EA sorting Own	1.2	1.61	0-5	0	1
EA sorting Other	1.4	1.47	0-4	1	0

Note. CA = Caucasian; EA = East Asian

Summary

The findings from Experiment 1 suggest that for unfamiliar faces, within-person variability in appearance affects our perception of identity more for other-race faces than own-race faces. However, two characteristics of our design limit the generalizability of our results. Firstly, our stimuli were images of celebrities. Variability in appearance may be greater for celebrities than for people in the general population; if so, then our findings may exaggerate the influence of face race on recognition. Secondly, our choice of stimuli did not allow us to have a complete design; we did not have a condition in which East Asian participants sorted unfamiliar East Asian faces. From a purely practical perspective, we were extremely unlikely to find many East Asian participants for whom the Chinese celebrities were unfamiliar.

We addressed each of these concerns in Experiment 2 in which both East Asian and Canadian participants sorted own- and other-race face photos by identity. All photographs were of non-celebrities and, to increase generalizability, two face pairs were used for each race. Thus, Experiment 2 incorporated a complete design and extended our work to new, non-famous identities.

2.3 Experiment 2

2.3.1 Method

2.3.1.1 Participants

We tested a total of 80 participants: 40 were East Asian students at Zhejiang Normal University, China (28 female; Mean age = 22; *SD* = 1.89) and 40 were Caucasian students at Brock University, Canada (37 female; Mean age = 17; *SD* = 2.20). Twenty

East Asian and 20 Caucasian participants sorted East Asian faces. The other 20 East Asian and 20 Caucasian participants sorted Caucasian faces.

2.3.1.2 Stimuli and Procedure

We recruited four Caucasian non-celebrity models and four East Asian non-celebrity models each of whom allowed us access to their pictures via social media (e.g., Facebook and QQ space). All models were young adult females. We paired up the models from each race, resulting in two Caucasian pairs and two East Asian pairs. The models within each pair were of a similar age and had a similar hair color. We selected the first 20 images from each model's social media Webpage where their face was bigger than 150 pixels in height, displayed a roughly frontal aspect, and not occluded in any way. We also tried to ensure that all of the photographs were taken on different days. As in Experiment 1, the images were cropped, changed to greyscale, printed on cards that were 38 x 50 mm in size, and grouped such that each participant was given a pile of 40 photographs—20 per each of two identities. Ten East Asian participants and 10 Caucasian participants sorted each of the four faces pairs.

2.3.2 Results and Discussion

2.3.2.1 Number of Perceived Identities

Parametric analyses were used for Experiment 2 given that variance did not differ across groups. Preliminary analyses revealed no effect of stimulus pair, all *p*s > .20, regardless of whether photographs were sorted by Caucasian or East Asian participants. All subsequent analyses are collapsed across face pairs.

As shown in Figure 2.4, Caucasian participants sorted own-race photos into a mean of 7.0 identities, (*SD* = 5.12; Median = 5; Mode = 2; Range = 2-20) and other-race photos into a mean of 9.3 identities, (*SD* = 4.89; Median = 8.5; Mode = 6; Range = 2-18). Likewise, East Asian participants sorted own-race photos into a mean of 7.3 identities, (*SD* = 4.99; Median = 5; Mode = 5; Range = 2-20) and other-race photos into a mean of 10.4 identities, (*SD* = 5.6; Median = 10; Mode = 11; Range = 4-22).

One-sample t-tests confirmed that in every condition the number of perceived identities was significantly greater than the two identities that were present (Caucasian participants sorting own and other-race faces, t (19) = 4.32, $p < .001$, $d = 1.34$, 95% CI (4.55; 9.35); t (19) = 6.68, $p < .001$, $d = 2.07$, 95% CI (7.01; 11.59); East Asian participants sorting own and other-race faces, t (19) = 4.70, $p < .001$, $d = 1.46$, 95% CI (4.91; 9.59); t (19) = 6.70, $p < .001$, $d = 2.09$), 95% CI (7.78; 13.02).

We conducted a 2 (participant race: Caucasian vs. East Asian) × 2 (face race: own vs. other race) between-subjects ANOVA. We found a significant main effect of face race ($F_{1, 76}$= 5.68, $p = .020$, $\eta_p{}^2 = .070$). As in Experiment 1, participants perceived significantly more identities for other-race faces ($M = 9.85$, $SE = 0.816$) than own-race faces ($M = 7.1$, $SE = 0.816$). The main effect of participant race ($F_{1, 76} = 0.37$, $p = .546$, $\eta_p{}^2 = .005$) and the interaction between face race and participant race ($F_{1, 76} = 0.12$, $p = .730$, $\eta_p{}^2 = .002$) were both nonsignificant.

2.3.2.2 Misidentification Errors

Unlike Experiment 1, we did not observe any effect of face race on misidentification errors. A 2 (participant race: Caucasian vs. East Asian) × 2 (face race: own vs. other race)

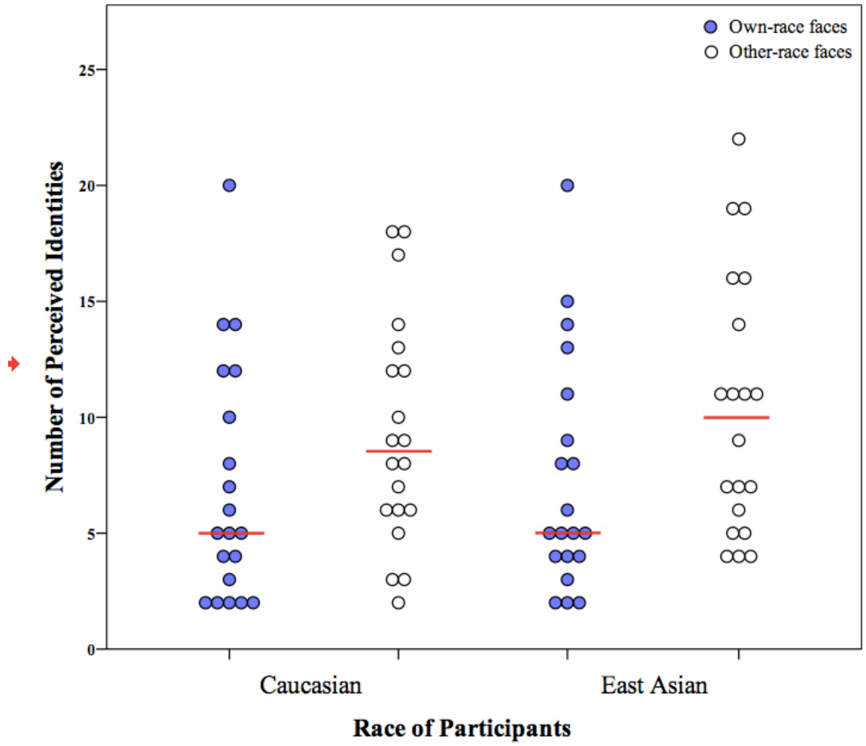

Figure 2.4. The number of perceived identities for Caucasian and East Asian participants sorting own-and other-race faces. Each dot represents the number of perceived identities for an individual participant, and the red line depicts the median.

between-subjects ANOVA revealed no significant effects, all *p*s > .60. As noted in Table 2.1, misidentification errors were rare in all conditions.

Summary

As in Experiment 1, in which we used celebrity faces, participants were more accurate in recognizing that multiple photographs of non-famous identities belong to the same identity when sorting own-race faces than when sorting other-race faces. Furthermore, there was no evidence of an impaired ability to discriminate among different other-race identities. Collectively, these findings draw attention to the flip side of the other-race effect: recognizing facial identity despite natural variation in appearance. The implication of these findings is considered in the General Discussion.

2.4 General Discussion

The findings of Experiments 1 and 2 replicate past research, which found that when faces are unfamiliar, pictures of the same person appear to belong to several distinct identities (Jenkins et al., 2011). Most notably, we provide the first evidence that within-person variability affects identity perception of other-race faces even more than it affects identity perception of own-race faces. Our participants perceived more identities when they were sorting unfamiliar other-race faces compared to unfamiliar own-race faces, and this was true for both celebrities and non-celebrities. Whereas research based on perceptual expertise emphasizes the effect of experience on discrimination and recognition (Meissner & Brigham, 2001; Tanaka et al., 2013), our results suggest that experience with a face category also influences perceivers' ability to extract identity information across multiple images, even in a perceptual task in which there are no memory demands (see Sporer et al., 2007; Sporer & Horry, 2011; Meissner et al., 2013 for similar findings in tasks that included memory demands and only two images of each identity).

Our findings cannot be explained by physiognomic differences between East Asian and Caucasian faces (i.e., two pictures from one race being easier to sort); East Asian and Caucasian participants sorted the same faces differently. Perceivers' difficulty in recognizing unfamiliar faces across natural variation in a person's appearance (e.g., changes in lighting and viewpoint) may be the result of unfamiliar face representations being based more heavily on lower-level image properties (e.g., Bruce, 1982; Bruce, Henderson, Newman & Burton, 2001; Burton, Wilson, Cowan & Bruce, 1999; see Young & Bruce, 2011 for a discussion; see Hancock, Bruce & Burton, 2000 for a review), properties that vary across images even when identity is held constant. When recognizing identities across changes in pose, expression, lighting, age or hairstyle, perceivers cannot rely on pictorial cues; rather, they must extract structural information that allows identity matching despite changes in appearance (Bruce & Young, 1986). Our findings are consistent with evidence that adults' ability to extract such structural information from unfamiliar other-race faces is impaired relative to own-race faces (Sporer & Horry, 2011; see also Ellis & Deregowski, 1981).

Valentine's (1991) influential model in which faces are conceptualized as single points in multidimensional face space cannot account for our findings. That model does account for difficulty in discriminating faces from categories with which observers have minimal experience (e.g. other-race and other-age faces); because other-race faces are less well represented by the dimensions of face space, observers lack sensitivity to differences among these faces (characterized as tightly clustered points in this multidimensional space) and one identity is easily mistaken for another (e.g., Byatt & Rhodes, 2004; see Young et al., 2012 for a review). However, building on Valentine's model, Lewis and Johnston (1999) and Tanaka et al. (1998) characterize each identity's representation as a region rather than a single point. The distance between contiguous points, which represents perceptual similarity along the dimensions of face space, determines the size of the region (Voronoi cell, attractor field, respectively) associated with each identity; thus faces in a densely populated location in face space will have smaller attractor fields. Neighboring regions in face space will compete with each other when an ambiguous incoming image is similar to both regions. This could result in two things: i) pictures of different people being incorporated into the same region, or ii) pictures of the same person being separated into different regions. Thus, it is because other-race faces, on average, are more similar perceptually to one another than own-race faces that they have smaller attractor fields and, consequently, are more difficult to recognize across natural variation in appearance.

An interesting direction for future research will be to explore the role of face space density and face space dimensions on tolerance for within-person variability. As one anonymous reviewer pointed out, typical own-race faces might be located in a relatively dense region of face space (but see Burton & Vokey, 1998 for a discussion); therefore, they may also have smaller attractor fields. If exemplar density alone determines tolerance for variability, then typical own-race faces, like other-race faces, should be more difficult to sort than less typical faces. However, in contrast to other-race faces, the dimensions of face space might better represent typical faces, making them less susceptible to idiosyncratic pictorial cues and easier to sort than other-race faces.

Theories of familiar face recognition (e.g., Jenkins & Burton, 2011; Jenkins et al., 2011; Burton, Jenkins, Hancock & White, 2005) imply that familiarity with a person defines the variability that will be incorporated into their representation. Previous behavioral findings suggest that expert performance with familiar faces does not generalize to unfamiliar faces (e.g., Burton et al., 1999, Bruce et al., 2001). Participants perceive multiple identities in a set of photos of a single person despite knowing hundreds of people of the same race and age (Jenkins et al., 2011). Furthermore, whereas telling participants that only two identities were present in a pile of 40 photographs improved performance with new images of those identities in a subsequent same/different matching task, no improvement was observed for new identities (Andrews, Jenkins, Cursiter, & Burton, 2015). Such findings suggest that variability should be understood for each face separately, rather than for faces as a class of object.

Whereas performance differences for familiar versus unfamiliar own-race faces emphasize the importance of experience with particular identity, our findings support a role for experience with a face category (another level of familiarity). While acknowledging that there may be qualitative differences between familiar and unfamiliar face processing (see Burton, 2013 for a discussion), our data suggest that experience with multiple faces from a given category influences one’s ability to recognize identities across images of unfamiliar people. Having fewer familiar other-race exemplars stored in memory might result in less knowledge of how individual other-race faces can vary in appearance, limiting our ability to recognize unfamiliar faces in ambient images. It may be only as we become familiar with multiple other-race individuals that we learn more about how any single identity can vary, just as infants and children need to hear a word spoken by many individuals in order to learn it well (Rost & McMurray, 2009; see Watson, Robbins & Best, 2014 for a review and discussion). As more other-race exemplars are incorporated into face space our sensitivity to facial dimensions increases, increasing inter-face spacing, and, consequently, the size of attractor fields.

A similar process may underlie the development of expert face processing during childhood. Given evidence the children's ability to simultaneously rely on multiple dimensions improves after 8 years of age (Nishimura, Maurer, & Gao, 2009) and that children are less sensitive than adults differences along the dimensions of face space (Jeffery et al., 2010; Short, Lee, Fu, & Mondloch, 2014), we suggest that the development of expertise during childhood can be conceptualized as learning multiple examplars resulting in increased sensitivity to the dimensions of face space, leading to larger inter-face distances and, consequently, larger attractor fields associated with unfamiliar identities. Therefore young children, like adults tested with other-race faces, are expected to make more errors when sorting unfamiliar own-race faces than adults.

The practical implications of our results are significant. Jenkins et al. (2011) highlight the significance of within-person variability on the utility of photo identification. Whereas almost any photograph is easily matched to the correct familiar identity, matching photographs of an unfamiliar person is more challenging (see Johnston & Edmonds, 2009 for a review). Based on evidence that other-race faces are judged more similar to each other than own-race faces, the challenge facing airport security officials is thought to be that of discriminating identities. Our results suggest another challenge: recognizing that the person carrying identification is the person on the passport despite changes associated with hairstyle, weight gain/loss, make-up, etc. (also see Meissner et al., 2013). This challenge is exemplified in the case of Suaad Hagi Mohamud, a Canadian who was detained and imprisoned in Nairobi when an airport official concluded that her 4-year-old passport photo was a picture of someone else (Aulakh, 2009, August 10). Previous studies in which participants were trained to recognize a single image of multiple other-race identities (Lebrecht, Pierce, Tarr & Tanaka, 2009) showed that such training is only minimally effective. To the extent that distance between identities in multidimensional face space is correlated with the size of their Voronoi cells or attractor fields, training people with multiple images of each identity may prove to be more useful (Andrews et al., 2015).

One potential limitation of our study is that the majority of Caucasian participants were female whereas the male:female ratio was more balanced in the East Asian groups. Although future studies should aim for an even distribution of males and females, our finding similar results for both participant groups in Experiment 2 suggests that this is unlikely to alter our conclusions. A further limitation of the sorting task is that misidentification rates will be impacted by the two identities used. Future studies in which multiple identities are presented in match-to-sample or same/different tasks will allow for a more refined assessment of the contribution of two problems—difficulty telling two identities apart and difficulty recognizing identities across natural variability in images—to the own-race recognition advantage.

Overall, our work gives new insights as to why we find recognizing other-race faces so challenging. Whereas prior work emphasizes an impaired ability to discriminate other-race faces (e.g., recognizing that faces belong to different people), we found an impaired ability to recognize an identity across images that incorporate natural variability (e.g., recognizing that faces belong to the same person). We believe that this should be incorporated into new and existing theories of the ORE.

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CHAPTER 3

Study 2: Recognizing “Bella Swan” and “Hermione Granger”: No own-race advantage in recognizing photos of famous faces[3]

3.1 Introduction

Mike Burton and colleagues have identified two shortcomings in studies of face recognition: focusing on recognition of faces learned in the lab and using tightly controlled images with each identity represented by a single (or two nearly identical) image(s). This approach fails to capture our task in daily life—indeed the very purpose of face recognition—which is to recognize familiar faces and to do so even when appearance (e.g., expression, make-up) changes. These limitations have impaired progress in understanding face recognition (Burton, 2013). Whereas familiar face representation is abstractive and image-invariant, unfamiliar face representation is image-dependent (Burton, Schweinberger, Jenkins, & Kaufmann, 2015), as highlighted in a clever study by Jenkins, White, Van Montfort, and Burton (2011). They presented participants with images that captured idiosyncratic variability in the appearance of two identities. When sorting 40 photographs (20/identity) into piles such that each pile contained all photos of a single identity, participants for whom the faces were familiar made two piles but those who were unfamiliar made eight.

These shortcomings also limit our understanding of one of the most studied phenomenon in face recognition: the other-race effect (ORE; better recognition of own- than other-race faces, Meissner & Brigham, 2001). Research investigating the ORE has

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[3] This chapter is based on the published article: Zhou, X., & Mondloch, C. J. (2016). Recognizing “Bella Swan” and “Hermione Granger”: No Own-Race Advantage in Recognizing Photos of Famous Faces. *Perception*, *45*(12), 1426-1429. doi 10.1177/0301006616662046. The article was published in the Short and Sweet section of the journal, which requires that the topic appeals to a broad audience and is written in a more relaxed formatting style (i.e., no separate Method and Results sections).

almost exclusively focused on recognition of tightly controlled images of unfamiliar identities (e.g., Mondloch et al., 2010; Rhodes, Hayward, & Winkler, 2006); little is known about our ability to recognize other-race faces when appearance varies and identities are familiar. One study showed that when sorting naturalistic photographs of unfamiliar identities, participants perceived twice as many identities for other-race faces, suggesting that recognizing unfamiliar other-race identities is especially challenging when appearance varies (Laurence, Zhou, & Mondloch, 2016). Here, we replicated this novel finding and examined whether familiarity with specific identities eliminates the ORE.

3.2 Method and Results

A total of 100 participants living in China (*M* = 21.35 years, range = 18–28) sorted grayscale photographs (20 per each of two physically similar female celebrities) into identity-specific piles. We selected the first 20 images of each identity from Google Image >150 pixels in height, displayed in frontal aspect, with no occlusions. Figure 3.1 shows comparable images of two identities (not used here). Two groups sorted unfamiliar faces comprising Japanese (Yuriko Yoshitaka, Erika Toda) or Caucasian celebrities (Millie Mackintosh, Renee Olstead). Two groups sorted familiar faces comprising Chinese (Mi Yang, Yifei Liu) or Caucasian celebrities (Emma Watson and Kristen Stewart, rendered famous via Harry Potter and The Twilight Saga). Familiarity was confirmed via a questionnaire.

A 2 (Familiarity: Familiar vs. Unfamiliar) x 2 (Face race: Own vs. Other) between-subjects ANOVA with number of piles (perceived identities) as the dependent variable

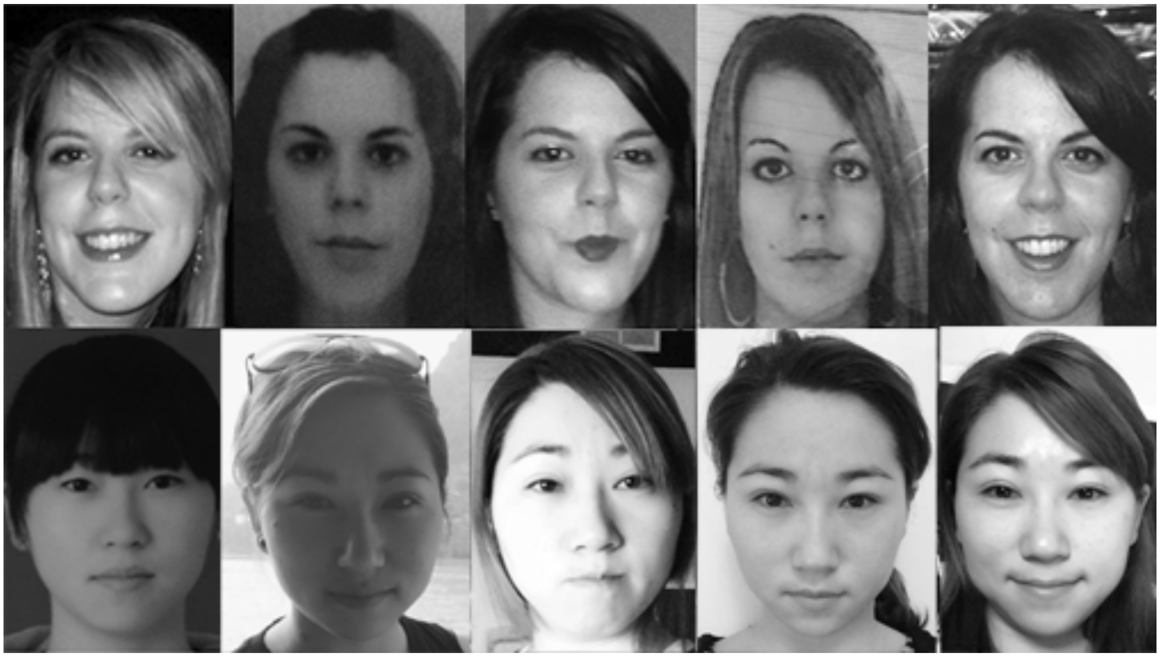

Figure 3.1. A portrayal of the kind of variability encountered in our sorting task.

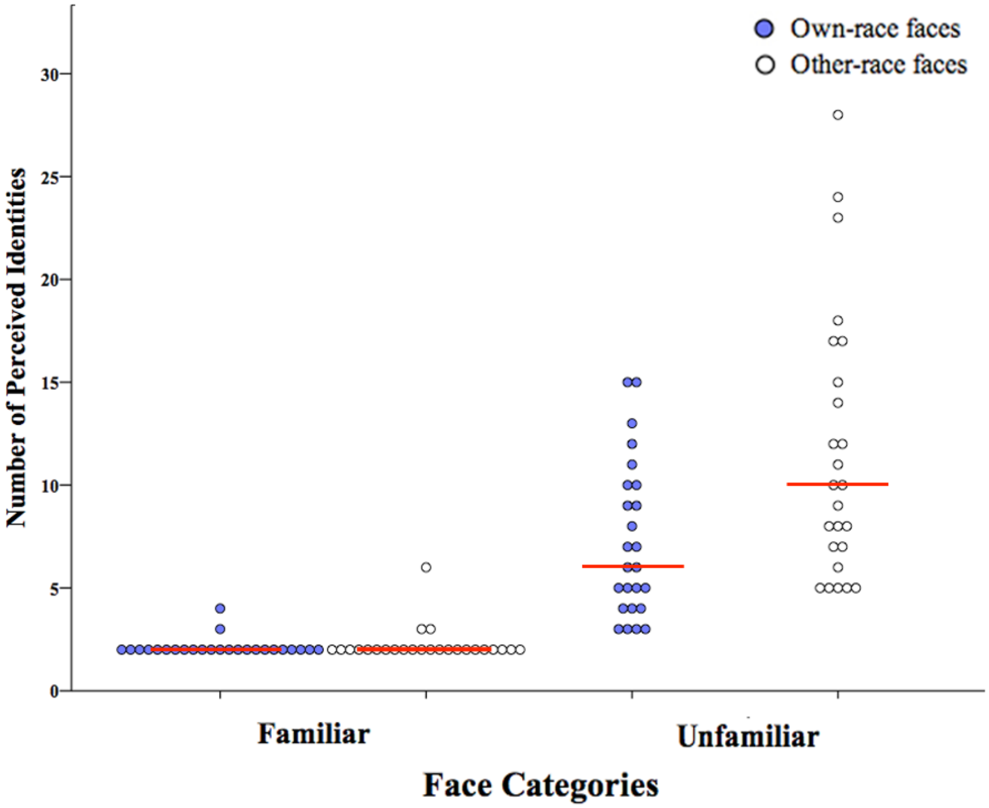

Figure 3.2. Number of perceived identities by individual participants. Red lines indicate medians.

(DV), revealed a significant interaction, $F(1,96) = 7.57$, $p = .007$, $\eta_p^2 = .07$. As shown in Figure 3.2, participants showed an own-race advantage when sorting unfamiliar faces, $t(48) = 2.85$, $p = .006$, Cohen's $d = 0.81$), with a mean of 11.56 versus 7.28 piles for other- (Median = 10; Range = 5-28) and own-race faces (Median = 6; Range = 3-15), respectively. In contrast, the ORE vanished when faces were familiar, $t(48) = -0.64$, $p = .526$, Cohen's $d = 0.18$) because almost every participant made two piles for own- (Mean = 2.12; Median = 2; Range = 2-4) and other-race faces (Mean = 2.24; Median = 2; Range = 2-6). An astute reader might wonder whether photographs of Watson and Stewart were inherently easy to sort. They were not. We tested an additional six participants who had not seen these popular films and were wholly unfamiliar with the celebrities; none made two piles (Mean=12.00; Median=12; Range=5-21).

Our findings provide novel insights about how other-race faces are represented. Valentine (1991) argued that other-race faces are densely clustered in the periphery of multidimensional face space because they are represented by few dimensions or perceivers are less sensitive to how the faces vary across these dimensions; dense clustering makes unfamiliar other-race faces difficult to recognize across variability in appearance (Laurence et al., 2016). We showed that when specific other-race identities become familiar via extensive exposure to within-person variability (social media, movies, and magazines), perceivers form an abstract representation allowing recognition across natural variation in appearance. Such learning might not be evident when exposure is limited to an iconic image (Carbon, 2008). This perceptual learning is identity-specific and does not generalize to the whole other-race category, perhaps because familiarity with a few other-race exemplars does not add dimensions to face space. Whether perceptual learning is as efficient for other-race faces as it is for own-race faces remains to be determined.

The current research has profound applied implications. Eyewitness testimony might be problematic when identifying an unfamiliar other-race suspect, but when witnessing a crime committed by someone with whom one is familiar, the accuracy of subsequent recognition might be independent of race. Our work suggests rethinking the concept of the ORE. Although frequently conceived as a problem of ‘‘face recognition,’’ it is more accurately depicted as a problem of ‘‘image recognition’’ or ‘‘face learning’’; there is no effect on ‘‘face recognition’’ once an other-race identity becomes familiar. In other words, Jackie Chan and Leonardo DiCaprio are equally likely to be recognized by fans when their appearance changes (e.g., when they grow a beard or shave their head).

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CHAPTER 4

Study 3: Judging Normality and Attractiveness in Faces: Direct Evidence of a More Refined Representation for Own-Race, Young Adult Faces[4]

4.1 Introduction

Adults possess an exceptional ability to discriminate and recognize individual faces, despite the fact that all faces share the same configural template (i.e., two eyes located above the nose and mouth). This perceptual expertise has been attributed to norm-based coding, a process by which individual face exemplars are encoded with reference to their deviation from the face norm (i.e., center of face space), which represents the average of all faces previously encountered (Valentine, 1991). Strong evidence for norm-based coding has emerged from studies examining face aftereffects (e.g., Leopold, O'Toole, Vetter, & Blanz, 2001; Rhodes & Jeffery, 2006; Rhodes et al., 2005; Schweinberger et al., 2010). For example, repeated exposure to an adaptor face (e.g., anti-Dan) shifts the norm toward that face, biasing perception selectively toward a face with attributes opposite to the adaptor (e.g., Dan; termed identity aftereffects). Likewise, exposure to faces distorted in a similar direction (e.g., features expanded outward) produces a temporary shift in the norm, such that unaltered faces appear distorted in the opposite direction while similarly distorted faces appear more attractive (termed figural aftereffects; Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003).

Norm-based coding is functionally important; it allows efficient extraction of subtle variations in the shared configuration among faces (Byatt & Rhodes, 1998). This process frees up neural resources by allowing the perceptual system to focus on the unique

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characteristics that are crucial for identifying a particular face, rather than storing a complete structural description of each face (Rhodes & Leopold, 2011; Rhodes, Watson, Jeffery, & Clifford, 2010; Webster & MacLeod, 2011). The functional value of norm-based coding is evident in the positive correlation between the magnitude of both figural eye-height (Dennett, McKone, Edwards, & Susilo, 2012) and identity aftereffects (Rhodes, Jeffery, Taylor, Hayward & Ewing, 2014) and individual differences in face recognition memory.

Valentine's influential norm-based coding model (1991) provides an elegant explanation for two well-known phenomena: the other-race effect (ORE; better recognition of own- than other race faces (see Bothwell, Brigham & Malpass, 1989; Meissner & Brigham, 2001 for reviews) and the other-age effect (OAE; better recognition of own-age; Anastasi & Rhodes, 2005; Perfect & Harris, 2003; Rhodes & Anastasi, 2012) or young adult faces (de Heering & Rossion, 2008; Kuefner, Macchi Cassia, Picozzi, & Bricolo, 2008) than faces from other age categories). Valentine proposed that the dimensions of face space are shaped by experience such that they maximally differentiate faces from categories with which adults have abundant experience. Consequently, faces from other categories (typically other-race and other-age faces) are densely clustered in the periphery of face space, making them hard to discriminate and recognize.

Category-contingent aftereffects provide partial support for this explanation. Adaptation to face categories distorted in opposite directions (e.g., compressed Caucasian versus expanded Asian faces) simultaneously shifts normality/attractiveness preferences in opposite directions. Opposing aftereffects have been found for race (Jaquet, Rhodes, &

Hayward, 2008; Little, DeBruine, Jones, & Waitt, 2008), orientation (Rhodes et al., 2004), species (Little et al., 2008), sex (Jaquet & Rhodes, 2008; Little, DeBruine, & Jones, 2005) and age (Little et al., 2008; Short, Proietti, & Mondloch, 2015) and suggest that separable norms are used to code faces from different face categories (e.g., race and species).

Although opposing aftereffects demonstrate that adults possess separable norms coding for faces from different categories, they do not address whether the norm and face space are less well differentiated for categories with which adults have less experience (e.g., other-race faces), a critical component of Valentine's model. This is because the magnitude of aftereffects does not vary as a function of perceptual expertise; adults do not show larger aftereffects for upright faces compared to inverted faces (Rhodes et al., 2004), for own-race compared to other-race faces (Jaquet et al., 2008), or for young adult compared to older adult faces (Short et al., 2015). Thus, the refinement of the norms and underlying dimensions used for faces from different categories remains unclear. In the current study, we directly test whether adults possess a more refined face space for own-race and young adult faces relative to other-race and older adult faces, respectively.

The method used to address this question in Experiment 1 is based on a previous study showing that poor recognition of older faces may be partially attributable to insensitivity to deviations from the norm in older relative to young adult faces (Short & Mondloch, 2013). In that study, participants were shown young and older adult face pairs in which one face was undistorted and the other image of the same identity had either compressed or expanded facial features. Participants were asked to judge which face in each face pair was more normal (normality task) and which was more expanded (discrimination task). The normality task is sensitive to norm-based coding because participants need to reference a norm. In contrast, the discrimination task does not require referencing a norm because participants can simply compare feature size. Short and Mondloch found that both young and older adults were more accurate for young than older adult faces in the normality task whereas they exhibited comparable accuracy for young and older faces in the discrimination task. Enhanced performance for young adult faces in the normality task was presumed to reflect reliance on a face space optimized for the dimensions of young adult faces, perhaps due to the early and continuous exposure most adults have to young adult faces throughout the lifespan. Consistent with this viewpoint, a recent study demonstrated that this enhanced sensitivity to the dimensions of young relative to older faces emerges as early as 3 years of age (Short, Mondloch, & Hackland, 2015).

If abundant experience with young adult faces sets up the perceptual system in a way that is preferentially tuned for the dimensions of young adult faces, then we would expect that abundant experience with own-race faces tunes the dimensions of face space for own-race faces in the same way, resulting in enhanced normality judgments for own- relative to other-race faces. In the current study, we directly tested this hypothesis. In Experiment 1, Caucasian and Chinese adults were tested with a modified version of the normality and discrimination tasks employed by Short and Mondloch (2013). Participants viewed own- and other-race face pairs rather than young and older adult face pairs. We predicted that both Caucasian and Chinese adults would be more accurate in judging the normality of own-race faces but would show comparable accuracy in discriminating own- and other-race faces.

In Experiment 2, to provide converging evidence for the conclusion that the dimensions of face space are more refined for the face categories with which adults have ample experience, we tested adults' sensitivity to variability in the attractiveness of own- versus other-race faces (Exp. 2a) and young versus older adult faces (Exp. 2b). Considerable evidence has suggested that similar to perceptions of normality, adults' perception of attractiveness is influenced by norm-based coding (e.g., Langlois & Roggman, 1990; Rhodes, 2006; Rhodes & Tremewan, 1996). Perceived facial attractiveness changes as a function of proximity to the norm, such that perceptual attractiveness decreases the farther a face is from the norm (e.g., Langlois & Roggman, 1990). If our mental representation of young, own-race faces is characterized by a more well-refined face space, then young, own-race faces should be more dispersed than older and other-race faces (Burton & Vokey, 1998), increasing consensus not only in judgments of normality, but also attractiveness.

If abundant experience with own-race and young adult faces makes the dimensions of face space more finely tuned for these face categories, then adults should be more likely to agree on (i.e., greater consensus; less between-rater variability) the attractiveness of individual faces from such face categories relative to face categories with which they have less experience. To test this hypothesis, we presented participants with undistorted images of own- and other-race faces (Exp. 2a) or young and older adult faces (Exp. 2b) and measured the extent to which participants agreed on the attractiveness of each face (between-rater variability), which is quantified by the magnitude of the standard deviation (SD) in attractiveness ratings for each face. We hypothesized that participants would show greater agreement (i.e., smaller mean standard deviations) for face categories with which they had greater cumulative life experience (i.e., own-race and young adult faces) than faces with which they had limited perceptual experience (i.e., other-race and older adult faces).

4.2 Experiment 1

4.2.1 Method

4.2.1.1 Participants

Twenty-four Caucasian adults (24 female; Mean age = 19.67 years, *SD* = 1.17, age range = 18-22) from Brock University, Canada and 24 Chinese adults (18 female; Mean age = 22.00 years, *SD* = 2.25, age range = 20-27) from Zhejiang Normal University, China participated in this experiment. All participants included in our analyses reported minimal contact with other-race identities based on their responses on a questionnaire (see Procedure section). All participants reported having less than two other-race friends and 98.75% of participants reported having zero other-race friends. We excluded five additional participants (three Caucasian and two Chinese adults) who reported significant experience with individuals of East Asian/Caucasian ethnicity. All participants gave written informed consent and received either research credit or a small honorarium for their participation.

4.2.1.2 Materials

Stimuli consisted of colored facial photographs of 12 Caucasian adults (6 male) and 12 Chinese adults (6 male). All stimuli were acquired from the Center for Vital Longevity Face Database (Minear & Park, 2004) and the Let's Face It database at Brock University. Faces were presented in a frontal view and posed a neutral expression. Faces were resized such that the distance from the hairline to the chin was approximately 450 pixels, and the spherize tool in Adobe Photoshop Version CS5 was used to expand and compress the internal features of each face (see Figure 4.1). The facial features of each faces were either expanded outward or compressed inward at three distortion levels (-30%, -20%, -10%, 10%, 20%, 30%), resulting in a total of six new versions of each face. Each level of distortion was then paired with the undistorted same-identity counterpart. The left/right position of the undistorted face in each face pair was counterbalanced such that the undistorted face appeared on the left side in half of the trials. An additional four identities were used in four practice trials. Practice trials consisted of an undistorted face paired with either an expanded or compressed face (±40%) of the same identity. The practice and test stimuli were approximately 33 × 20 cm when presented on a 23-inch computer monitor and were viewed from a distance of approximately 60 cm. Stimuli were presented and participants' responses were recorded using Superlab 4.5 software.

4.2.1.3 Procedure

This study received clearance from the Research Ethics Board at Brock University. All participants were tested individually in two tasks: a normality judgment task and a discrimination task. The order in which participants completed the two tasks was counterbalanced such that half of the participants were tested with the normality task followed by the discrimination task and the other half were tested in the reverse order. In both tasks, each trial comprised a 500-ms fixation cross, followed by a face pair that was presented for 3000 ms. Once the face pair disappeared from the screen, it was replaced by a screen prompting participants to press a key indicating which face was either more normal-looking (normality task) or more expanded (discrimination task). Within each task, race of face was blocked; half of the participants were tested with Caucasian faces first and the other half were tested with East Asian faces first. Within each block, both face identities and distortion levels were randomized for each participant. In the discrimination task, the expanded face in each pair was defined as having more stretched (i.e., expanded outward) features than its same-identity counterpart (e.g., undistorted face compared to a -10% face). Twelve identities across 6 levels of distortion for each of the two race categories resulted in a total of 144 face pairs that were presented to participants in each task. Prior to the actual test, participants were presented with four practice trials in which the distortion was increased to ±40%. On each practice trial, participants were shown an undistorted face paired with an expanded or compressed face of the same identity.

Upon completion of both tasks, participants completed a questionnaire assessing the amount of contact they have had with other-race identities (e.g., Chinese participants' contact with Caucasian individuals). For example, they indicated how many of their top ten friends were of East Asian/Caucasian ethnicity, and how much current and previous experience they have had with other-race identities.

4.2.2 Results and Discussion

To simplify our analysis, we collapsed across expanded and compressed trials within each distortion level. In the normality task, we calculated the proportion of trials in which participants selected the undistorted face in a face pair as being more normal. In the discrimination task, we calculated the proportion of trials in which participants selected the more expanded face in a face pair as being more expanded (i.e., the undistorted face when the distorted face was compressed, but the expanded face when the distorted face was expanded). Task order did not influence the accuracy of normality

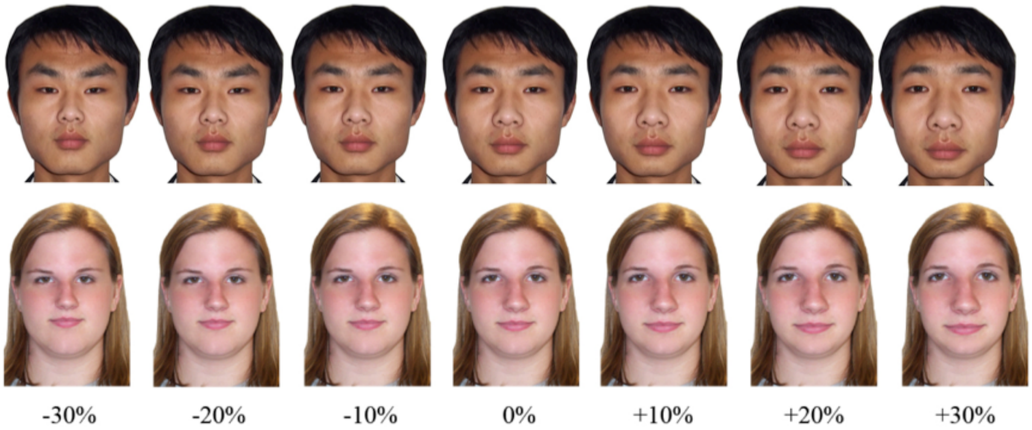

Figure 4.1. Sample distortion continua for a Chinese identity and a Caucasian identity. Each face pair comprised an undistorted face paired with a compressed or an expanded version of the same identity.

judgments and discrimination (*p*s > .12); thus task order was excluded from all further analyses. We conducted a 2 (participant race: Caucasian, Chinese) × 2 (task type: normality, discrimination) × 2 (face race: Caucasian, East Asian) × 3 (distortion: 10%, 20%, 30%) mixed-model ANOVA, with participant race as a between-subjects variable and task type, face race and distortion levels as within-subjects variables.

Because our primary question concerned the influence of face race on normality versus discrimination judgments, we focus here on main effects and interactions involving task type. We found significant main effects of task type ($F_{1, 46} = 60.86$, $p < .001$, $\eta_p^2 = .57$), face race ($F_{1, 46} = 21.99$, $p < .001$, $\eta_p^2 = .32$) and distortion level ($F_{1, 45} = 540.55$, $p < .001$, $\eta_p^2 = .96$), such that accuracy was higher in the discrimination task (*M* = 0.87, *SE* = 0.01) than in the normality task (*M* = 0.76, *SE* = 0.01) and for own-race faces (*M* = 0.83, *SE* = 0.01) than for other-race faces (*M* = 0.80, *SE* = 0.01). Accuracy increased as distortion level increased (10%: *M* = 0.68, *SE* = 0.01; 20%: *M* = 0.83, *SE* = 0.01; 30%: *M* = 0.93, *SE* = 0.01). There was also a task type by distortion interaction ($F_{1, 45} = 57.68$, $p < .001$, $\eta_p^2 = .72$), which indicated that the difference in performance across the two tasks decreased as distortion level increased (i.e., the task became easier; see Figure 4.2a).

Notably, we found a significant interaction between task type and face race ($F_{1, 46} = 15.00$, $p < .001$, $\eta_p^2 = .25$; see Figure 4.2b). Paired-sample *t*-tests confirmed that both Caucasian and Chinese participants were more accurate in judging the normality of own-race faces (*M* = 0.78, *SE* = 0.01) than other-race faces (*M* = 0.73, *SE* = 0.01, $t_{47} = 5.42$, $p < .001$, Cohen's *d* = 0.59). In contrast, accuracy for own- (*M* = 0.87, *SE* = 0.01) and other-race (*M* = 0.87, *SE* = 0.01) faces did not differ in the discrimination task ($t_{47} = 5.34$, *p* = 0.60, Cohen's *d* = 0). This task type by face race interaction was not qualified by interactions with either participant race or distortion level, *p*s > 0.41. Furthermore when examined independently, both Caucasian and Chinese participants showed an own-race advantage on the normality task (*p*s < .010) but not the discrimination task (*p*s > .100). To determine whether participants' greater accuracy in judging the normality of own-race faces than other-race faces is attributable to better image learning in the course of the experiment for own- than other-race faces (i.e., to participants recognizing previously selected faces), we conducted an ANOVA in which block (1st vs 2nd half of trials), face race, participant race, and distortion levels were factors. There was no effect of block and no interaction involving block was significant (*p*s > .325). Thus, more accurate performance for own- than for other-race faces in the normality task is not attributable to image learning (i.e., greater sensitivity to normality in own-race faces did not emerge overtime).

In summary, both Caucasian and Chinese adults showed deficits in detecting the normality of other-race compared to own-race faces despite no effect of face race on their ability to detect the expansion of facial features. This is consistent with evidence that young and older adults show a young adult face advantage in the normality but not the discrimination task (Short & Mondloch, 2013). Discrepant results across the two tasks directly points to reduced efficiency in the use of norm-based coding for other-race faces, another category with which most people have less experience. Extensive perceptual experience with own-race faces tunes the dimensions of face space for own-race faces, making judgments of normality more accurate for own- than other-race faces. But lack of perceptual experience with other-race faces does not influence accuracy in the

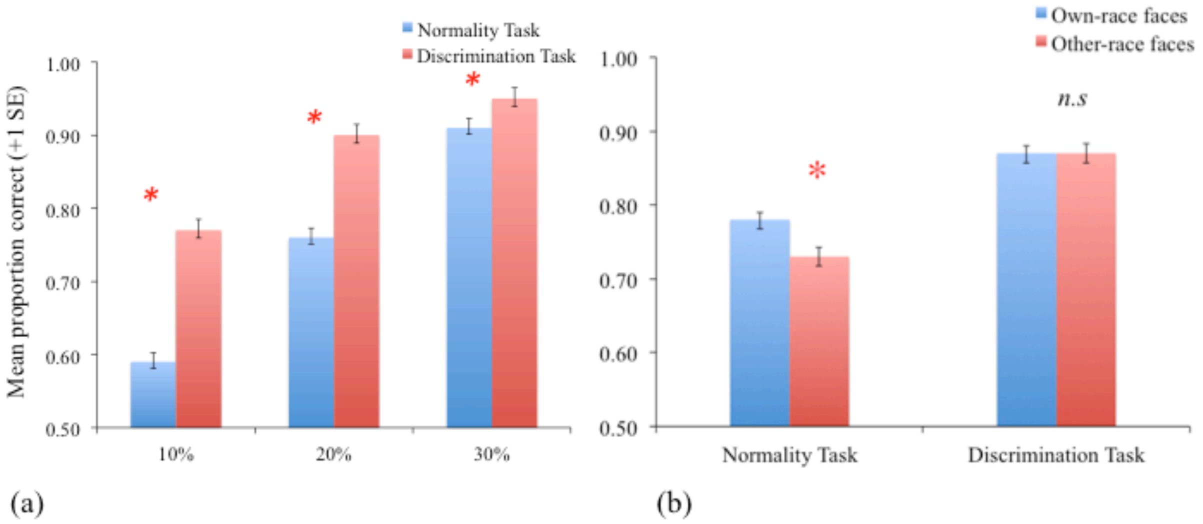

Figure 4.2. Mean proportion correct for the discrimination and normality tasks at (a) each level of distortion collapsed across face race and for (b) own- and other-race faces collapsed across distortion levels. * $p < .05$.

discrimination task, a task that does not require the use of norm-based coding. This argument receives support from evidence that inverting the face pairs eliminates the young adult face advantage in the normality task but not the discrimination task (Short & Mondloch, 2013).

Experiment 2

Similar to judgments of normality, judgments of attractiveness are influenced in part by how much an individual face deviates from an average face; facial attractiveness is inversely related to distance from the mean (Langlois & Roggman, 1990; Light, Hollander, & Kayra-Stuart, 1981; Morris & Wickham, 2001; O'Toole, Deffenbacher, Valentin, & Abdi, 1994; Rhodes, 2006; Rhodes & Tremewan, 1996; but see Alley & Cunningham, 1991). Similar mean attractiveness ratings across different cultures (Cunningham, Roberts, Barbee, Druen, & Wu, 1995; Langlois et al., 2000) and age groups (Cross & Cross, 1971) suggests a degree of consensus regarding which faces are most versus least attractive. However, mean ratings for an individual face ignore between-rater variability (consensus), a metric that we hypothesized would be influenced by experience.

If extensive experience with own-race and young adult faces optimizes the dimensions of face space for these face categories, resulting in faces from other categories being more densely clustered with poorly refined norms, then there should be less consensus among raters when judging faces from categories with which they have less experience. To test this hypothesis and provide converging evidence for a face space optimized for own-race and young adult faces, we showed participants 40 undistorted faces from each of two categories and asked participants to rate each face on a 7-point attractiveness scale. In Experiment 2a, Caucasian and Chinese participants rated the attractiveness of Caucasian and East Asian faces; in Experiment 2b, young and older adults rated the attractiveness of young and older adult faces. To quantify consensus, for each face, we calculated the standard deviation of ratings across participants. We hypothesized that there would be less between-rater variability (i.e., smaller mean standard deviation) in ratings of individual faces for own-race faces (Exp. 2a) and young adult faces (Exp. 2b) relative to other-race and older adult faces, respectively.

4.3 Experiment 2a

4.3.1 Method

4.3.1.1 Participants

Forty Caucasian undergraduates (37 female; Mean age = 20.48 years, *SD* = 5.67, age range = 17-25) from Brock University, Canada and 40 Chinese undergraduates (35 female; Mean age = 22.15 years, *SD* = 2.43, age range = 18-26) from Zhejiang Normal University, China participated in this experiment. As in Experiment 1, Caucasian and Chinese participants reported very little contact with other-race individuals. All participants included in our analyses reported having less than two other-race friends; 98.75% of participants reported having zero other-race friends. An additional 19 participants (two Chinese, 17 Caucasian) were excluded from the final analysis due to reported significant experience with individuals of other-race ethnicity. Participants received either research credit or a small honorarium for their participation.

4.3.1.2 Materials

Stimuli comprised colored photographs of 40 Caucasian faces (20 female) and 40 East Asian faces (20 female). All stimuli were acquired from the Center for Vital

Longevity Face Database (Minear & Park, 2004) and from the Let's Face It database at Brock University. Each face was presented in a frontal view and with a neutral expression. Using Adobe Photoshop Version CS5, we removed the neck, background details, and distracting blemishes from the original pictures and resized them such that the distance from the hairline to the chin was approximately 500 pixels. All stimuli were presented and responses were recorded using SuperLab 4.5 software.

4.3.1.3 Procedure

This study received clearance from the Research Ethics Board at Brock University. After providing written informed consent, participants sat 60 cm in front of a 23-inch computer and were told that they would be shown a series of faces and that it was their job to rate each face in terms of its attractiveness. Participants were told that they would use a 7-point attractiveness rating scale, with 1 being not at all attractive and 7 being extremely attractive. Participants were told to attempt to use the full range of the scale and to think about the attractiveness of each face with regard to other faces of that race when making their responses.

Face race was blocked such that half of the participants viewed Caucasian faces followed by East Asian faces, and half viewed East Asian faces followed by Caucasian faces. Each block contained 40 trials and each trial consisted of a 500-ms fixation cross followed by a face that appeared for 3000 ms. Participants had an unlimited amount of time to rate each face's attractiveness via keypad on the 7-point scale. Before each block, participants were presented with all 40 faces from that block, one at a time for 1 second each, with a 500-ms ISI. This was done so that participants would have a sense of the range of variability in the attractiveness of the faces, thus ensuring that the first few faces would not be given abnormal ratings. As in Experiment 1, upon completion of the attractiveness task, participants completed a questionnaire assessing the amount of contact they had with other-race identities.

4.3.2 Results and Discussion

For each Caucasian and East Asian face, we calculated the mean attractiveness and the standard deviation in attractiveness ratings; calculations were done separately for Caucasian and Chinese participants. The mean attractiveness rating for each face reflects the average (i.e., central tendency) rating provided by Caucasian or Chinese raters. The standard deviation in attractiveness ratings reflects the extent to which raters agree with each other regarding the attractiveness of a particular face. In other words, higher standard deviations in attractiveness ratings indicate greater between-rater variability (i.e., less consensus) in attractiveness ratings.

Task order and face sex did not have a significant effect on the mean and SD attractiveness ratings, nor did they interact with any other variables (all *p*s > .09); thus task order and face sex were excluded in all subsequent analyses. All follow-up t-tests were 2-tailed.

Mean attractiveness ratings. A 2 (face race: Caucasian, East Asian**)** × 2 (participant race: Caucasian, Chinese) mixed-model ANOVA examining mean attractiveness ratings for own- and other-race faces revealed no main effects of face race ($F_{1,\,78} = 1.12$, $p = .29$, $\eta_p^2 = .01$) and participant race ($F_{1,\,78} = 0.32$, $p = .58$, $\eta_p^2 = .004$). Furthermore, there was no significant face race by participant race interaction ($F_{1,\,78} = 2.23$, $p = .14$, $\eta_p^2 = .03$), indicating that Caucasian and Chinese adults showed comparable average attractiveness ratings for both own- and other-race faces. This was further confirmed by a significant positive correlation between Caucasian and Chinese participants' mean attractiveness ratings for both Caucasian ($r = 0.61$, $p < .001$) and East Asian faces ($r = 0.62$, $p < .001$). In other words, increases in Caucasian raters' mean attractiveness rating for Caucasian and East Asian faces were associated with increases in Chinese raters' mean attractiveness rating for the same faces.

Standard deviation in attractiveness ratings. We next examined whether Caucasian and Chinese raters showed greater between-participant variability (e.g., less consensus) in rating the attractiveness of other-race relative to own-race faces. We conducted a 2 (face race: Caucasian, East Asian) × 2 (participant race: Caucasian, Chinese) mixed-model ANOVA with the standard deviations in attractiveness ratings for own- and other-race faces as the dependent variable. We found a significant interaction between face race and participant race ($F_{1, 78} = 5.24$, $p = .03$, $\eta_p^2 = .06$; see Figure 4.3). Independent-sample *t*-tests confirmed that Caucasian adults showed greater between-participant variability when rating the attractiveness of other-race faces ($M = 1.41$, $SE = 0.03$) than when rating the attractiveness of own-race faces ($M = 1.33$, $SE = 0.03$; $t_{78} = 2.18$, $p = .03$, Cohen's $d = 0.47$). However, Chinese adults showed comparable between-participant variability when rating the attractiveness of both own- ($M = 1.36$, $SE = 0.03$) and other-race faces ($M = 1.39$, $SE = 0.03$; $t_{78} = -0.64$, $p = .53$, Cohen's $d = 0.16$).

In summary, consistent with our hypothesis, Caucasian participants showed reduced consensus when rating the attractiveness of East Asian faces compared to Caucasian faces. Previous studies suggest that perceived facial attractiveness reflects norm-based coding, with attractiveness ratings inversely related to the distance from the norm (e.g., Rhodes & Tremewan, 1996). Among Caucasian participants, reduced consensus when

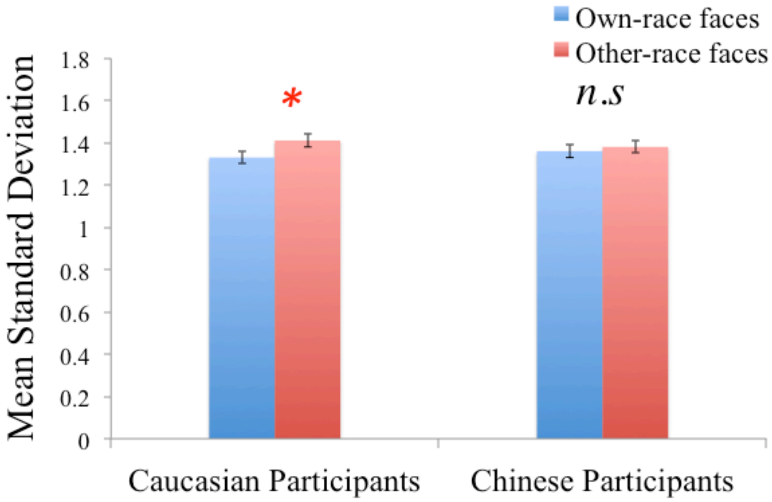

Figure 4.3. Caucasian and Chinese adults' mean standard deviation in attractiveness ratings for own- and other-race faces. * $p < .05$, *n.s* = nonsignificant

judging the attractiveness of other-race faces is consistent with their impaired ability to judge the normality of other-race faces (Experiment 1). In contrast, despite showing higher accuracy when judging the normality of East Asian compared to Caucasian faces (Experiment 1), Chinese participants did not show reduced consensus when judging the attractiveness of Caucasian faces. This might be attributable to Chinese participants having greater exposure to Western media (e.g., Western movies, singers, news) than Caucasian participants have to East Asian media. To the extent that actors and singers are typically above average in attractiveness, this experience might influence Chinese participants' judgments of attractiveness more so than their judgments of normality, a possibility that should be examined in future studies. Collectively the results of Experiments 1 and 2a provide direct evidence that the dimensions of face space are more refined for own- than other-race faces. In Experiment 2b, we wanted to confirm these findings with another face category with which adults have differential experience: young and older adult faces. In particular, we examined whether consensus in attractiveness ratings varies as a function of face age.

4.4 Experiment 2b

Short and Mondloch (2013) reported that both young and older adults are more accurate in judging the normality of young relative to older adult faces under conditions in which their ability to discriminate faces from the two categories was comparable. In Experiment 2b, we measured the degree of consensus among young and older adults when judging the attractiveness of young versus older adult faces. Greater consensus when judging young adult faces would provide converging evidence of a more refined norm for young faces, consistent with the dimensions of face space being optimized for young adult faces.

4.4.1 Method

4.4.1.1 Participants

Forty Caucasian undergraduate students from Brock University (35 female; *M* = 19.60 years, age range = 18-24) and 40 senior citizens living in independent housing in the Niagara region of Ontario (29 female; *M* = 71.88 years, age range = 60-89) participated in this experiment. Senior citizen participants were all in good health, and 39 of the 40 senior participants had 20/30 vision or better. Undergraduates received research credit or a small honorarium and senior citizens received a gift card for their participation in the study. All participants completed a questionnaire assessing their weekly face-to-face contact with both young and older adults. All participants included in our analyses reported spending more time with own-age peers (*M* = 45.24 hours and 53.73 hours per week for young and older adults, respectively) than other-age individuals (*M* = 7.63 hours and 7.69 hours per week). An additional two undergraduates were tested but excluded from the final data set because they failed to pay attention during testing (n = 1) or did not fill out the questionnaire properly (n = 1).

4.4.1.2 Materials

Stimuli comprised colored photographs of 40 Caucasian young adult (20 female; age range = 18-29) and 40 Caucasian older adult (20 female; age range = 70-81) faces. All stimuli were acquired from the Center for Vital Longevity Face Database (Minear & Park, 2004) and resized such that the distance from the hairline to the chin was approximately 500 pixels. Young adult stimuli were identical to those used in Experiment 2a. As in

Experiment 2a, all photographs were cropped such that only the face and hair remained and all distracting blemishes were removed. All stimuli were presented and responses were recorded using SuperLab 4.5 software.

4.4.1.3 Procedure

The procedure of Experiment 2b was identical to that of Experiment 2a but older adult faces were shown instead of East Asian faces and the questionnaire measured the amount of current contact with young versus older adult faces.

4.4.2 Results and Discussion

Similar to Experiment 2a, we calculated the mean attractiveness rating and standard deviation for each young and older adult face.

Mean attractiveness ratings. A 2 (face age: young, older) x 2 (participant age: young, older) mixed-model ANOVA with mean attractiveness ratings as the dependent variable revealed a main effect of participant age, $F_{1,\,78} = 86.76$, $p < .001$, $\eta_p^2 = .53$, such that faces were rated as more attractive by older adults ($M = 4.32$, $SE = .07$) than by young adults ($M = 3.73$, $SE = .10$). There was no main effect of face age, $F_{1,\,78} = 2.34$, $p = .13$, $\eta_p^2 = .03$, nor was there a significant face age by participant age interaction, $F_{1,\,78} = .17$, $p = .68$, $\eta_p^2 = .002$. The lack of a significant interaction indicates that young and older adults provided comparable attractiveness ratings for both face ages; this was further confirmed by a significant positive correlation between young and older adults' mean attractiveness ratings for young adult ($r = .77$, $p < .001$) and older adult faces ($r = .77$, $p < .001$).

Standard deviation in attractiveness ratings. A 2 (face age: young, older) x 2 (participant age: young, older) mixed-model ANOVA with the standard deviations in attractiveness ratings as the dependent variable revealed a main effect of face age ($F_{1,\,78}$ = 13.96, p < .001, η_p^2 = .15; see Figure 4.4). Overall, there was greater between-participant variability in attractiveness ratings for older adult faces (M = 1.32, SE = .02) than for young adult faces (M = 1.24, SE = .02). There was no main effect of participant age ($F_{1,\,78}$ = .24, p = .63, η_p^2 = .003), nor a significant face age by participant age interaction ($F_{1,\,78}$ = .55, p = .46, η_p^2 = .007).

In summary, just as Caucasian adults showed greater consensus in their attractiveness ratings of own- relative to other-race faces, both young and older adults showed greater consensus in their attractiveness ratings for young relative to older adult faces. This is consistent with previous evidence that young and older adults are more sensitive to deviations from the norm in young relative to older faces (Short & Mondloch, 2013). It is surprising, perhaps, that older adults showed an advantage for young adult faces in this task despite recent abundant experience with older adult faces. This is in contrast to Chinese young adults who, likely because of exposure to Western media, did not show an own-race advantage on our attractiveness task. We suspect that the continuous young adult face bias in older adults reflects the special influence of early experience in shaping perceptual expertise—experience that is dominated by young faces (Macchi Cassia, Bulf, Quadrelli, & Proietti, 2013; Short, Semplonius, Proietti, & Mondloch, 2014). Collectively, these results provide direct evidence of a more refined face space (a well-defined norm and sensitivity to deviations along the underlying dimensions) for own-race and young adult faces relative to faces from other categories.

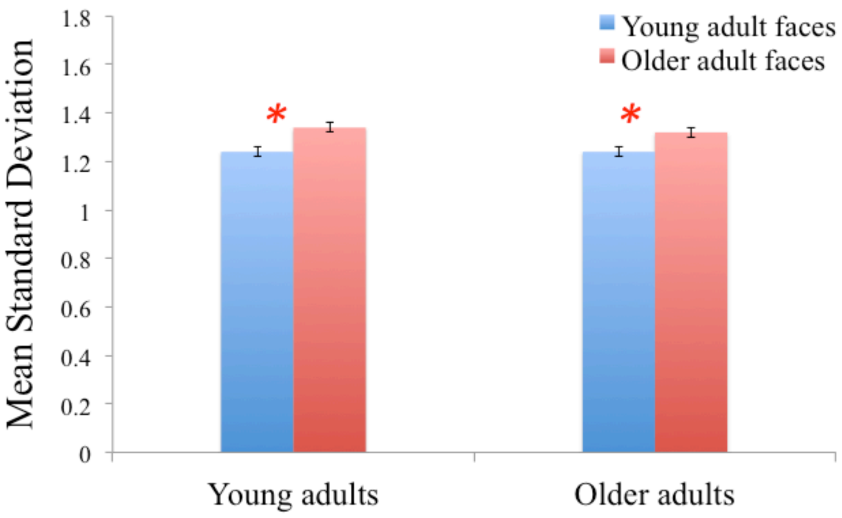

Figure 4.4. Young and older adults' mean standard deviation in attractiveness ratings for young and older adult faces. * $p < .05$.

4.5 General Discussion

Collectively, our results provide the first direct evidence that multidimensional face space is more refined for own- than other-race faces and provide converging evidence that both young and older adults' face space is more refined for young than older adult faces (see Short & Mondloch, 2013). We discovered an own-race advantage in judgments of normality but not discrimination (Experiment 1) and among Caucasian participants, less between-participant variability in attractiveness ratings for own-race than for other-race faces (Experiment 2a). We also found less between-participant variability in attractiveness ratings for young than for older adult faces both among young and older participants (Experiment 2b). These results suggest that the dimensions of face space are optimized for face categories with which people have ample perceptual experience (i.e., own-race faces; young adult faces). A particular strength in this set of experiments is that we tested adults from different race and age groups; consequently variability in normality and attractiveness judgments cannot be attributed to stimulus effects.

It has been well established that other-race faces and older adult faces are recognized less accurately than own-race and young adult faces (Bothwell et al., 1989; de Heering & Rossion, 2008; Meissner & Brigham, 2001). This has been attributed to norm-based coding, but few studies have systematically examined the relationship between norm-based coding and recognition deficits. Although opposing aftereffects suggest that separable norms are used to encode faces from different categories, the hypothesis that the face norm and the dimensions underlying face space are less well differentiated for faces from less encountered categories has not been directly tested in studies of aftereffects. Here we provide the first direct evidence of this hypothesis.

Unlike judging which of two faces is more expanded, judging normality requires perceptual expertise (i.e., knowledge of what an average face from that category looks like). This argument is supported by evidence that inversion impairs performance on the normality task (but not the discrimination task) and eliminates the young adult face advantage (Short & Mondloch, 2013). In the current study, despite no difference in the accuracy with which Caucasian and Chinese adults were able to discriminate own- versus other-race faces, their judgments of normality were more accurate for own-race faces. This result reflects reduced sensitivity to deviations from a prototypical other-race face and inefficiency in the use of norm-based coding for other-race faces, a pattern likely resulting from limited perceptual experience with other-race faces. This finding is consistent with evidence that young and older adults are more sensitive to deviations from normality in young than older adult faces (Short & Mondloch, 2013), suggesting a reliance on a face space that is optimized for the dimensions for young adult faces.

In Experiment 2, we provided converging evidence for less efficiently tuned dimensions of face space for other-race and older adult faces by using a different task: attractiveness judgments. We found that Caucasian adults showed more consensus (less variability) when rating the attractiveness of Caucasian faces compared to East Asian faces, with no difference among Chinese adults. Moreover, both young and older adults were more likely to agree on the attractiveness of young adult faces than older adult faces. Greater between-participant variability in perceived attractiveness for other-race and older adult faces is consistent with our conclusion that the perceptual processing system is preferentially tuned for face categories with which people have more perceptual experience.

The results of the present study support the norm-based coding model of the own-race and own-age/young adult face recognition advantage and highlight the important role of perceptual experience in shaping the face norm and the dimensions underlying face space. The dimensions of face space are refined through perceptual experience to represent the facial properties that are optimal for discriminating identities from highly familiar categories. Consequently, faces from unfamiliar categories, such as other-race faces and older adult faces, are tightly clustered in the periphery of face space (Valentine, 1991). This model explains why perceivers have an impaired ability to detect deviations from normality and greater between-perceiver variability in attractiveness ratings for other-race and older adult faces. This may be one reason why participants make more errors in recognition tasks involving other-race and older adult identities (e.g., Golby, Gabrieli, Chiao & Eberhardt, 2001; MacLin & Malpass, 2001; Wright, Boyd & Tredoux, 2003).

Our finding that there is a perceptual advantage for own-race and young adult faces is consistent with evidence that both N170 amplitude and the N170 inversion effect are influenced by face race and age. The amplitude of the N170 is smaller for own- than other-race faces (e.g., Wiese, Kaufmann, & Schweinberger, 2014) and for young than older faces in both young and older adults (Wiese, Schweinberger, & Hansen, 2008), whereas the N170 inversion effect shows the opposite pattern (Komes, Schweinberger, & Wiese, 2015; Viziolia, Rousseleta, & Caldaraa, 2010; Wiese, Komes, & Schweinberger, 2013). This early perceptual advantage impacts recognition; the own-race recognition advantage is robust, as is the own-age advantage among young adults. In contrast, findings are inconclusive in older adult samples (see Proietti, Macchi Cassia, &

Mondloch, 2015 for a review), perhaps because of later processing stages (e.g., as reflected in the N250; Wiese, Kachel, & Schweinberger, 2013) being influenced by accumulation of experience with different age groups over the lifespan (Anastasi & Rhodes, 2006) and the special influence of early experience in shaping perceptual expertise for adult faces (Macchi Cassia et al., 2013).

Our finding that face space is more refined for own-race and young adult faces also has explanatory value for a less investigated challenge in face recognition: recognizing identity when appearance varies. Two pictures of the same person can look very different and pictures of two different people can look very similar. When sorting photographs of unfamiliar faces into piles such that each pile includes all of the pictures of one identity, adults frequently separate photos of one person into multiple piles (i.e., they perceive different pictures of the same person as belonging to different identities). For example, when sorting a pile of 40 photographs comprising 20 pictures of two different identities, adults make about seven piles (i.e., they perceive about seven different identities; Jenkins, White, Van Montfort, & Burton, 2011). They make twice as many piles (perceive twice as many identities) when sorting unfamiliar other-race identities (Laurence, Zhou, & Mondloch, 2016), suggesting that recognizing identity in photos that capture natural within-person variability in appearance among other-race faces is especially challenging.

This finding was interpreted in light of extensions of Valentine’s norm-based coding model, according to which each face is represented as a region (attractor field), rather than a single point, in face space (Tanaka, Giles, Kremen, & Simon, 1998). The attractor field reflects the range of inputs that are perceived as belonging to a given identity (i.e., our ability to tolerate within-person variability in appearance). The size of an identity's attractor field is inversely correlated with the density of nearby representations, and thus hypothesized to be smaller for other-race and older adult faces than for own-race and young adult faces. Laurence et al. (2016) argued that smaller attractor fields for other-race faces not only make other-race faces harder to tell apart but increase the difficulty in recognizing an identity in the context of natural changes in appearance. The current study provides evidence that other-race faces are more densely clustered than own-race faces in face space, with a smaller inter-face distance—a key component to this argument. It would be worthwhile to investigate the relationship between individual differences in sensitivity to deviations from the norm and the ability to recognize pictures of faces that incorporate a wide range of natural variations.

Issues for Future Research

Our findings provide direct evidence that deficits in recognizing other-race and older adult faces can be attributed to a less refined face space for faces from these categories. They also raise several issues worthy of further investigation. In particular, we highlight the need to refine our conceptualization of face space. First, it is not clear exactly what the dimensions underlying face space are. They might be features and their spacing (e.g., nose length, distance between the eyes,) or more abstract dimensions (e.g., eigenfaces; Hancock, Burton, & Bruce, 1996). Although norm-based coding has enormous explanatory power, it is important to better specify the nature of the underlying dimensions.

Second, the process through which perceptual experience shapes the dimensions of face space has not been specified. Opposing aftereffects suggest that we have separable face spaces for own- and other-race faces (Jaquet, Rhodes, & Hayward, 2008) and young versus older faces (Short et al., 2015). Partial transfer of aftereffects across face race (Jaquet & Rhodes, 2008) and age (Short et al., 2015) suggests shared underlying dimensions and separable prototypes/norms. Some dimensions are almost certainly shared across categories (Short et al., 2015). This characterization of face space accounts for our findings in several ways. First, it is likely that any one dimension is not equally diagnostic for faces from all categories. To the extent that dimensions are optimized to discriminate faces from categories with which people have more perceptual experience (e.g., own-race and young adult faces), they will be less effective for discriminating faces from other categories (e.g., other-race and older adult faces). For example, eye color may be a salient dimension for discriminating Caucasian identities, but Asian identities might be more clustered on this dimension. In addition, we propose that regions of face space associated with different categories vary in the number of dimensions represented and/or the length of the underlying vectors (a conceptualization of sensitivity to differences along dimensions). Just as children rely on fewer dimensions than adults (Nishimura, Maurer, & Gao, 2009), it is likely that the very limited number of other-race and older adult face exemplars in one's face space severely restricts the number of underlying dimensions. As noted by Burton and Vokey (1998), fewer dimensions might leave the vast majority of faces clustered in the center of face space. As dimensions are added (which happens throughout development for own-race, young adult faces), faces become more dispersed, making them easier to discriminate and recognize. Our results suggest that this dispersion also leads to greater consensus in attractiveness judgments because there is more variability among faces in their proximity to the center of face space. While in contrast to Valentine's (1991) claim that faces are most densely clustered in the center of face space, it is consistent with his argument that perceived attractiveness is influenced by distance from the center. Future studies should aim to clarify how representations vary across face categories.

There is also evidence showing that children are less sensitive than adults in differentiating along the dimensions of face space (Anzures, Mondloch, & Lackner, 2009; Short, Hatry, & Mondloch, 2011; Short, Lee, Fu, & Mondloch, 2014) and their ability to simultaneously use multiple dimensions improves after 8 years of age (Nishimura et al., 2009). Future studies should investigate whether the increase of perceptual expertise with age enhances children's sensitivity to deviations from the face norm and their sensitivity to the dimensions along which faces vary.

In summary, two methodologies were used to examine the representation of own- versus other-race faces and young versus older adult faces in face space. Adults were more sensitive to how faces deviate from an average face when judging own- relative to other-race faces and were less likely to agree on the attractiveness of other-race and older adult faces. Collectively, these results provide direct evidence that perceptual experience with own-race, young adult faces optimizes the dimensions of face space for own-race and young adult faces. Such reduced sensitivity to deviations from the face norms for categories with which we have less experience may explain the special challenge of recognizing other-race and older adult identities.

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CHAPTER 5

Study 4: The Other-Race Effect is Not Modulated by Differential Use of Shape and Texture Cues During Face Learning and Recognition

5.1 Introduction

Face perception serves as one important basis for human social interactions. On a daily basis, perceivers rely on the accurate extraction of stable identity-based characteristics (e.g., age, sex and ethnicity) as well as dynamic social signals (e.g., emotional state and direction of attention) from faces to function effectively in the social world. Adults' remarkable expertise in extracting identity-based cues is limited to face categories with which they have abundant perceptual experience. For example, one of the most replicated phenomena in face perception is that perceivers tend to discriminate and recognize faces of their own ethnic group more accurately than faces of different ethnic groups (see Bothwell, Brigham, & Malpass, 1989; Meissner & Brigham, 2001, for reviews). This other-race effect (ORE) emerges during infancy (Anzures, Quinn, Pascalis, Slater, & Lee, 2013a; Anzures et al., 2013b; Gauthier & Nelson, 2001; Kelly et al., 2005; 2007), and is robust across different participant populations and a variety of methodologies (e.g., recognition tasks, matching tasks and sorting tasks; Maclin & Malpass, 2001; Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010; Laurence, Zhou, & Mondloch, 2016). Given that the ORE has many deleterious consequences involving the misidentification of racial out-group members (e.g., social embarrassment or erroneous eyewitness testimony), understanding the mechanisms underlying the ORE has profound implications not only for models of face recognition but also for applied settings.

One of the classic measures of the ORE is the old/new face recognition task, in which participants are presented with own- and other-race faces during a study phase and then asked to recognize those faces when they are intermixed with novel faces. In this task, d', a measure of overall accuracy, takes into account both perceivers' ability to recognize previously learned faces (hits) and their ability to detect that a face is novel (correct rejections)—two components of accuracy that are analyzed in the current research because they represent separable aspects of face learning. It has been consistently found that participants make fewer hits and more false alarms (inversely proportional to correct rejections; i.e., incorrectly classify a novel face as learned) for other- than own-race faces, leading to a smaller d' for other-race faces (Meissner & Brigham, 2001; Young, Hugenberg, Bernstein, & Sacco, 2012).

Growing evidence examining own-race face recognition suggests that the importance of two cues to facial identity—shape and texture—differs for learned vs. newly encountered faces. Shape cues refer to the shape as well as the size of the individual facial features, and their second-order configuration (e.g., interocular distance; Richler, Mack, Gauthier, & Palmeri, 2011). Texture cues represent the reflectance properties of faces, such as luminance, hue and saturation (e.g., Beale & Keil, 1995; Bruce et al., 1991; Kloth, Damm, Schweinberger, & Wiese, 2015; Itz, Schweinberger, & Kaufmann, 2016; Russell, Biederman, Nederhouser, & Sinha, 2007). Although the term texture is the commonly used in the field of psychology, the terms reflectance and albedo are used in the field of computer vision (O'toole, Vetter, & Blanz, 1999). All of these terms refer to the light-transfer function of the surface (Russell, Chatterjee, & Nakayama, 2012). While shape is particularly important for the initial encoding of unfamiliar own-race faces, texture information is more important for recognizing familiar/learned own-race faces (Burton, Schweinberger, Jenkins, & Kaufmann, 2015; Jenkins & Burton, 2008; but see Russell, Chatterjee, & Nakayama, 2012). In the current study, we examined to what extent the impairments in encoding and recognition of other- relative to own-race faces are attributable to the different utilization of shape and texture cues.

Two classic approaches have been taken to examine the contributions of shape and texture to face recognition: exaggerating these cues by selectively caricaturing shape or texture and selectively reducing these cues by replacing a face's shape or texture with an average shape or texture. Taking the first approach, several studies have provided evidence that shape cues are critical for encoding unfamiliar faces (i.e., for face learning) but less so for the recognition of familiar faces. For example, Schulz, Kaufmann, Kurt, & Schweinberger (2012) found an initial encoding advantage for unfamiliar faces with exaggerated idiosyncratic shape (also see Itz, Schweinberger, Schulz, & Kaufmann, 2014); participants learned veridical, spatially caricatured or anticaricatured faces and were asked to recognize these unfamiliar faces in a test phase. Spatial caricaturing and anticaricaturing exaggerated and diminished the metric differences between each individual face and a gender matched average face, while preserving the texture of original faces. Recognition accuracy was higher for shape caricatures than both veridicals and anticaricatures, a pattern observed in both hits and correct rejections. In line with this finding, Kaufmann and colleagues found that spatially caricatured faces elicited larger occipitotemporal N170, N250, and late-positive component (LPC; Kaufmann & Schweinberger, 2008; 2012) than veridical faces, an effect that is evident for unfamiliar but not for familiar faces. This suggests that shape caricaturing might facilitate the initial structural encoding and the activation of identity-specific semantic information for unfamiliar faces.

Whereas shape cues are critical for encoding novel faces, they become less reliable for the recognition of familiar faces. Representations of familiar faces are resistant to shape normalization (e.g., to a loss of identity-specific shape information; Burton, Jenkins, Hancock, & White, 2005) and spatial distortions such as stretching (Hole, George, Eaves, & Rasek, 2002), suggesting that alternative information— i.e. texture—plays a more important role for recognizing familiar (learned) faces (e.g., Itz, Golle, Luttmann, Schweinberger, & Kaufmann, 2017; Andrews, Baseler, Jenkins, Burton, & Young, 2016). Using the second approach, Russell and Sinha (2007) directly examined the effects of shape and texture cues in the recognition of personally familiar faces (e.g., personal friends). The presented faces were either shape-only faces, which contained the original shape but average texture, or texture-only faces, which contained the original texture but average shape. Participants showed better recognition of their friends' faces from texture (texture-only faces) than from shape information (shape-only faces). Such recognition impairments for familiar faces caused by the reduction of texture cues were also evident in undergraduates when recognizing their lecturers' faces (Kaufmann, Itz, & Schweinberger, 2016).

Using an old/new face recognition task, Itz et al. (2014) provided the first direct evidence of different utilization of shape and texture cues in the recognition of newly learned faces. Participants learned veridical, shape-caricatured (original texture) and texture-caricatured (original shape) unfamiliar faces; these learned faces were intermixed with novel faces in the test phase. Whereas recognition of learned faces benefited only from texture caricaturing, correct rejection of novel faces (a proxy for face encoding) tended to benefit more from shape than texture caricaturing. Notably, the relative use of shape and texture cues for familiar vs. unfamiliar faces is associated with individual differences in face recognition skills (Itz et al., 2017; Kaufmann, Schulz, & Schweinberger, 2013; but see Russell et al., 2012, in which individuals with prosopagnosia, super-recognizers, and control participants were tested). Specifically, individuals with above-average, compared to individuals with below-average, face recognition skills exhibit an even greater utilization of texture and an even smaller utilization of shape for identifying familiar and newly learned compared to unfamiliar faces (Itz et al., 2017; Kaufmann et al., 2013).

Here we hypothesized that the ORE may be attributable to adults relying on shape cues when recognizing learned other-race faces, a pattern comparable to individuals with poor recognition skills continuing to rely on shape (rather than texture) cues when recognizing learned own-race faces. In two experiments, participants were instructed to learn a series of Caucasian and East Asian faces followed by an old/new recognition task. In Experiment 1, taking the first approach, we selectively exaggerated the diagnostic information of both own- and other-race faces by caricaturing either their shape or texture properties. If the ORE is attributable to greater reliance on shape and reduced reliance on texture in the recognition of learned other-race faces, then participants should benefit more from texture than shape caricatures for learned own-race faces, but not for leaned other-race faces. In Experiment 2, taking the second approach, we selectively replaced the original shape or texture information of own- and other-race faces with the average shape or texture and examined whether eliminating idiosyncratic shape or texture information impairs learning and recognition of own- versus other-race faces. Participants learned veridical faces and the contribution of shape and texture to subsequent recognition was examined by showing texture-only, shape-only or the veridical versions of these faces at test. If the ORE is, at least partially, driven by the inefficient use of texture cues in the recognition of other-race faces, eliminating the texture cues (shape-only faces) would impair people's recognition of own-race faces to a greater extent than their recognition of other-race faces.

5.2 Experiment 1

5.2.1 Methods

5.2.1.1 Participants

Forty Caucasian adults (34 males, *M* age = 19.80, SD = 2.09, age range = 18-25) from Brock University participated in this experiment. All participants included in the final analyses reported little contact with other-race identities; all reported having fewer than two East Asian friends, and 18 (45%) of them reported having zero East Asian friends. An additional two participants were excluded from the final analysis because they reported significant experience with individuals of East Asian ethnicity. All participants gave written informed consent and received either research credit or a small honorarium for their participation. This study received clearance from the Research Ethics Board at Brock University.

5.2.1.2 Stimuli

Full-color Caucasian and East Asian faces (36 per race) showing neutral expressions were selected from the 3D face database at Brock University. Using the

DI3Dcapture^{TM} system (version 6.1.1; Dimensional Imaging, Glasgow, UK), each face had been captured by four 10-megapixel cameras and the four images of each face were then interpolated to create a three-dimensional object (.di3b; OBJ files).

We applied a similar method used by Itz et al. (2014) to create the shape and texture caricatures (SC, TC). First, the shape and the texture of each face were transferred onto standardized meshes containing 878 vertices using the shape and material transfer plugins in DI3Dview^{TM} (version 6.6.1; Dimensional Imaging, Glasgow, UK). During the shape transfer process, 152 reference points were placed on each face to allocate the facial shape to the correct positions on the standardized 3D mesh, which was then reshaped to the shape of the individual face. During the material transfer process, the texture information of each face was transferred to the shape mesh by allocating the four images from the cameras to the corresponding quadrant of the shape mesh. Using the Iterative Closest Point (ICP) alignment tool, all 3d faces (OBJ files) were then aligned according to a standardized mesh. Finally, using the morph plugin, shape or texture information of each face was caricatured relative to the gender- and race-matched average while holding the other dimension constant (e.g., shape morph with preserved texture), such that deviations of the veridical faces from the average were accentuated by 50% (see Figure 5.1). These steps resulted in a total of 216 morphed wavefront OBJ files (a veridical image, a shape caricature, and a texture caricature for each of 72 faces).

For each version (veridical, SC, TC) of each of the 72 faces we created six two-dimensional bitmap images in Photoshop (CS5, 12.0) that differed only in viewing angle: 10^{o} downward and full frontal; 10^{o} downward and 15^{o} to the left; 10^{o} downward and 15^{o} to the right; 10^{o} upward and full frontal; 10^{o} upward and 15^{o} to the left; 10^{o} upward and

15^o to the right. The six images for each identity were then categorized into two sets (set A and B); one set was presented in the learning phase and the other in the test phase (see Procedure section). Set A included 10^o downward, 10^o downward/15^o to the left, and 10^o upward/15^o to the right. Set B included 10^o upward, 10^o downward/ 15^o to the right, and 10^o upward/15^o to the left (see Figure 5.2). All faces were standardized at 640 by 640 pixels, and each face (22.58 by 22.58 cm) was displayed on a black background at an image resolution of 72 pixels/cm. Stimuli were presented with PsychoPy 1.8 (Peirce, 2007; 2009) in the center of a 15-inch color monitor with a black background and a viewing distance of approximately 100 cm (viewing angle of 12.88° by 12.88°).

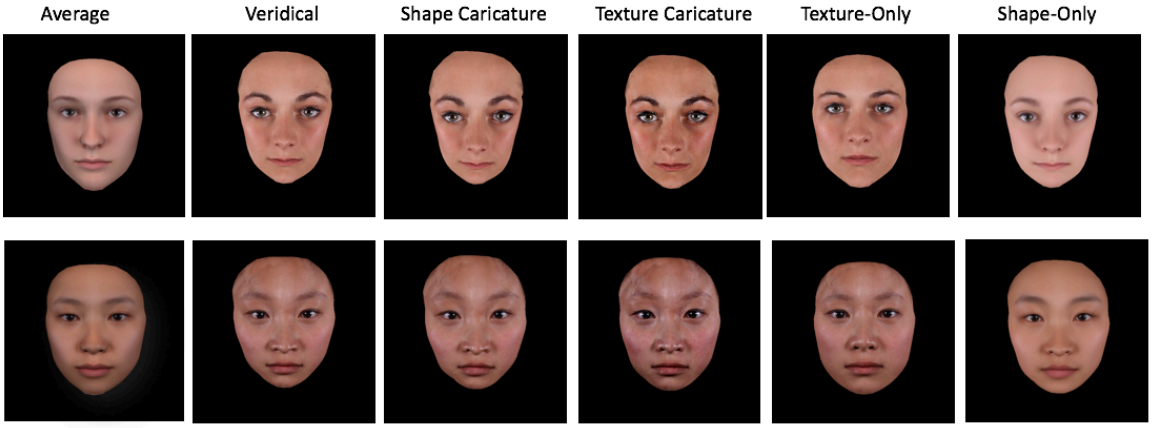

Figure 5.1. Examples of shape caricatured and texture caricatured own- and other-race faces (Experiment 1); and own- and other-race text-only and shape-only faces (Experiment 2).

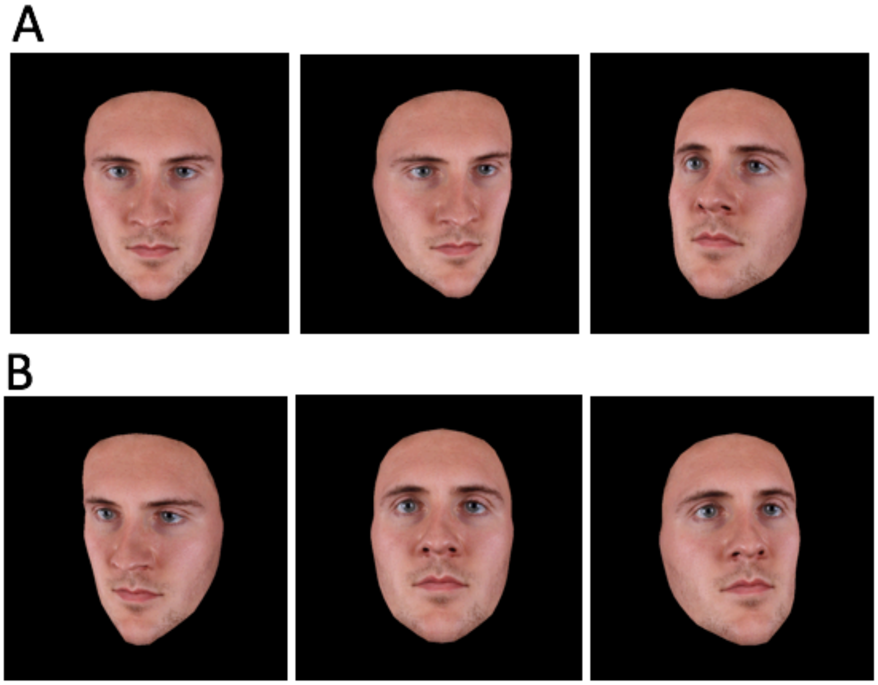

Figure 5.2. Examples of different viewing angles for the same veridical male face. Set A included 10° downward, 10° downward/15° to the left, and 10° upward/15° to the right. Set B included 10° upward, 10° downward/ 15° to the right, and 10° upward/15° to the left.

5.2.1.3 Procedure

Each participant completed a one-hour session, comprising four practice trials (two per race) followed by 216 test trials (108 per race). Both practice and test trials contained a learning phase and a recognition phase. The race of the faces was blocked, such that half of the participants were presented with Caucasian faces first and the other half with East Asian faces first.

In the learning phase, participants were instructed to learn 18 faces; six were veridicals (VR), six were shape caricatures (SC) and the other six were texture caricatures (TC). Each face was learned from three different viewing angles (either from Set A or Set B) and each set of viewing angle was presented twice. Thus, each learning trial comprised successive presentations of three images of a single face; each image was shown for 2 s, with an inter-stimulus interval (ISI) of 0.5 s. Each 3-image chain was shown twice. Both the order of face identities and the order of images for a given face identity were randomized for each participant, with the constraint that the six images of the same face identity were never shown in direct succession. To encourage participants to form a unified representation of each face based on the 3-image chain, the interval between the offset of the last image of one face and the onset of the first image of the next face was 1.2 s, rather than the within-face ISI of 0.5 s.

After participants had completed the learning phase, they were instructed to perform an old/new face recognition task. In this task, participants were presented with the 18 learned faces intermixed with 18 novel faces. Each learned face was presented in the format in which it had been learned (VR, TC, SC) and each novel face was assigned to one of the three formats (six faces per format) so as to equate the number of learned vs.

novel faces in each of the three formats. Each face was presented from three viewing angles (but not in direct succession), with learned faces shown from different viewing angles than those used in the test phase (e.g., if Set A had been shown during learning, Set B was shown in the test phase). The order in which images were presented was randomized for each participant, ensuring no successive repetitions of the same face. Participants indicated whether each face had been learned (seen in the learning phase) or was novel, by pressing one of two keys ("Z" for learned; and "M" for novel faces) on a standard North American computer keyboard. Each recognition trial began with a fixation cross, presented in the center of the screen for 0.5 s, followed by a face image for 1.5 s and a blank screen for 1.2 s. Participants were instructed to respond as quickly as possible without making mistakes; an error sound played if they failed to respond within 1.5 s, indicating that they needed to respond faster.

5.2.2 Results

Where appropriate, we performed Epsilon correction for heterogeneity of covariances throughout (Huynh & Feldt, 1976). In the case of the three post-hoc comparisons (paired samples t-tests), the significance level was Bonferroni-adjusted to $\alpha = .017$ (Abdi, 2007). Because we were specifically interested in the differential contribution of shape and texture cues to encoding new faces (reflected in correct rejections) vs. recognizing learned faces (reflected in hits), d' (a measure of overall accuracy) was not of interest. Instead, we analyzed hits and correct rejections separately.

Accuracy. To examine whether shape and texture information are utilized differently for own- and other-race faces in face learning and recognition, we conducted a 2 (face race: Caucasian vs. East Asian faces) × 2 (familiarity: learned vs. novel) × 3 (caricature type: VR vs. SC vs. TC) repeated-measures ANOVA with proportion correct as the dependent variable. Mauchly's Tests of Sphericity indicated that the assumption of sphericity had not been violated, *ps* > .159.

We found significant main effects of face race, $F(1, 39) = 18.16$, $p < .001$, $\eta_p^2 = .32$ and caricature type, $F(2, 78) = 20.80$, $p < .001$, $\eta_p^2 = .35$. Accuracy was higher for own- ($M = 0.73$, $SE = 0.01$) than for other-race faces ($M = 0.67$, $SE = 0.01$). Paired sample t-tests confirmed that accuracy was lower for veridical faces ($M = 0.64$, $SE = 0.02$) than for both shape ($M = 0.72$, $SE = 0.01$) and texture caricatures ($M = 0.73$, $SE = 0.01$), *ps* < .001, with no difference between the two caricature types, $p = .720$. In addition, we found a significant interaction between caricature type and familiarity, $F(2, 78) = 3.81$, $p = .026$, $\eta_p^2 = .09$. Separate one-way repeated measures ANOVAs were conducted for learned and novel faces collapsed across face race. Accuracy varied across caricature type for novel faces, $F(2, 78) = 13.29$, $p < .001$, $\eta_p^2 = 0.25$. Accuracy was greatest for SC ($M = 0.77$, $SE = 0.02$), followed by TC ($M = 0.73$, $SE = 0.02$) and then VR faces ($M = 0.67$, $SE = 0.03$); all paired-sample t-tests were significant, *p*s < .04. Accuracy also varied across caricature type for learned faces, $F(2, 78) = 9.13$, $p < .001$, $\eta_p^2 = 0.19$. In contrast to novel faces, accuracy was higher for TC ($M = 0.73$, $SE = 0.02$) than for both SC ($M = 0.68$, $SE = 0.02$) and VR faces ($M = 0.62$, $SE = 0.03$; *p*s < .021), with no significant difference between the SC and VR faces, $p = .065$. Notably, the three-way caricature type x familiarity x face race interaction was not significant, $F(2, 78) = 0.50$, $p = .615$, $\eta_p^2 = .01$; thus, the interaction of caricature type and familiarity was independent of face race (see Figure 5.3).

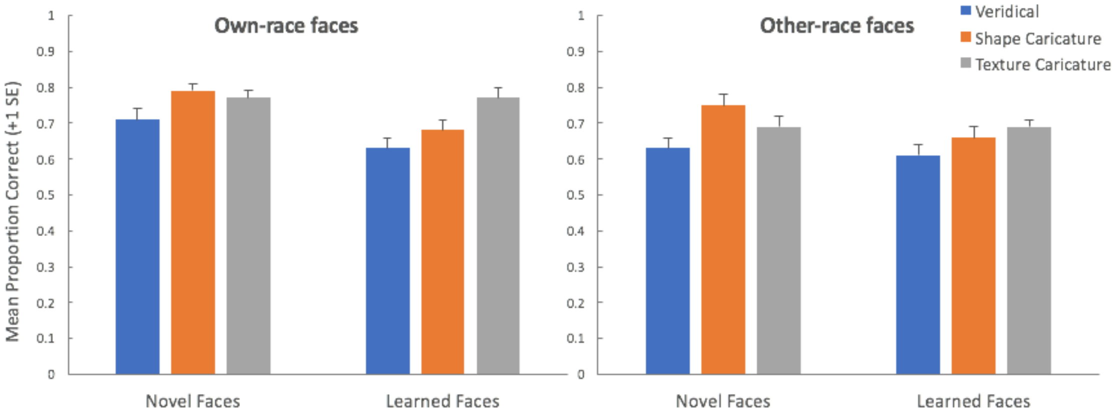

Figure 5.3. Accuracy for novel and learned own-race faces (left) and other-race faces (right) in each face type condition.

RT. The 2 (face race) × 2 (familiarity) × 3 (caricature type) repeated measures ANOVA for mean reaction times for correct responses revealed significant main effects of familiarity, *F*(1, 70) = 5.88, $p = .021$, $\eta_p^2 = .14$, and caricature type, *F*(2, 70) = 3.43, $p = .043$, $\eta_p^2 = .09$. Response times were faster for learned (*M* = 793ms, *SE* = 16) than for novel faces (*M* = 823ms, *SE* = 16; $p = .021$). Response times were slower for VR faces (*M* = 820ms, *SE* = 15) than both TC (*M* = 805ms, *SE* = 15) and SC faces (*M* = 798ms, *SE* = 16), *p*s < .044, with no significant difference between TC and SC faces, $p = .414$. This pattern confirms that the impact of shape and texture caricatures on accuracy cannot be attributed to speed/accuracy tradeoffs.

5.2.3 Discussion

In Experiment 1, we examined whether selectively caricaturing shape or texture cues to facial identity differentially impacts perceivers' encoding of newly encountered own- vs. other-race faces and their recognition of learned faces from these two categories. Our study was guided by evidence that the impaired recognition of own-race faces is associated with a failure in the transition from shape to texture cues (Kaufmann et al., 2013). We proposed that the ORE might be driven by a similar failure when recognizing other-race faces. We replicated Itz et al.'s (2014) finding that, relative to veridical faces, the correct rejection of novel faces benefits from both shape and texture caricatures. In addition, whereas Itz et al. (2014) only reported a numerically greater benefit from shape than texture cues that failed to reach conventional levels of statistical significance, in the present study we observed significantly greater benefits from shape than texture cues. This advantage for shape caricatures was absent in the recognition of learned faces; relative to veridical faces, accuracy for learned faces was higher only for texture caricatures. In contrast to our hypothesis, however, we observed a comparable transition from shape to texture cues for own- and other-race faces, despite an overall other-race effect.

Our results suggest that different mechanisms underlie individual differences in recognizing own-race faces on the one hand, and differences in the accuracy with which own- vs. other-race faces are recognized on the other hand; only the former is associated with a failure to rely on texture in lieu of shape when recognizing learned faces. Prior to drawing strong conclusions, we aimed to replicate this finding using a different approach in Experiment 2.

5.3 Experiment 2

Experiment 2 was designed to provide converging evidence that the ORE is not attributable to the different utilization of shape and texture cues during the learning of own- vs. other-race faces. Participants learned veridical faces during the study phase; in the test phase we selectively eliminated shape or texture information by replacing original shape with average shape (texture-only faces) or original texture with average texture (shape-only faces). To ensure faces were learned during the study phase, we asked participants to learn only six (rather than 18) faces per block. Furthermore, we provided semantic information for each face (each face was assigned an occupation) during learning and verified that participants had learned the occupation associated with each face prior to the test phase. We provided semantic labels to maximize learning of all faces. Of interest, such labeling has been reported to be instrumental for the fast development of categorical perception effects (a proxy for robust perceptual representations) for unfamiliar faces (Kikutani, Roberson, & Hanley, 2010).

Consistent with evidence that recognition of personally familiar faces is especially impaired by the removal of texture information (shape-only faces; Itz et al., 2017; Russell & Sinha, 2007; Kaufmann, Itz, & Schweinberger, 2016) and based on the results of Experiment 1, we hypothesized that recognition of learned faces would be especially impaired for shape-only faces. Based on the results of Experiment 1, we hypothesized that correct rejection of novel faces would be impaired for both shape- and texture-only faces with greater impairment for texture-only faces. Most importantly, we hypothesized that the pattern of effects would be comparable for own- and other-race faces.

5.3.1 Method

5.3.1.1 Participants

Twenty-four Caucasian adults (21 females, *M* age = 19.50, *SD* = 1.91, age range = 17-24) from Brock University participated in this experiment. All participants included in the final analyses reported little contact with other-race identities (i.e., all reported having no more than two East Asian friends).

5.3.1.2 Stimuli

The 72 face identities used in Experiment 1 were also used here. In contrast to Experiment 1, new versions of each face were created by replacing the original shape or texture information with the average shape or texture information using the morph plugin in DI3Dview^{TM} (version 6.6.1; Dimensional Imaging, Glasgow, UK). For each face, the shape-only version (i.e., SP-only faces) contained the shape information of the veridical face, while the texture information was fully replaced by the texture information of the gender- and race-matched average. Likewise, the texture-only version (i.e., TX-only faces) contained the texture information of the veridical face, while the shape information was fully replaced by the shape information of the gender- and race-matched average (see Figure 5.1).

5.3.1.3 Procedure

This study received clearance from the Research Ethics Board at Brock University. Each participant completed a 1-hour session, comprising three blocks of trials for both own- and other-race faces. Six identities were introduced in each block; half of the participants completed the three own-race blocks first and half completed the three other-race blocks first.

Each block of trials began with a learning phase, during which participants learned six veridical faces, each of which was associated with one of six possible occupations (e.g., lawyer, physician). Each identity was assigned a unique occupation (see Appendix A for our occupation list) with different occupations used across blocks; the assignment of occupation to each face was randomized for each participant. The occupation was presented for 2s followed by three images of the face; each image was shown for 2s with an ISI of 0.5s. As in Experiment 1, the three images differed in viewing angle (Set A or Set B), the order of images within identities and the order of identities were randomized for each participant, each occupation and 3-image chain was shown twice, ensuring that the same chain was not shown in succession, and the interval between identities was set as 1.2 s.

To confirm that participants had learned each face, the learning phase was followed by a verification task in which participants were presented with a single image of each learned face along with a list of three of the six occupations from that block. Participants were asked to indicate which occupation matched the presented face.

Participants were given unlimited time to make responses in this task. If participants failed to correctly identify all six occupations, they were shown the entire set of learning stimuli again, with each three-image chain presented only once. All participants successfully completed this task within 10 attempts.

After successfully completing the verification task, participants completed an old/new recognition task identical to that in Experiment 1. Each of the six learned faces was presented from three novel viewpoints in one of three formats: VR (i.e. veridical), SP-only, TX-only (two faces per format); the format assigned to each face varied randomly across participants. The six learned faces were intermixed with three images (Set A or Set B) of six novel faces (two faces per format). This sequence of learning, verification, and test phases were completed six times (three times for each face race) by each participant.

5.3.2 Results

There was an own-race advantage during the learning phase. In the verification task, participants needed significantly more attempts for other- ($M = 2.50$, $SE = 0.55$) than own-race faces ($M = 1.29$, $SE = 0.32$), $t = 2.32$, $p = .030$, Cohen's $d = 0.55$.

For the test phase, a 2 (face race: Caucasian vs. East Asian faces) × 2 (familiarity: learned vs. novel) × 3 (face type: VR vs. SP-only vs. TX-only) repeated-measures ANOVA was conducted, with proportion correct as the dependent variable. There were significant main effects of face race, $F(1, 23) = 5.22$, $p = .032$, $\eta_p^2 = .19$, familiarity, $F(1, 23) = 31.23$, $p < .001$, $\eta_p^2 = .58$, and face type, $F(2, 23) = 99.82$, $p < .001$, $\eta_p^2 = .81$. As in the verification task, participants were more accurate for own- ($M = 0.72$, $SE = 0.01$) than other-race faces ($M = 0.68$, $SE = 0.02$; $p = .032$). The face race x familiarity interaction was not significant, $F(2, 46) = 0.44$, $p = .516$, $\eta_p^2 = .02$, suggesting similar own-race benefits both for encoding novel faces and recognizing learned faces. The main effect of familiarity reflects that participants were more accurate when detecting that a face was novel than when recognizing a learned face, as reflected in their showing a higher proportion of correct rejections ($M = 0.81$, $SE = 0.03$) compared to hits ($M = 0.59$, $SE = 0.02$; $p < .001$). Paired samples t-tests (with alpha level adjusted as in Experiment 1) investigating the effect of face type confirmed that accuracy was greatest for VR faces ($M = 0.85$, $SE = 0.02$), followed by TX-only faces ($M = 0.70$, $SE = 0.02$) and then SP-only faces ($M = 0.55$, $SE = 0.01$); all pairwise comparisons were significant, ps < .001.

Notably, we found a significant interaction between familiarity and face type, $F(2, 46) = 66.68$, $p < .001$, $\eta_p^2 = .74$. A one-way ANOVA showed a significant effect of face type for novel faces, $F(2, 46) = 18.23$, $p < .001$, $\eta_p^2 = 0.44$. Accuracy was comparable for VR ($M = 0.84$, $SE = 0.03$) and SP-only faces ($M = 0.90$, $SE = 0.03$), $p = .078$, and higher for both of these than for TX-only faces ($M = 0.69$, $SE = 0.04$), ps < .001. A one-way ANOVA also showed a significant effect of face type for learned faces, $F(2, 48) = 108.93$, $p < .001$, $\eta_p^2 = 0.83$. In contrast to the pattern observed for novel faces, accuracy was greatest for VR faces ($M = 0.86$, $SE = 0.03$) followed by TX-only faces ($M = 0.70$, $SE = 0.03$) and then SP-only faces ($M = 0.21$, $SE = 0.04$). All pairwise comparisons were significant, ps < .001. Critically, the three-way face type by familiarity by face race interaction was not significant, $F(2, 46) = 0.62$, $p = .545$, $\eta_p^2 = .03$, suggesting that the interaction of face type and familiarity was independent of face race (see Figure 5.4).

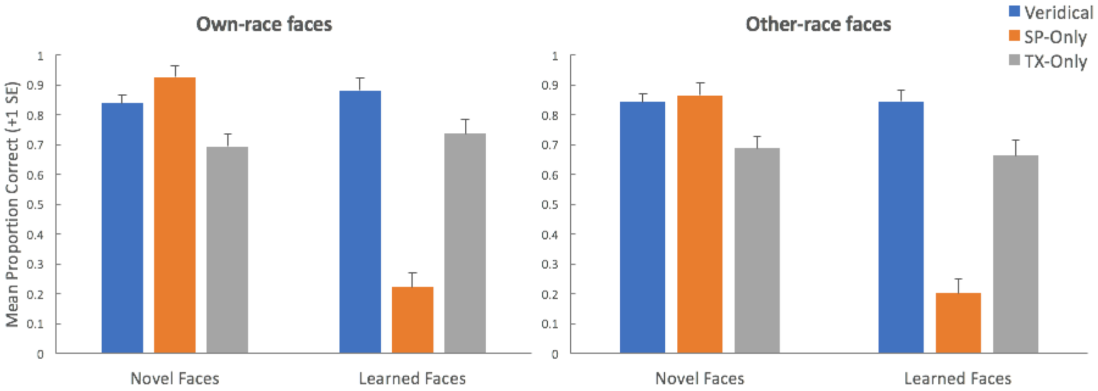

Figure 5.4. Accuracy for novel and learned own-race faces (left) and other-race faces (right) in each face type condition.

5.3.3 Discussion

Experiment 2 replicated the pattern of results from Experiment 1, using a different approach: Manipulating shape and texture cues had a comparable effect on encoding and recognition of own- and other-race faces. Relative to veridical faces, encoding of novel faces (correct rejections) was impaired by selectively eliminating shape information (texture-only faces). This is in line with the results from Experiment 1, in which caricaturing shape provided a larger benefit than caricaturing texture when novel faces were presented in the test phase. In turn, recognition of learned faces (hits) was impaired by selectively decreasing both texture (shape-only faces) and shape (texture-only faces) information, however with much larger impairments for shape-only faces which appeared to be extremely difficult to recognize in the absence of idiosyncratic texture information (Figure. 5.4). Again, this result is well in line with the findings from Experiment 1 in which recognition of learned faces only benefitted from texture caricatures. Importantly these patterns were observed for both own- and other-race faces. It is important to note that the comparable use of shape vs. texture cues for own- and other-race faces was observed in the context of an overall own-race advantage. In Experiment 2, participants learned own-race faces in fewer attempts than other-race faces and in both experiments they were more accurate for own- than other-race faces in the test phase. These experiments provide converging evidence that the ORE is not attributable to different utilization of shape and texture cues during the learning of own- vs. other-race faces.

5.4 General Discussion

The aim of this study was to investigate whether impairments in the encoding and recognition of other-race faces relative to own-race faces are attributable to differential utilization of shape and texture cues. Taking two approaches, and consistent with previous studies (Itz et al., 2014; Kaufmann et al., 2013), we showed that whereas shape cues are critical for the encoding of novel faces, texture cues become more important for the recognition of learned faces. Notably, despite an overall ORE, the shift from shape to texture dominance during face learning was comparable for own- and other-race faces, suggesting the different utilization of shape and texture cues in face learning does not contribute to the ORE. This conclusion is consistent with suggestions that early perceptual mechanisms of face processing are qualitatively similar for own- and other-race faces, and just work less efficiently for other-race faces (e.g., Wiese, Stahl, & Schweinberger, 2009). Importantly, in our study, faces were learned from three different viewing angles and then presented at three novel viewing angles at test; therefore, it is unlikely that differences in performance associated with changes in shape and texture cues are based on image recognition.

Encoding Novel Faces

The correct rejection of novel own- and other-race faces benefitted from shape caricatures (Experiment 1) and was impaired by the reduction of shape cues (Experiment 2). Like Itz et al. (2014), we also found an encoding advantage for faces with exaggerated texture cues in Experiment 1. However, the benefit of caricaturing texture was less than that of caricaturing shape, and in Experiment 2 decreasing texture did not impair the encoding of novel faces. Spatial caricaturing exaggerates the spatial relations between an individual and an average face, thus enhancing the perceived distinctiveness of faces as well as the analysis of second-order configuration (Benson & Perrett, 1991; Perkins, 1975; Stevenage, 1995; Valentine, 1991). The observed encoding advantages for shape caricatures for own- and other-race faces are in line with recent studies using photorealistic faces to examine own-race face recognition (Kaufmann et al., 2013; Itz et al., 2014) as well as early studies using line drawings to examine other-race face recognition (Byatt & Rhodes, 1998; 2004). Using photorealistic faces, our study demonstrates that both shape and texture cues are important in the encoding of novel own- and other-race faces, with shape cues playing the more critical role for both face categories.

Recognizing learned faces

Consistent with previous studies using both personally familiar and newly learned faces (Itz et al., 2014; Kaufmann, Itz, & Schweinberger, 2016; Russell et al., 2007), we found that recognition of learned faces benefits from exaggerated texture cues (Experiment 1) and in turn is dramatically impaired by the elimination of texture cues (Experiment 2). Most importantly, despite being generally less accurate in the recognition of learned other- than own-race faces, perceivers relied less on shape and more on texture for learned faces from both face categories. These results suggest that once a face is learned, regardless of the race, idiosyncratic shape cues play little or no role in recognition; rather, texture cues are critical.

Successful recognition of these familiar faces is thought to depend on perceivers' sensitivity to texture cues because shape cues vary widely across different images of the same identity (e.g., as head orientation and facial expression change), and thus are less reliable cues to identity (Burton, 2013). This is directly supported by the evidence that familiar own-race face recognition is intact despite spatial distortions (Hole, George, Eaves, & Rasek, 2002) and despite the removal of idiosyncratic shape properties. In that sense, the present findings align well with other results in challenging the idea that familiar face recognition is based on precise spatial information in faces (Burton et al., 2015). Reliance on texture cues to recognize familiar own- and other-race faces is in line with recent evidence that highly familiar other-race faces are recognized despite variability in appearance across images (Zhou & Mondloch, 2016). The importance of using texture cues in the recognition of both familiar own- and other-race faces was hinted at by Russel and Sinha (2007). They found an accurate recognition of personally familiar faces when only texture cues were available (i.e., after the removal of original shape cues), a pattern seen for both own- and other-race faces (Russel & Sinha, 2007). Our study provides direct evidence that in the process of becoming familiar with a newly encountered face, idiosyncratic texture cues are used in a comparable way for own- and other-race faces.

Mechanisms Underlying the Other-Race Effect

Our finding of a comparable transition from shape to texture cues in the learning of own- and other-race faces raises an important question: what drives the ORE? Both perceptual expertise and social motivation likely contribute to the ORE and our focus is on the role of perceptual expertise; we do not address the relative contributions of these two factors (for an excellent recent study of this issue, see Wan, Crookes, Reynolds, Irons, & McKone, 2015). One possibility is that despite relying on shape and texture information in similar ways for own- and other-race faces during encoding and recognition, adults' quantitative sensitivity to these cues is reduced for other-race faces. Indeed, considerable research examining the ORE has been taken to support this hypothesis that the ORE is partially driven by reduced sensitivity to identity information in other-race faces. For example, in the scrambled/blurred task, after studying a set of faces, when asked to make old/new judgments about scrambled (configural information eliminated) and blurred (featural information reduced) images, accuracy is higher for own- than for other-race faces, suggesting reduced sensitivity to the facial features and their second-order relations in other- than own-race faces (e.g., Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010; Rhodes et al., 2009). Reduced sensitivity to shape cues in other-race faces is evident even when memory demands are minimized by having participants make same/different judgements about pairs of faces that differ in the shape of features or the spacing among them (Mondloch et al., 2010). This insensitivity to shape-related properties likely underlies less efficient learning of other-race faces than own-race faces in Experiment 2 of the current study (i.e., our finding that participants needed more attempts to reach learning criterion for other-race faces than own-race faces in the occupation verification task).

The reduced sensitivity to facial cues is also consistent with recent evidence that the representation of other-race faces in multi-dimensional face space is less well refined than that of own-race faces (Zhou, Short, Chan, & Mondloch, 2016). According to Valentine’s influential multi-dimensional face space model (MDFS), faces are represented as points in a multidimensional face space. The location of each face is determined by its values on the dimensions along which faces can vary (including differences in shape and texture). The dimensions of face space are refined through experience to maximally differentiate faces from categories with which the perceiver has maximal experience—typically upright, own-race faces (Valentine, 1991). Limited perceptual experience with other-race faces makes them relatively densely clustered in the periphery of face space, leading to impaired discrimination and recognition—a hypothesis that is supported by recent evidence that adults are more sensitive to deviations from normality in own- than other-race faces (Zhou, Short, Chan, & Mondloch, 2016). Taken in the context of the current study, we conclude that the ORE is driven by reduced sensitivity to both shape and texture cues, but not differential reliance on these cues when encoding novel faces or when recognizing familiar faces.

Limitations and Future Directions

Of necessity, we used only a single level (50%) of caricaturing shape and texture cues. Future research should directly examine our hypothesis that differences in sensitivity to shape and texture cues drive the ORE by systematically varying caricature levels (e.g., 15%, 30%, 45%, 60%). In conjunction with our current findings, higher threshold sensitivity to shape and texture changes in other-race compared to own-race faces would suggest that the ORE reflects quantitative, rather than qualitative, differences in perception.

In addition, several lines of evidence have indicated that the use of shape and texture cues modulates brain responses associated with own-race face recognition. Understanding commonalities and differences underlying own- and other-race face learning would be enhanced by including measures of underlying neural mechanisms. Itz and colleagues found that benefits from texture cues for learned faces are associated with an enhanced posterior N250, a component that has been related to the activation of stored representations of faces (Itz et al., 2014). In addition, the preceding occipito-temporal P200 component appears to be selectively sensitive to idiosyncratic shape information relative to a prototypical average face (Kloth, Rhodes, & Schweinberger, 2017; Schulz, Kaufmann, Walther, & Schweinberger, 2012). Using fMRI, Andrews et al. (2016) found that face-selective regions, such as the FFA, showed an equal sensitivity to shape and texture properties in the recognition of familiar own-race faces. However, we are unaware of psychophysiological and neuroimaging studies investigating the role of shape and texture information for the ORE. It therefore remains for future studies to examine not only the time-course and anatomical basis of processing own- vs. other-race faces, but also how this is associated with the use of shape and texture properties.

Conclusion

In conclusion, taking different approaches, we found that participants showed comparable transition from shape to texture dominance in the learning of own- and other-race faces. The current study extends our prior understanding of the mechanism underlying the ORE. We reported here for the first time that although other-race faces are learned less efficiently relative to own-race faces, the shift from shape to texture cues is comparable, suggesting that the ORE cannot be attributed to the different utilization of shape and texture cues during face learning.

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CHAPTER 6

Study 5: Encoding Differences Affect the Number and Precision of Own- vs. Other-Race Faces Stored in Visual Working Memory

6.1 Introduction

Faces convey abundant visual information including static identity characteristics (e.g., age, sex, ethnicity, and attractiveness), as well as dynamic cues (e.g., facial expressions, eye gaze). Despite our exceptional ability to rapidly process complex visual information from faces and to use this information effectively during social interactions, humans' expertise in face processing is limited to those face categories with which we have abundant perceptual experience (e.g., own-race faces). Across a broad range of research paradigms investigating face recognition, there is a robust other-race effect (ORE), defined here as inferior performance when identifying faces of a different race than faces of the same race as the perceiver (see Bothwell, Brigham, & Malpass, 1989; Meissner & Brigham, 2001, for reviews). The ORE is one of the primary causes for false conviction based on erroneous eyewitness testimony (Behrman & Davey, 2001; Hugenberg, Young, Bernstein, & Sacco, 2010; Scheck, Neufeld, & Dwyer, 2003; Sporer, 2001). Understanding the mechanisms of the ORE, therefore, has profound implications both for models of face recognition and for applied settings.

In numerous studies examining face recognition, participants have been presented with own- and other-race faces during a study phase and then asked to recognize those faces when they are intermixed with novel identities (the old/new face recognition task). A ubiquitous finding is that participants consistently make more false alarms (incorrectly identifying an unseen face as familiar) and fewer hits (correctly identifying a previously seen face as familiar) for other-race compared to own-race faces, reflecting impairments in the encoding, storage and/or retrieval of other-race face representations from memory (Meissner & Brigham, 2001; Young, Hugenberg, Bernstein, & Sacco, 2012). A similar own-race advantage is found when learning is more extensive (e.g., Cambridge Face Memory Test, in which faces were learned from multiple angles; McKone et al., 2012); and when memory demands are minimized by asking participants to make same/different judgments for pairs of faces that differ only in feature shape or spacing (e.g., Hayward, Rhodes, & Schwaninger, 2008; Mondloch et al., 2010).

While the ORE is known to be robust, traditional measures only provide a single binary measure of perceivers' memory performance; each response is scored as being either correct or incorrect, failing to capture potential variability in the quality of the representation. The assumption that the representation of any given face stored in memory is a perfect representation is theoretically untenable and has recently been challenged by studies examining the precision with which basic visual features (colors, orientations) are stored in visual working memory (VWM; Bays, Catalao, & Husain, 2009; Wilken & Ma, 2004; Zhang & Luck, 2008;) as well as long-term memory (LTM; Brady, Konkle, Gill, Oliva, & Alvarez, 2013; also see Luck & Vogel, 2013 for a review).

A recent and more refined approach, the continuous response paradigm, provides a more sensitive index of the structure of memory (and perceptual) representations (Bays, Catalao, & Husain, 2009, Bays & Husain, 2008; Brady, Konkle, & Alvarez, 2011; Heyes, Zokaei, & Husain, 2016; Sarigiannidis, Crickmore, & Astle, 2016). In the continuous response paradigm, participants are asked to recall and report the remembered target, which is presented in an array of stimuli that vary along a continuous feature dimension (e.g. color, orientation). Response error is evaluated by calculating the angular deviation between the target item and the item reported by the participant. Statistical mixture modeling allows one to measure three sources of overall error (Bays, Catalao, & Husain, 2009; Bays & Husain, 2008; Brady, Konkle, Gill, Oliva, & Alvarez, 2013): a) failure in encoding or retrieving the target item, leading to a random response (i.e., guessing); b) variability/ noisiness of the stored representation, leading to decreased precision when the target is recalled; and c) representation of the target item being interrupted by a non-target item, which leads to a swap error (i.e., recalling the non-target instead of the target). This methodological combination of continuous recall and mixture modeling could therefore provide a more refined examination of the nature of own- and other-race face representations, and the types of errors that lead to recognition impairments for other-race faces.

Although the continuous response paradigm has been widely used in studies examining VWM for basic features (e.g., hue, line orientation), its use with more complex stimuli is limited. Lorenc et al. (2014) investigated the role of perceptual experience in encoding and storing face representation in VWM by contrasting VWM for upright vs. inverted faces. They reported a significant loss of precision for inverted, relative to upright, faces with no difference in the guess rate. Given that the fidelity of representations in LTM is constrained by those in VWM (Brady, Konkle, Gill, Oliva, & Alvarez, 2013), this finding suggests that the difference in recognition performance between upright and inverted faces could be attributed to the effect of visual experience on the fidelity of face representations encoded in VWM. What effect visual experience has on the fidelity of own- compared to other-race faces remains unknown.

Here we provide the first examination of the extent to which the ORE is attributable to a failure to encode and retrieve other-race faces from memory vs. a loss of precision in the representations of other-race faces. To examine this question we used the continuous response paradigm in which participants were asked to maintain own- or other-race faces in VWM, and to report a target face on a unique circular face space that smoothly varied along the dimension of identity (see Figure 6.1). The angular deviation between the target face and the face selected by the participant provides a more sensitive measure of face memory than can be obtained through traditional face recognition paradigms as it captures continuous variability in face representations.

In two experiments we examined the nature of the representations of own- and other-race faces that are stored in VWM. In Experiment 1 we presented two faces on each trial, one of which was then cued for recall. By applying mixture modeling to the raw error, we differentiated three potential sources of error that contribute to the ORE: random guesses, swap errors and lack of the precision for the remembered face. In Experiment 2 we presented only one face but varied presentation time. Applying mixture modeling here allowed us to examine whether reducing presentation time especially impaired VWM for other-race faces.

6.2 Experiment 1: Storing two faces with ample encoding time

6.2.1 Methods and materials

6.2.1.1 Participants

Fifteen Caucasian adults (1 male, ages 19-30 years, *SE* =0.68) from Brock University participated in the study and were included in the final analysis, a sample size comparable to that in other studies using the continuous response paradigm.

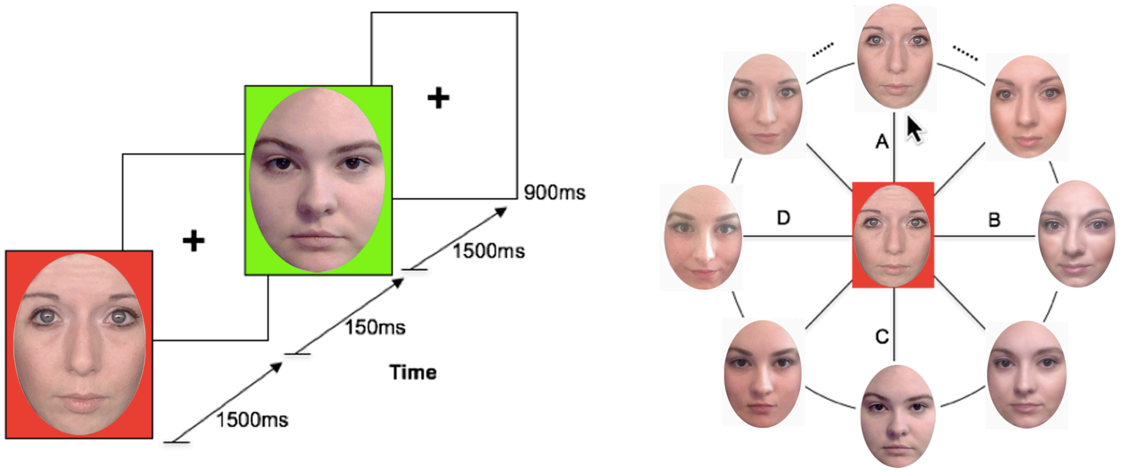

Figure 6.1. A schematic of the continuous response task used in the first experiment. On each trial, participants were presented with two study faces for 1500ms, each of which was paired with a cue color. Following the 900ms delay, participants were presented with eight faces made of up morphs from four identities. Participants were instructed to report as accurately as possible the identity of the cued (e.g., red) target face. When participants moved the mouse along the face wheel, the face in the center changed simultaneously to indicate the face that they were reporting, which changed continuously between the displayed anchor faces. Note. Permissions preclude showing the faces used in the actual study; faces in the figure are for demonstration only.

All participants were from Brock University, reported minimal contact with other-race identities and verbally confirmed normal or corrected-to-normal vision. An additional seven participants were excluded from the final analysis because they reported extensive contact with Asian identities (n=1) or had extremely poor performance (n=6, i.e., guess rate exceeded 2.5 sd of the mean). All participants provided written informed consent and received either research credit or a small honorarium for their participation. This study received clearance from the Research Ethics Board at Brock University.

6.2.1.2 Stimuli

Four Caucasian and four East Asian faces were acquired from the *Let's Face It* database at Brock University. All faces were female, physically similar, displayed in full-front view and unfamiliar to the participants. Each identity was paired with each of the other same-race identities to create six pairings. We then used a linear morphing procedure to create 19 morphed faces for each pairing by blending the two faces in 5% steps (e.g., 95/5, 90/10, … , 5/95). Nineteen morphs across six face pairs for each of the two race categories resulted in a total of 236 faces (228 morphs; eight originals) that were used in the experiment.

A unique circular face space comprised of Caucasian or East Asian faces, analogous to a colour wheel, was created on each trial by randomly placing the four original (anchor) faces with equal distances between them. Based on their relative location, morphed faces were then placed among the anchor faces, such that identity varied continuously around the wheel. Thus, in the 360° circular face space, 80 faces (four anchors; 76 morphs) were evenly distributed, making the difference between any two neighboring faces equivalent to 4.5°. All faces were standardized at 395 by 510 pixels and were presented on a 19-inch computer monitor with the viewing distance approximately 60 cm. Stimuli were presented and participants' response were collected using PsychoPy1.8 (Peirce, 2007; 2009)

6.2.1.3 Procedure

Each participant completed a 1-hour session, comprising eight practice trials (four/race) followed by 240 test trials. The race of face was blocked such that half of the participants were presented with Caucasian faces first and the other half with East Asian faces first.

Each trial began with a sequential presentation of two faces (e.g., 90%A-10%B; 55%C/45%D) that were chosen randomly from the face space (could be anchor or morphed faces), followed by a delay period of 900ms, and then a face wheel (see Figure 6.1). The two faces were cued by different colors (red or green) and were presented sequentially for 1500ms each with a 150ms interstimulus interval. A 1500ms presentation time ensures full encoding of each face in VWM (Lorenc et al., 2014). One of the two faces was randomly assigned as the target face and the other as the non-target face. Participants were unaware of which face was the target and were instructed to memorize both of them. After the 900ms delay, a red or green rectangle appeared in the center of the screen indicating which face was the target. Eight randomly chosen and equidistant faces from the face wheel were presented around the central target item at equal intervals. Participants were instructed to locate the target face by using a computer mouse to select a point on the face wheel. While they moved the mouse along the face wheel, the face in the center changed simultaneously to indicate the face they were selecting. Like the composition of the face wheel, the color (red/green) and the position (first/second) of the target were randomized across trials. Participants proceeded at their own pace and were asked to be as accurate as possible in their decision.

6.2.1.4 Data analysis

Overall response error. Response error was calculated for each trial as the angular deviation (in degrees; -180° to 180°) between the correct orientation of the target face and the orientation of the face reported by the participant. To obtain a generic measure of the overall precision of response, we calculated the reciprocals of the standard deviation (1/*SD*) of response error across trials separately for own- and other-race faces.

Model fitting for own- and other-race faces. To further identify the sources of increased response error for other-race faces, we fit a three-component model to each participant dataset for own- and other-race faces. The three-component model is described by the following equation (Bays et al., 2009; 2011):

$$p(\hat{\theta}) = \alpha\phi_{\kappa}(\hat{\theta} - \theta) + \beta\frac{1}{m}\sum_{i}^{m}\phi_{\kappa}(\hat{\theta} - \varphi_i) + \gamma\frac{1}{2\pi}$$

where α, β and γ represent the probability of reporting the correct target face, the probability of mistakenly reporting the non-target faces, and the probability of responding randomly, respectively. Here, $\alpha + \beta + \gamma = 1$. In addition, θ represents the correct orientation of the target face and $\hat{\theta}$ represents the orientation of the face reported by the participant. ϕ_{κ} is the von Mises (circular normal) distribution with the mean zero and the concentration parameter κ. Greater κ indicates a more concentrated von Mises distribution. m is the number of non-target faces, in this case, $m = 1$, and $\{\varphi_1, \varphi_2, \dots \varphi_m\}$ are the orientations of the m non-target faces. Maximum likelihood estimates of the mixture parameters α, β and γ for each participant and face race were obtained using an expectation-maximization algorithm (Myung, 2003; Suchow, Brady, Fougnie, & Alvarez, 2013).

According to these models, the overall response distribution comprises a mixture of three components (Bays et al., 2009): 1) pure guesses, defined as responses that were distributed uniformly across the face space, representing the probability that perceivers guessed randomly because of failures in the encoding and/or retrieval of presented faces; 2) target (correct) responses, which were from a von Mises distribution (circular-normal distribution) centered on the target face, indicating the probability that perceivers correctly remembered the target face; and 3) non-target responses, drawn from the same von Mises distribution but centered on the non-target face (i.e., the distractor face), indicating the probability of misremembering the distractor as the target face (swap error). The proportion of correct responses is transformed into an estimate of the number of successfully maintained faces by multiplying the probability of correct responses by the set size (n=2) for both own- and other-race faces. The fidelity of own- and other-race faces stored in visual working memory was estimated using the standard deviation of the von Mises distribution obtained from the mixture model for own- and other-race faces. SD is inversely related to precision, where a larger SD represents a more dispersed distribution of the responses, indicating a less precise face representation stored in VWM.

6.2.2 Results

6.2.2.1 Overall response error

The distribution of errors for own- and other-race faces is shown in Figure 6.2. A paired-sample t-test revealed a significant main effect of face race ($t_{14} = 3.69$, p = .002, Cohen's *d* = 0.95); overall, participants had smaller response errors for own-race faces (M_{SD} = 56.61°) than for other-race faces (M_{SD} = 69.66°).

6.2.2.2 Mixture modeling of response error

The result of the model fit is plotted in Figure 6.2. Paired sample t-tests revealed a lower correct response rate for other-race faces (*M* = .58) than own-race faces (*M* = .78, t_{14} = 3.57, *p* = .003, Cohen's *d* = 0.95). The significant difference in the proportion of correct responses was attributable to a significant difference in guess rate (*M* = .24 vs .03 for other- vs. own-race faces; t_{14} = 3.36, *p* = .005, Cohen's *d* = 0.88), with no difference in swap errors (*M* = .18 vs .19 for other- vs. own-race faces; t_{14} = 0.17, *p* = .865, Cohen's *d* = 0.04). The change in guess rate reflects a diminished number of stored faces for other-race (*k* = 1.16) relative to own-race (*k* = 1.56) faces. Notably, precision did not differ between own- and other-race faces, t_{14} = 0.74, *p* = .472, Cohen's *d* = 0.19, as indicated by comparable standard deviations of von Mises distributions for own-race faces (35.26°) and other-race faces (32.34°).

6.2.3 Discussion

While holding two potential target faces in VWM and given ample encoding time, participants made significantly larger errors in their recall of other- compared to own-race faces, as indicated by the greater angular deviations (SD) between the target face and the

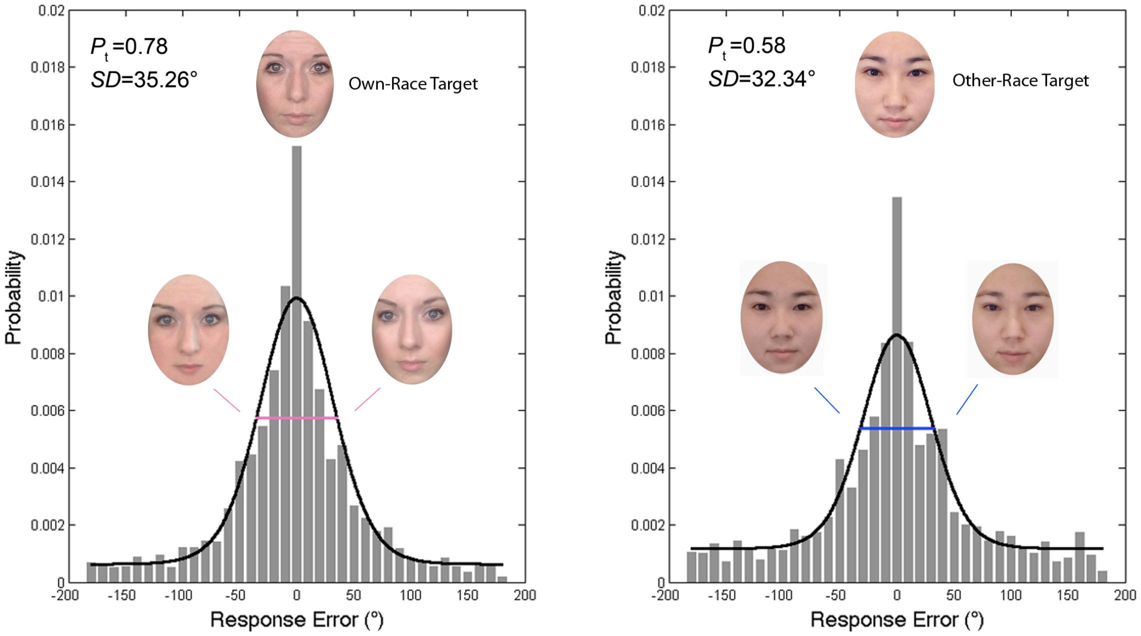

Figure 6.2. The distribution of response errors for own (left) - and other-race (right) faces. The histogram displays the proportion of binned responses relative to the target face. Black lines display the three-component mixture model, fit to the raw error. With two potential target faces on each trial, the mixture model combines a uniform guessing distribution with a circular-normal distribution of correct and non-target (swap) responses. The pink and blue solid lines indicate the width of the von Mises (circular normal) distribution at 1 SD and are flanked by corresponding identities (±1 SD of error). P_t indicates the proportion of correctly reported targets, and *SD* indicates 1 SD of the circular error for these responses. Note. Permissions preclude showing the faces used in the actual study; faces in the figure are for demonstration only.

faces that was reported by the participant. Results of mixture modeling further informed us that the increase in overall errors for other-race faces was attributable to an increased guess rate, but not in reduced precision or an increase in swap errors. Therefore, differences in performance between own- and other-race faces can be attributed to impairments in the encoding, consolidation and/or retrieval of other-race face representations, rather than a change in either the precision with which remembered faces are stored or an increase in identity confusion.

6.3 Experiment 2: Storing one face with limited encoding time

In Experiment 1, participants were given ample time (1500ms) to encode each of two faces; one face was then cued for recall. This protocol is maximally sensitive to storage limitations, defined here as the maximal fidelity with which own- and other-race faces are stored (Bays, Gorgoraptis, Wee, Marshall, & Husain, 2011). Limitations in encoding are best captured by very brief presentations (Bays et al., 2011). To examine whether any observed differences in Experiment 1 were attributable to differences in encoding as compared to storage limitations, in Experiment 2 we examined whether reducing presentation time (from 1500 to 200ms) especially impairs the probability and/or precision of correct responses for other-race faces. To isolate limitations in encoding we further reduced the set size to one in Experiment 2, thus working well below the capacity of VWM for own- and other-race faces observed in Experiment 1.

6.3.1 Methods and materials

6.3.1.1 Participants

20 adults (4 males, ages 18-25 years, *SE* = 0.45) from Brock University participated in the study.

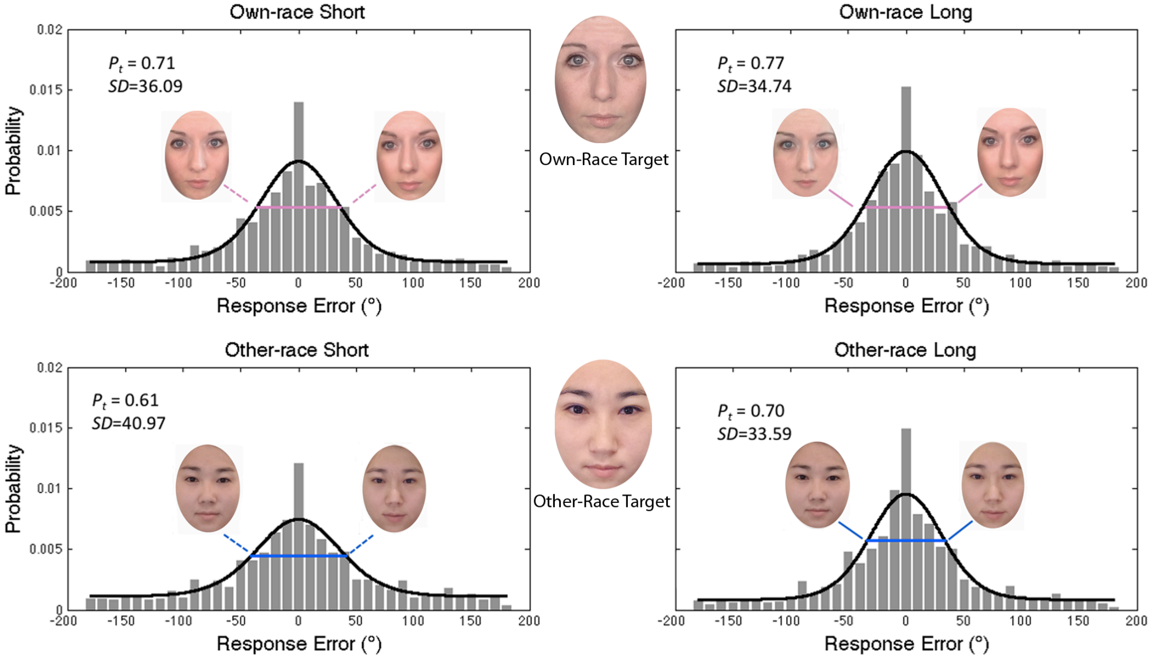

Figure 6.3. The distribution of response error for own-race (top) and other-race (bottom) faces when the faces were presented for 200ms (left) and 1500ms (right).
The histograms display the proportion of binned responses relative to the target face. Black lines display the mixture model, fit to the raw response error. With only a single target face on each trial, the mixture model combines a uniform guessing distribution with a circular-normal distribution of correct responses. The pink and blue solid lines indicate the width of the von Mises (circular normal) distribution at 1 SD and are flanked by corresponding identities (±1 SD of error). P_t indicates the proportion of correctly reported targets, and *SD* indicates 1 SD of the circular error for these responses. Note. Permissions preclude showing the faces used in the actual study; faces in the figure are for demonstration only.

6.3.1.2 Stimuli and procedure

The stimuli and procedure were identical to Experiment 1 with two exceptions: (1) there were 420 test trials and on each test trial only one face was presented; (2) the presentation time of target face varied across trials. On half of the trials faces were presented for 200ms and on the other half for 1500ms (as in Experiment 1).

6.3.2 Results

6.3.2.1 Overall response error

The distribution of errors from Experiment 2 is displayed in Figure 6.3. A 2 (Face race: own- vs. other-race faces) X 2 (Presentation time: 200ms vs. 1500ms) repeated measures ANOVA revealed significant main effects of face race ($F_{1,19} = 7.68$, $p = .012$, $\eta_p{}^2 = .29$) and presentation time ($F_{1,19} = 40.26$, $p < .001$, $\eta_p{}^2 = .68$). Participants were more precise for own-race faces ($M_{SD} = 59.57^o$) than other-race faces ($M_{SD} = 65.89^o$) and when faces were presented for longer time ($M_{SD} = 58.69^o$) than when faces were presented for shorter time ($M_{SD} = 66.77^o$). The face race x presentation time interaction did not reach significance ($F_{1,19} = 1.85$, $p = .190$, $\eta_p{}^2 = .09$). These results demonstrate that independent of the number of faces or length of encoding time, participants demonstrated greater error in their recall of other- compared to own-race faces, consistent with the ORE.

6.3.2.2 Mixture modeling of response error

Given the absence of a non-target face in Experiment 2, a two-component mixture model, proposed by Zhang and Luck (2008) was used. The components in this model are comparable to those in the three-component model and described by the following equation (here $\alpha + \gamma = 1$):

$$p(\hat{\theta}) = \alpha\phi_{\kappa}\left(\hat{\theta} - \theta\right) + \gamma\frac{1}{2\pi}$$

Because the guess rate is inversely proportional to correct responses, so here we only analyzed the proportion of correct responses. A 2 (Face race: own- vs. other-race faces) X 2 (Presentation time: short vs. long) repeated measures ANOVA revealed significant main effects of face race ($F_{1,19} = 7.87$, $p = .011$, $\eta_p^2 = .29$) and presentation time ($F_{1,19} = 17.90$, $p < .001$, $\eta_p^2 = .49$). As shown in Figure 6.3, participants made significantly fewer correct responses for other-race faces ($M = .66$) than for own-race faces ($M = .74$) and for the shorter presentation time ($M = .66$) than for the longer presentation time ($M = .74$). Consequently, the number of recalled faces was lower for other- ($k = .66$) than own-race ($k = .74$) faces and for shorter presentation time ($k = .66$) than for longer presentation time ($k = .74$). Notably, the face race x presentation time interaction did not approach significance ($F_{1,19} = 1.27$, $p = .274$, $\eta_p^2 = .06$), indicating that reducing presentation time did not especially impair the probability of an other-race face being recalled.

The Precision of VWM (1/*SD of the von Mises distribution*) was greater for the longer presentation time ($M_{\text{SD}} = 34.17^{\circ}$) than the shorter presentation time ($M_{\text{SD}} = 38.53^{\circ}$), as revealed by the significant main effect of presentation time ($F_{1,19} = 7.51$, $p = .013$, $\eta_p^2 = .28$). The main effect of face race was not significant ($F_{1,19} = .67$, $p = .424$, $\eta_p^2 =.03$), but the interaction between face race and presentation time approached significance ($F_{1,19} = 3.31$, $p =.085$, $\eta_p^2 =.15$). Based on a priori hypotheses we conducted paired-sample *t* tests; these confirmed that reducing presentation time significantly reduced precision for other-race faces ($M_{\text{SD}} = 40.97^{\circ}$ vs. 33.59° for 200 vs. 1500ms; $t_{19} = 2.82$, $p = .011$, Cohen's $d = 0.63$). In contrast, precision was comparable for shorter ($M_{\mathrm{SD}} = 36.09^{\circ}$) and longer presentation times ($M_{\mathrm{SD}} = 34.74^{\circ}$) for own-race faces ($t_{14} = 0.70$, $p = .494$, Cohen's $d = 0.16$).

6.3.3 Discussion

Overall, participants' precision of recall was impaired when encoding time was reduced to 200ms and when encoding other- compared to own-race faces. The mixture modeling revealed that the increase in response error caused by a reduction in encoding time was driven by fewer correct responses for both own- and other-race faces and a loss of precision that was specific to other-race faces. Thus under conditions that are maximally sensitive to encoding limitations, the probability of a correct response was reduced for both own- and other-race faces and the fidelity of other-race, but not own-race, face representations was impaired. The implications of these novel findings for both mechanisms underlying the ORE and models of face representation are discussed below.

6.4 General discussion

In summary, using a novel continuous response paradigm, we provided the first evidence that the ORE is attributable to increased error in the representation of other-race faces in VWM. We then used mixture modeling to examine how three sources of error contribute to the ORE: a failure to encode and retrieve other-race face representations (guess rate), reduced precision for other-race faces, and/or increased interruption from non-target faces (identity confusion). Based on this analysis, we revealed two novel findings. First, following ample exposure to own- and other-race faces, the ORE was evident in an increased guess rate, but not in reduced precision or an increase in identity confusion. Second, limiting encoding time impaired precision for other- but not own-race faces. Collectively, these results suggest that the ORE is caused by a failure to rapidly consolidate other-race faces into coherent and stable representations in VWM.

Our findings build on two previous studies showing that perceptual experience affects how faces are stored in VWM (Humphreys, Hodsoll, & Campbell., 2005; Lorenc et al., 2014). To the best of our knowledge, the only previous study to explicitly contrast VWM for own- and other-race faces used the change blindness paradigm (Humphreys et al., 2005). These authors reported faster change detection for own-race than other-race faces, but this paradigm precludes examining the separate contributions of a failure to encode and retrieve other-race faces versus reduced fidelity in their representation. Lorenc et al. (2014) used the continuous response paradigm to compare VWM for upright and inverted faces (two face categories with which adults have differential experience). Precision, but not capacity, of VWM was greater for upright than inverted faces. Here, for the first time, we applied the continuous response paradigm to examine the ORE. Like Lorenc et al., we found that perceptual experience influences the precision of VWM for faces; reducing presentation time to 200ms impaired precision for other-race, but not own-race, faces. Unlike Lorenc et al., we also found that experience influences the number of faces that can be maintained in VWM. These differential patterns might reflect a difference between the two studies in the dimensions along which faces continuously varied rather than differential effects for orientation vs. face race: Whereas the faces in Lorenc et al's study varied in both age and sex, ours differed only in identity. Encoding and maintaining gender and sex in VWM might be easier than encoding and maintaining identity, as suggested by both fewer correct responses and greater variability of face representations reported by participants in our study. Nonetheless all of these studies provide strong evidence that VWM for faces is impacted by experience. Moreover, given that the fidelity of LTM representations is constrained by those encoded and maintained in VWM (Brady et al., 2013) our study suggests that ORE observed in LTM can be attributed, at least in part, to differences in the ability to establish high-fidelity representations in VWM for other- compared to own-race faces.

The inefficiency with which other-race faces are rapidly encoded and consolidated into stable representations is consistent with a large body of electrophysiological studies examining the neural mechanisms of the ORE. These studies reported smaller amplitudes of N170 and P200 for other- than own-race faces (Ito & Urland, 2005; Senholzi & Ito, 2012; Vizioli, Foreman, Rousselet, & Caldara, 2009; Vizioli, Rousselet, Foreman, & Caldara, 2009; but see Balas & Nelson, 2010; Herrmann, Schreppel, Jäger, Koehler, Ehlis, & Fallgatter, 2007; Stahl, Wiese & Schweinberger, 2008) —ERP components that peak over tempero-occipital brain regions about 170ms and 200ms after stimulus onset. N170 and P200 are thought to reflect structural encoding of faces (i.e., processing physiognomic information to form a sensory representation) and configural processing (i.e., integrating facial features into a whole). These electrophysiological studies suggest reduced efficiency in structural encoding and configural processing for other-race faces, consistent with behavioural evidence (see Mondloch et al., 2010; Michel, Rossion, Han, Chung, & Caldara, 2006; Rhodes, Hayward, & Winkler, 2006; Tanaka, Kiefer, & Bukach, 2004).

One possible explanation for differential encoding and maintenance of own- and other-race faces in VWM is related to how own- and other-race faces are mentally represented. According to Valentine’s influential norm-based coding model (Valentine, 1991), faces are represented in a multidimensional face space and are encoded with reference to their deviation from a face prototype/norm that represents the average of all faces previously encountered. Representing individual faces relative to a prototype ensures efficient extraction of subtle variations in the shared configuration among faces (Byatt & Rhodes, 1998), and individual differences in norm-based coding correlate with individual differences in recognition accuracy (Dennett, McKone, Edwards, & Susilo, 2012; Rhodes, Jeffery, Taylor, Hayward, & Ewing, 2014). Multidimensional face space is influenced by experience; adults' representation of both other-race (Zhou, Short, Chan, & Mondloch, 2016) and other-age (Short & Mondloch, 2013) faces is less well refined than that of own-race and own-age faces. To the extent that face space is maximized for discriminating and recognizing own-race faces, encoding and storing representations of other-race faces in VWM likely entails a higher perceptual load; one consequence of this load appears to be a reduction in the precision with which other-race faces are stored in VWM. This explanation is consistent with evidence that complex objects (e.g., Chinese characters, random polygons) place greater demands on VWM and lead to a reduced VWM capacity relative to simple objects (Alvarez & Cavanagh, 2004; also see Brady, Konkle, & Alvarez, 2011 for a review). Although own- and other-race faces do not differ in stimulus complexity, as evident in the ORE being independent of race of face and race of participants (e.g., Ng & Lindsay, 1994; Sporer, 2001), limited perceptual experience with other-race faces increases the demands on VWM.

Of necessity we presented identical images of unfamiliar identities at study and test. The function of face perception in daily life, however, is to recognize familiar identities despite within-person variability in appearance (e.g., in lighting, hairstyle, expression, viewpoint; Burton, 2013). Impairments in VWM for other-race faces might contribute to increased errors in recognizing that two different images of an unfamiliar other-race face belong to the same identity (Laurence, Zhou, & Mondloch, 2016) and likely impact processes by which a newly encountered face becomes familiar (e.g., ensemble encoding—the rapid and automatic formation of an average; Kramer, Ritchie, & Burton, 2015).

In summary, we argue that the impaired VWM performance for other-race faces, evident in the failure to rapidly establish high-precision representations for those faces, is likely carried forward into LTM. These impairments cascade to cause greater recognition errors for other-race faces, an effect that has been consistently found in tasks that require the retrieval of face representations from LTM (e.g., old/new recognition task). Indeed, inefficient encoding and storage of other-race faces in VWM might reduce the impact of exposure to newly encountered faces on the refinement of their representation in multi-dimensional face space. Given the potential legal consequences of wrongful eyewitness recognition, the practical implications of our study are significant. Intervention and training programs aiming to improve recognition memory for other-race faces should emphasize the efficiency with which other-race identities are encoded so as to increase the capacity and precision of visual working memory for such faces.

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CHAPTER 7

General Discussion

Since the early twentieth century, the other-race effect has attracted enormous attention of researchers (Meissner & Brigham, 2001; Young, Hugenberg, Bernstein, & Sacco, 2012 for reviews). Decades of research has characterized the cognitive mechanisms underlying and the moderators of the other-race effect. A variety of methodologies have been used to investigate different aspects of own- and other-race face recognition. These methodologies captured differential perceptual discrimination of own- and other-race faces, recognition based on the recalling of representations from memory, perceivers' sensitivity to shape and spacing of facial features in own- and other-race faces, and the refinement of the coding dimensions associated with own- and other-race faces. Training paradigms have been developed to attenuate the other-effect effect (Tanaka & Pierce, 2009; McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2011). Researchers have also investigated how the recognition bias for own-race faces influences, and is influenced by, racial stereotypes and attitudes (Ferguson, Rhodes, Lee, & Sriram, 2001; Lebrecht, Pierce, Tarr, & Tanaka, 2009; Levin, 2000; Walker & Hewstone, 2008).

Collectively, the results of this dissertation highlight the commonalities and the differences between the processing of own- and other-race faces and provide novel insights about the cognitive mechanisms underlying the other-race effect. One difference between the recognition of own- and other-race faces is in perceivers' ability to recognize faces despite natural variation in appearance: This ability is impaired for other-race faces (Study 1). A commonality, however, is the ease with which familiar faces are recognized despite this same natural variability (Study 2). I next conducted three lines of studies to investigate the perceptual and cognitive mechanisms that might contribute to other-race faces being harder to encode and recognize. In two cases, I identified differences between own- and other-race face perception. First, I provided evidence that the representations of other-race faces are less refined in face space than the representations of own-race faces, leading to a reduced sensitivity to the deviations from normality in other- than own-race faces, and increased between-rater variability in the judgment of attractiveness of other- relative to own-race faces (Study3). Given that the dimensions of face space are refined through perceptual experience, my Study 3 therefore provides direct support for the perceptual experience model for the ORE. Second, I showed that differential perceptual experience with faces from different ethnic groups also impairs the efficiency with which these faces are encoded and maintained in visual working memory (Study 5), a memory system that is responsible for temporarily holding visual information to serve the needs of ongoing tasks (Luck & Vogel, 2013). Failure to rapidly establish high-precision representations for other-race faces is likely carried forward into long-term memory, causing greater recognition errors for other-race faces, an effect that has been consistently found in tasks that require the retrieval of face representations from long-term memory. Capturing the potential variability in the representations of own- and other-race faces stored in visual working memory, rather than merely recording perceivers' binary memory performance, this study highlights the quantitative rather than qualitative differences in the encoding and storage of own- and other-race face representations in visual working memory system. When encoding time is limited, the ORE is driven by the representations of other-race faces stored in VWM being less precise or fuzzier. Despite differences in both VWM and the refinement of representations, I also discovered a commonality in how own- and other-race faces are encoded and recognized. Despite being less efficient in learning an other-race face, the two sources of cues to facial identity—shape and texture—are used in a similar way for own- and other-race faces. I propose that it might be that despite relying on shape and texture information in similar ways for own- and other-race faces during encoding and recognition, adults' quantitative sensitivity to these cues is reduced for other-race faces, likely a result of continuous asymmetries in own- and other-race perceptual experience across lifespan.

The following three sections (7.1-7.3) will separately discuss the mechanisms of other-race effect in the context of different sources of variability in appearance (both natural within-person variability, and variability associated with experimentally induced shape and texture changes), the refinements of own- and other-race face representations, and in the storage and retrieval of memory for own- and other-race faces. Based on these discussions, I propose a working hypothesis (7.4) to integrate the different aspects of ORE so as to provide a more comprehensive understanding of the ORE in face recognition. Finally, in the last section of the general discussion (7.5), I highlight a number of new avenues that could be explored in future studies.

7.1 Recognizing own- and other-race identities despite changes in appearance

Incorporating within-person variability in identities' appearance to examine own- and other-race identity person is an important part of my thesis. Traditionally, the other-race effect has been investigated in the context of between-person variability, focusing on the discrimination among own- and other-race identities. However, recent studies examining own-race face recognition have suggested that the effect of within-person variability on identity person is large (Burton, Jenkins, Schweinberger, 2011; Cursiter, 2013; Murphy, Ipser, Gaigg, Cook, 2015; see Burton, 2013 for a review). In the real world within-person variability in appearance sometimes exceeds between-person variability in appearance (Hancock, Bruce, & Burton, 2000), reducing the utility of pictorial cues (information specific to a particular image, such as shadows). Past studies ignoring within-person variability might preclude our understanding of fundamental factors underlying the challenges in other-race face recognition.

Past studies have classified the variations in appearance into two categories—one regarding the variations in face characteristics, and one regarding environmental and camera variations (Hancock et al., 2000; Cursiter, 2013). Variations in facial characteristics include changes in expression, hairstyle, hair color, makeup, as well as the variations that occur with changes in aging, stress level and health condition (e.g., weight gain or loss and tiredness). These variations can have a great influence on the facial configuration and the distinctiveness of a given identity (Coetzee, Perrett, & Stephen, 2009; Hancock et al., 2000). The environmental and camera variations are lighting, the scene complexity that a face is in, the distance between the camera and the target face, capturing angles, and the variations associated with different types of camera lens. How the two types of within-person variability influence the formation of a robust representation of an own- and an other-race face has not been specified, and it is likely that they co-act to generate the reliable other-race effect. For example, the metric differences between individual facial features might change when the identity shows a different expression (movement of the mimetic musculature of the face; Pantic & Patras, 2006), and also when the picture taker uses a different camera angle, which might alter the specific pattern of shading (e.g., low-angle shot might make the chin look bigger and the distance between eyes and eyebrows look smaller).

My Study 1 suggested that recognizing an unfamiliar face despite changes in appearance is hard and even more challenging when the face is from a different ethnic group. My Study 2 however, suggested that recognizing an other-race identity across variability in appearance is trivially easy when the other-race face is familiar to the perceiver. The series of studies together suggest that the fundamental differences between unfamiliar and familiar own-race face recognition (see Burton, 2013; Johnston, Edmonds, 2009 for reviews) also exist in unfamiliar and familiar other-race face recognition and that the other-race effect is limited to unfamiliar faces. Like unfamiliar own-race face recognition (Burton, Schweinberger, Jenkins, & Kaufmann, 2015), unfamiliar other-race face recognition is fragile and image-dependent; unfamiliar other-race face recognition is even less tolerant to changes in appearance than unfamiliar own-race recognition. Nevertheless, representations of both familiar own- and other-race face recognition are abstract and image-invariant and both are highly resistant to natural variability in appearance. In Study 4, using a face learning paradigm, I demonstrated that when acquiring familiarity with own- and other-race faces (face learning), the two main sources of facial variability (shape and texture properties) are used comparably for own- and other-race faces, although other-race faces are learned less efficiently. The transition from a reliance on both shape and texture cues to a reliance on texture cues is comparable for own- and other-race faces.

These novel findings therefore raise important questions regarding the other-race effect: How are abstract and reliable representations of familiar other-race faces achieved?

How does perceptual experience shape the processes by which own- and other-race faces become familiar? And what critical factors should an effective training paradigm capture in order to improve participants' learning and recognition of other-race faces?

One direction of examining these questions would be incorporating within-person variability during face learning. Indeed, recent studies incorporating within-person variability of faces to examine the acquisition of familiar own-race faces have suggested that within-person variability in appearance might be the process by which a face becomes familiar (Andrews, Jenkins, Cursiter & Burton, 2015; Bindemann & Sandford, 2011; Dowsett, Sandford & Burton, 2016; Menon, White & Kemp, 2015; Ritchie & Burton, 2016). Andrews and colleagues replicated Jenkins et al's (2011) finding that sorting ambient images of two different unfamiliar identities is highly error-prone. In contrast, performance is greatly improved by informing participants of the number of identities present. Notably, exposure to within-person variability of target identities in the sorting task facilitated participants' subsequent matching of novel images of the target identities (Andrews et al., 2015). Likewise, Dowsett and colleagues found that participants' performance in a 1-in-30 matching task can be improved by providing with multiple images of the target identity (Dowsett et al., 2016). The extent to which individuals are exposed to within-person variability in appearance during learning modulates perceiver' subsequent perceptual matching as well as their recognition of learned faces. The more variability in appearance perceivers learned, the better perceivers were able to recall the learned faces from their memory and recognize new instances (Ritchie & Burton, 2016; Murphy et al., 2015). Some programs have been developed aiming to document the difficulty of recognizing faces based on the various sources of variability in appearance, such as in pose, ambient lighting, expressions, size of the face, and distance between the camera and target face (e.g., Face and Ocular Challenge Series (FOCS); Good, Bad and Ugly (GBU) face challenge, Phillips et al., 2012; Face Recognition Vendor Test, (FRVT), Ngan & Grother, 2015). Moreover, recent studies examining computer-based face recognition suggest that recognition algorisms based on photometric and appearance-based variability can optimize accuracy in face matching and recognition (O'Toole et al., 2007; O'Toole, An, Dunlop, Natu, & Phillips, 2012). These studies, together with my finding that the other-race effect can be eliminated entirely after acquiring considerable familiarity with an individual face, I propose that exposure to a wide range of natural variations of appearance might be a key to learning other-race faces, and to forming stable representations of familiar other-race faces. It is likely that learning of unfamiliar other-race faces can also benefit from the learning of how other-race faces vary. However, such benefits of learning and the efficiency with which stable representations of faces are derived from multiple instances may differ for own- and other-race faces. This is because the efficiency of learning other-race faces is likely constrained by the impairments in the encoding and processing of own- and other-race faces identified in my dissertation (e.g., insensitivity to shape of facial features, as well as their second-order relations in other-race faces; inefficiency with which coherent representations of other-race faces are consolidated in VWM; less refined representations of other-race faces in face space).

Studies investigating the processes by which own- and other-race faces become familiar should also consider distinguishing the separate role of different sources of facial properties, such as shape and texture cues, during own- and other-race face learning. Liu and colleagues found that learning faces from multiple poses can facilitate their recognition across changes in illumination; in contrast, learning faces with different illuminations did not facilitate recognition of faces across changes in pose (Liu, Bhuiyan, Ward, & Sui, 2009). Their study suggests that pose and illumination variations play different roles in the initial encoding of novel faces, with information derived from pose variations being key for the learning of new faces (Liu et al., 2009; also see Longmore, Liu, & Young, 2008). This finding is also consistent with past studies and the findings of my Study 4, suggesting that whereas shape cues are important for the encoding of novel faces, texture cues are more important for the recognition of learned faces. Studies investigating the neural basis of own-race face learning also suggested that benefits from texture cues for learned faces are associated with an enhanced posterior N250, a component that has been related to the activation of stored representations of faces (Itz, Schweinberger, Schulz, & Kaufmann, et al., 2014). My Study 4 demonstrated that although other-race faces are learned less efficiently, the transition from reliance on shape cues to texture cues during face learning is comparable for own- and other-race faces. This finding particularly highlights the use of appropriate cues in learning both own- and other-race faces.

7.2 Refinement of face norm and face space for own- and other-race faces

Throughout the current series of studies, Valentine's influential multidimensional face space framework and norm-based coding model provide explanatory power. The series of studies provide evidence that the ORE is associated with perceivers' tolerance of within-person variability in appearance (Study 1 and 2), their sensitivity to deviations from normality and attractiveness in own- vs. other-race faces (Study 3), the utilization of different facial cues to encode and recognize own- and other-race identities (Study 4), as well as the efficiency with which coherent and stable representations of faces are consolidated in visual working memory (Study 5). While acknowledging that there are some shared commonalities in the processing of own- and other-race faces (Study 2 & 4), the differences between the cognitive processing of own- and other-race face are evident (Study 1, 3 & 5). These differences might be directly associated with how representations of own- and other-race faces are mentally processed in multidimensional face space. Notably, the reliable other-race effect observed in my studies provides some indication that the refinement of face space and a face norm likely takes extensive and continuous perceptual experience with other-race race identities to achieve.

The finding that representations of both own- and other-race faces can be activated by multiple images, although this is limited when a face is unfamiliar, provides direct support for Tanaka's attractor field model (Tanaka, Giles, Kremen & Simon, 1998; also see Lewis & Johnston, 1998 for Voronoi cell model). The attractor field model is an extension of Valentine's face space model (1999) and suggests that each face is represented as a region rather than a single point in multidimensional face space. The attractor fields (Tanaka et al., 1998; also see Tanaka & Corneille, 2007) around each point in face space reflect the range of inputs that are perceived as belonging to a given identity, allowing recognition despite changes in appearance (e.g., in expression, makeup, hairstyle, illumination, or orientation). The size of an identity's attractor field is determined by the density of nearby representations (i.e., by its location in face space) and determines the range of acceptable inputs. Because the dimensions of face space are more refined for own-race faces, these faces should have larger inter-face distances than other-race faces, which are clustered together in the periphery of face space. My Study 2 suggests that it is likely that extensive exposure to a specific other-race identity facilitates the expansion of the attractor field of that given identity, therefore allowing the establishment of an abstract representation of an other-race identity. However, such perceptual learning is identity-specific and does not generalize to the whole other-race category, perhaps because familiarity with a few other-race exemplars does not add dimensions to face space or increase sensitivity to differences along dimensions, consistent with Burton's finding that within-person variability in own-race faces is likely idiosyncratic (Burton, Kramer, Ritchie, & Jenkins, 2016).

There are still several key aspects of face space and the norm-based coding model that remain largely unspecified. One is about the nature of the dimensions of face space. They might represent the shape and size of facial features (e.g., nose length), the spacing between individual facial features (distances between eyes) and/or comprise more abstract dimensions (e.g., eigenfaces, the eigenvectors of the covariance matrix of the set of face images; Hancock, Burton, & Bruce, 1996). Given the ambiguous definition of dimensions of face space, it is conceptually difficult to capture how different perceptual experience with own-and other-race face refines the dimensions of face space. Partial transfer of aftereffects across face race (Jaquet, Rhodes, Hayward, 2008; Short, Lee, Fu, & Mondloch, 2014) and age (Short, Proietti, & Mondloch, 2015) suggests there are some dimensions that are almost certainly shared across race and age categories. Would it be possible to take the advantage of perceivers' sensitivity to such shared dimensions and train people to improve their sensitivity to other dimensions that are not shared by own- and other-race faces?

In addition, it is not specified whether the other-race effect is attributable to the differences in the quantity or the quality of dimensions underlying face space (or their combination). More specifically, is the other-race effect driven by there being fewer dimensions available for other- than own-race faces and/or by the dimensions of other-race faces being less fine-tuned such that perceivers lack sensitivity to differences along the dimensions? Using multidimensional scaling analyses, Nishimura and colleagues investigated adults and children's perceived similarity of a set of homogeneous faces (all faces had the same hair and posed a neutral expression). They found that whereas adults use multiple dimensions for similarity judgments, children tend to rely on a single dimension for each judgement, despite demonstrating sensitivity to multiple dimensions (Nishimura, Maurer, & Gao, 2009). Is it possible that, like children who lack of the perceptual experience with faces in general relative to adults, perceivers rely on fewer dimensions to encode other- than own-race faces? These questions are beyond the scope of the current dissertation, but should be specified in future studies.

The third question that needs further clarification is how the refinement of the dimensions of face space changes as a function of familiarity with specific own- and other-race faces. According to the attractor field model (Tanaka et al., 1998), the size of an identity's attractor field is determined by the density of nearby representations (i.e., its location in the face space) and determines the range of acceptable inputs. Because the dimensions of face space are more refined for own- than other-race faces, own-race faces would have larger inter-face distances than other-race faces, which are clustered in the periphery of face space. If acquiring the full familiarity with considerable number of other-race identities would expand the attractor filed for these other-race identities, we would expect to see an increase in perceivers' sensitivity to the properties of the relevant dimensions, which might in turn generalize to the recognition of newly encountered other-race faces. This hypothesis does not contradict the findings of my Study 2, which suggests that familiarity with a few other-race exemplars likely does not add dimensions to face space. But the number of exemplars needed for a significant change in the refinement of face space should be quantified in future studies.

7.3 Face representations stored in visual working memory and long-term memory

Working memory is the system used to temporarily store and manipulate information lasting in the order of seconds (Baddeley, 2003). It has been found to be highly correlated with a wide range of cognitive functions, such as selective attention, executive function, fluid intelligence, processing speed and reasoning/problem solving (see Downing, 2000; Fukuda, Awh, & Vogel, 2010; Johnson et al., 2013; Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001). Visual working memory allows us to block out distractions, keeping information updated quickly and functioning effectively in the visual world. It serves as an interface between perception, long-term memory and action (Miyake & Shah, 1999) and is considered to be the basis of general cognitive function (Dempere-Marco, Melcher, & Deco, 2012).

Impairments in the encoding, storage and/or retrieval of other-race face representations from memory have been reported in numerous behavioral studies (e.g., fewer hits and greater false alarms in the old/new face recognition task; see Meissner & Brigham, 2001 for a review). A large body of electrophysiological studies examining the neural mechanisms of the ORE also suggests that the other-race effect emerges at an early perceptual stage of face processing and is associated with different structural encoding and configural processing of own- vs. other-race faces. For example, some studies reported smaller amplitudes of N170 and P200 for other- than own-race faces (Ito & Urland, 2005; Foreman, Rousselet, & Caldara, 2009; Vizioli, Rousselet, Foreman, & Caldara, 2009; but see Balas & Nelson, 2010; Stahl, Wiese & Schweinberger, 2008). Given the important role of visual working memory for processing complex visual stimuli, such as faces, and the initial behavioral and neural evidence supporting the existence of impairments in visual working memory for other-race faces (Humphreys, Hodsoll, & Campbell, 2005), it is surprising that very few studies have examined how representations of own- and other-race faces are stored in visual working memory. Consistent with psychophysiological studies (Foreman et al, 2009; Stahl et al., 2008), Study 5 provided evidence that the ORE emerges at an early stage of information processing, and is attributable to the inefficiency with which other-race faces are rapidly consolidated into stable representations in visual working memory. Some studies suggest that fidelity of representations in long-term memory is constrained by those in visual working memory (Brady, Konkle, Gill, Oliva, & Alvarez, 2013). The results of my study suggest that the ORE observed in long-term memory may be attributed, at least in part, to differences in the ability to establish high-fidelity representations in VWM for other- compared to own-race faces.

The continuous response paradigm provided us with a valuable approach to explore how differential perceptual experience with own- and other-race faces influences the capacity and the precision of visual working memory for own- and other-race faces. In future studies this novel protocol should be modified to investigate the differences in pure perceptual representations of own- and other-race faces as well as the face representations stored in long-term memory. For example, two faces (one target and one test) could be presented simultaneously and participants could be asked to adjust the test face to match the target face on the face wheel. This perceptual task does not require memory demands, but could be used to test perceivers' perceptual sensitivity to the properties of facial features. In addition, participants could also be asked to recall representations of personally familiar faces (or newly learned other-race faces) from their long-term memory and to match these familiar face representations on a face wheel. This would provide an examination of the precision of long-term memory for own- versus other-race faces.

Using these modifications of the continuous-response paradigms, Brady and colleagues (2013) tested the precision of visual information (e.g., for the color of simple objects such as chairs, and balloons) encoded and stored in visual working memory and in long-term memory. Participants were shown target objects, each shown in a randomly selected color, and were asked to choose from a color wheel what color matched the color of the target object that they had seen. The task was a perception task, a visual working memory task, or a long-term memory task. In the perception condition, the target object and the test object are shown simultaneously and participants were asked to perceptually match the colors of two objects. Whereas the visual working memory task required participants to retain the colors of three objects in the memory for a short period of time (e.g., 1s), the long-term memory task required participants to retain the colors of 232 objects in memory for a long period of time (11 minutes). They found that there is a significant loss of precision in perceivers' representation of simple objects (e.g., chairs and balloons) from perception to visual working memory; however, the precision of hundreds of representations encoded and retrieved from long-term memory is the same as that of three actively stored representations in visual working memory (Brady et al., 2013). These results suggest that the fidelity of visual working memory and long-term memory share a similar limit. Would a similar pattern be found for more complicated visual stimuli (i.e., faces)? Would differential perceptual experience with own- and other-race faces make the relationship between the fidelity of visual working memory and the fidelity of long-term memory differ for own- and other-race faces? Exploring these questions would help better understand how own- and other-race faces are stored in visual working memory and the long-term memory system, and what factors modulate the process of the formation of familiar other-race face representations.

7.4 A Working Hypothesis

Collectively, the five studies comprising my dissertation suggest that the other-race effect is likely a multiply-determined phenomenon that can be caused/affected by multiple perceptual and cognitive factors. The recognition deficits for other-race faces exist at a perceptual level as well as at a mnemonic level. The ORE is attributable to deficits in recognizing other-race identities despite changes in appearance, to less refined representations of other-race faces in face space, and to the inefficiency with which coherent representations of faces are consolidated in and retrieved from visual working memory.

Despite the perceptual and mnemonic differences in the processing and learning of own-and other-race faces, these differences tend to be quantitative rather than qualitative. For example, when the stream of facial representations enters the visual system, perceivers can quickly extract critical facial characteristics, form stable sensory representations of own-race faces, and actively maintain the representations in visual working memory for ongoing cognitive processing. However, they are less efficient when doing so for other-race faces. Likewise, other-race faces are learned less efficiently than own-race faces, but the utilization of shape and texture cues during face learning are not qualitatively different for faces of two racial groups. Therefore, I propose that the impaired encoding and learning of other-race faces are not driven by fundamentally different utilization of facial cues but rather by the fact that perceivers' quantitative sensitivity to these cues is reduced for other-race faces. Aftereffect studies suggested that adults rely on separable norms to encode own- and other-race faces (Jaquet et al., 2008), and building on that, my study provides direct evidence that face norm and dimensions of face space are less differentiated for other-than own-race faces. Notably, my study showed that the ORE is attributable to impairments in extracting stable representations of other-race faces across variations in appearance. Nevertheless, as suggested by my study, such impairment is limited to unfamiliar other-race face recognition. Perceivers can ultimately form stable representations of both familiar own- and other-race faces, allowing recognition across variations in appearance. Whereas both unfamiliar own- and other-race face recognition is image-dependent and is susceptible to variations in appearance, both familiar own- and other-race face recognition is more abstractive and image-independent.

Bruce and Young's influential model of face recognition (Bruce & Young, 1986), suggests that unfamiliar and familiar face recognition falls along different routes. Recognition of unfamiliar faces involves structural encoding of faces, directed visual processing, as well as facial expression and speech analysis. Structural encoding of faces ensures a formation of quick and basic description of faces, and directed visual processing allows the quick extraction of physical aspects of faces such as age, gender and race. In addition to that, recognition of familiar faces involves the activation of face recognition unit, followed by the person identity node, and then name generation (Bruce & Young, 1986). Successful recognition of familiar faces is achieved when there is a match between the products of accurate structural encoding and previously stored representations of familiar faces, held in face recognition units (Bruce & Young, 1986). Therefore, successful recognition of someone's face requires not only the accurate extraction of facial properties that are critical for identifying the face (optimize the products of structural encoding and face analysis), but also requires an optimal recognition unit that best captures how the face looks.

It is likely that limited perceptual experience with other-race faces in general impairs perceivers' sensitivity to the shape of facial features and the spatial configuration among facial features of a given unfamiliar other-race face (e.g., impairs structural encoding). This impaired sensitivity further impairs their accurate extraction of critical characteristics that define the face and their ability to quickly consolidate the representations of an other-race face into a stable representation in visual working memory. These factors together make the products of structural encoding and analysis of the unfamiliar other-race face less accurate. In addition, when an unfamiliar other-race face is encountered, the face representation stored in the face recognition unit unlikely captures how the face truly looks, making the appropriate utilization of texture cues (e.g., luminance) less available, thus further impairing the formation of a stable representation of the face across variations in appearance. Notably, these factors are unlikely independent from each other. Instead, they are mutually interactive and may be modulated by the perceivers' motivation and existing face norm. For example, the efficiency with which representations of own- and other-race faces are manipulated and stored in visual working memory may influence perceivers' ability to extract appropriate shape and texture cues during face learning. The ability to process shape and texture-relevant information in faces may in turn affect how quickly critical facial information is maintained and updated in visual working memory. The two may together influence the refinement of face representations stored in recognition units in memory, consequently changing the threshold of activation of the face recognition units. Theoretically, the whole cognitive system can be governed by one's existing perceptual experience as well as one's social cognition, such as racial bias and racial attitude, which in turn, may exert differential influence on one's ability to process identity-specific information.

These bidirectional influences co-act to generate the reliable ORE. To test these hypotheses, one direction would be to individually manipulate the influential factors and investigate how the change of a given factor influences the other factors, and consequently the recognition of own- and other-race faces. For example, one can manipulate the cognitive load on VWM by changing the number of faces that need to be stored in VWM (or the complexity of the contexts where the faces were seen), and investigate its influences on perceivers' sensitivity to shape and texture cues in own- and other-race faces, and on perceivers' sensitivity to deviations from own- and other-race norm. Another direction would be to investigate the role of individual differences in shaping perceivers' ability to from stable representations of faces across changes in appearance, to use shape and texture cues during face learning, to represent faces in face space, and to consolidate these face representations in VWM. If these aspects of ORE are symmetrically interactive, we would expect to see a high correlation across different tasks.

The other-race effect is a direct result of perceptual narrowing (Pascalis et al., 2005). Perceptual narrowing has also been shown to occur within other domains, such as music and speech perception (Hannon & Trehub, 2005; Kuhl, Tsao, & Liu, 2003). Our perceptual system tends to be shaped by perceptual experience to represent the characteristics of stimulus categories with which we have most experience (e.g., own-race faces, native language and native musical rhythms). However, the generalization of learning across domains might be different. For example, learning of Mandarin for an English-speaking person would likely be largely influenced by the differences between English and Mandarin, two very different language systems in the composition of vocabularies, phonics, structure of grammars, as well as the use of inflection. Certain rules of grammars may be used to generalize to the learning of Mandarin, but some may not. Indeed, generalization of learning between English and Mandarin might be much harder than generalization of learning between English and Dutch, two language systems that belong to the same Indo-European language family (Renfrew, 1990). Just as English and Dutch share properties, faces from different racial groups share a similar configural template, namely two eyes are located above a nose and a mouth. How is the learning of an Asian face influenced by the existing (e.g., Caucaisan) face norm? Are there certain dimensions that are shared across faces from different racial groups? Evidence from aftereffects studies suggests so, given that partial transfer of aftereffects occur across face race (Jaquet et al., 2008)? Then, to what extent they can be used to generalize the learning of Asian faces? These questions can be investigated in the future studies.

In addition, there is long-standing debate in the developmental face perception literature regarding whether there are qualitative or quantitative differences between children and adults' face recognition and whether the improvement of face processing with age results from development of general cognitive skills (e.g., memory, attention, strategy use, concentration ability) or from face-specific development (i.e., shaped by perceptual experience with faces). Recent evidence shows that children show certain characteristics of adult-like face processing, despite an overall reduced performance on face recognition tasks. For example, like adults, they process faces holistically (de Heering, Houthuys, & Rossion, 2007), they use norm-based coding (Short, Hatry, & Mondloch, 2011), and they are sensitive to the shape of facial features and the spacing among facial features (Mondloch, Le Grand, & Maurer, 2002; Quinn & Tanaka, 2009). Do the perceptual and cognitive mechanisms underlying children's own-race face recognition and adults' other-race face recognition share some similarities? If the differences in performance on the face recognition tasks in adults for own- versus other-race faces parallels those observed when comparing to children versus adults, we would expect to see an improvement of face processing during childhood even after controlling for the effect of general cognition, suggesting that improvement of face processing with age is, at least in part, face-specific. This is because impairments in adults' recognition of other-race faces compared to own-race faces cannot attributable to the general cognition. In turn, examining the development of face processing would help clarify the role of perceptual experience in adults' own- and other-race face recognition in addition to the influence of social cognition. If some of the mechanisms underlying children's immaturities in face recognition and adults' poor recognition of other-race faces are attributable to the same mechanisms (i.e., face-specific experience), we would also expect to see that adults' recognition of own- and other-race faces changes as a function of perceptual experience with faces from different racial groups even after controlling for the influence of social cognition (e.g., perceivers' motivation and racial attitude). These questions call for an integrative study of perceptual experience that encompasses both developmental studies and studies in which adults are tested with faces from different categories. In addition to these general questions, the next section discussed several immediate follow-up studies.

7.5 Future Directions

Although the current research found evidence for recognizing the identity of unfamiliar faces in the context of variability in appearance, I did not test what factors might influence this challenge. Past studies have suggested that participants' performance in the sorting task is modulated by visual constrains and the similarity of the faces being sorted (Andrews et al., 2015; Cursiter, 2013). For example, both informing participants the correct number of sorting identities (Andrews et al., 2015) and asking participants to sort dissimilar looking, rather than highly similar looking identities (Cursiter, 2013), results in perceivers correctly grouping different images of the same identities together (they rarely make confusions between the two target identities). In addition, social cognitive models suggest that some social cognitive factors (e.g., motivation, social categories) modulate the amplitude of the ORE (Bernstein, Young, & Hugenberg, 2007).

Future studies stemming from this work should examine how perceptual expertise and social cognitive factors jointly influence people's ability to 'tell own- and other-race faces together'.

My Study 2 highlighted the ability of adults to build up stable representations of familiar other-race faces. However, I did not test how such stable representations are achieved and how differential perceptual experience with own- and other-race faces shapes this process. Evidence from our lab (Baker, Laurence, & Mondloch, 2017) suggests that adults require exposure to less variability in appearance than do children to acquire familiarization with own-race faces. It would be interesting to investigate how exposure to different degrees of variability in appearance can influence the learning of own- and other-race face. If adults' learning of other-race faces is comparable to children's learning of own-race faces, then they should require exposure to more variability in the appearance of other-race faces than in the appearance of own-race faces to become familiar. In addition, my Study 2 suggests that although when specific other-race identities become familiar, perceivers can form an abstract representation allowing recognition across natural variations in appearance, such perceptual learning is identity-specific and does not generalize to the whole other-race category. This result suggests that perhaps familiarity with just a few other-race exemplars does not add dimensions to face space. Future studies should examine whether training participants to gain sensitivity to some dimensions in the face space can facilitate the learning of other neighboring dimensions. For example, one could examine whether learning a set of similar looking other-race identities would help perceivers to generalize this familiarity to the other novel identities who look similar to the learned identities, but not to dissimilar looking identities.

My Study 4 suggested that one possible source of the reliable other-race effect is that perceivers are less sensitive to the shape and texture cues in own- and other-race faces. Future studies should directly test this hypothesis and examine how perceivers' encoding and recognition of own- and other-race faces changes as a function of continuous change in the caricaturing level. If participants are less sensitive to the shape and texture cues in other- than own-race faces, perceivers would need greater caricaturing levels to recognize other-than own-race faces (e.g., the hits for 30% texture caricatured own-race faces might be equal to the hits for 60% texture caricatured other-race faces). Such a finding would confirm that the ORE is driven by quantitative, rather than qualitative, differences in the processing of own- and other-race faces.

The finding that perceivers are inefficient in rapidly consolidating other-race faces into coherent and stable representations in VWM is consistent with a large body of electrophysiological studies as well as studies using different memory paradigms (e.g., old/new face recognition task, change blindness paradigm). Past studies examining visual working memory for simple objects have suggested that the visual working memory is highly limited in capacity and the memory performance decays as a function of the set size (Luck et al., 2013). However, I did not directly test how capacity of visual working memory for own- and other-race faces changes with the increase of the set size (e.g., I did not manipulate the number of faces that need to be maintained in the visual working memory). This is another question that is worthy of examination. My normality study (Study 3) suggest that the dimensions of face space are less refined for both other-race and older adult faces, two face categories with which adults typically have limited perceptual experience. Despite this similarity, other-race faces and older adult faces differ in some ways. Whereas race is a stable characteristic across lifespan, age continuously changes. It would be interesting to examine in the future studies that how different perceptual experience with these face categories (e.g., other-race and other-age faces) shapes the capacity and the fidelity of visual working memory for these face representations.

7.5 Conclusions

In summary, the results of this dissertation provide evidence that the other-race effect is not only attributable to impairments in the discrimination of other-race faces; it also reflects impairments in perceivers' ability to recognize unfamiliar other-race faces despite changes in appearance. The other-race effect is modulated by familiarity: when a specific other-race identity becomes familiar, perceivers can form an abstract representation allowing recognition across natural variation in appearance. Limited perceptual experience with other-race faces makes the dimensions of face space less refined for these faces and influences the efficiency with which other-race faces are rapidly consolidated into coherent and stable representations in visual working memory. Despite being less efficient in learning other- than own-race faces, the transition from shape to texture cues is comparable for own- and other-race faces, suggesting that the use of shape and texture cues are not qualitatively differ for own- and other-race faces. These commonalities and differences in the processing and encoding of own- and other-race faces help elucidate the cognitive mechanism underlying the other-race effect. In the context of multiculturalism and globalization, these findings have broad theoretical implications for perceptual expertise accounts of ORE and profound practical implications for eye-witness testimony and social interactions.

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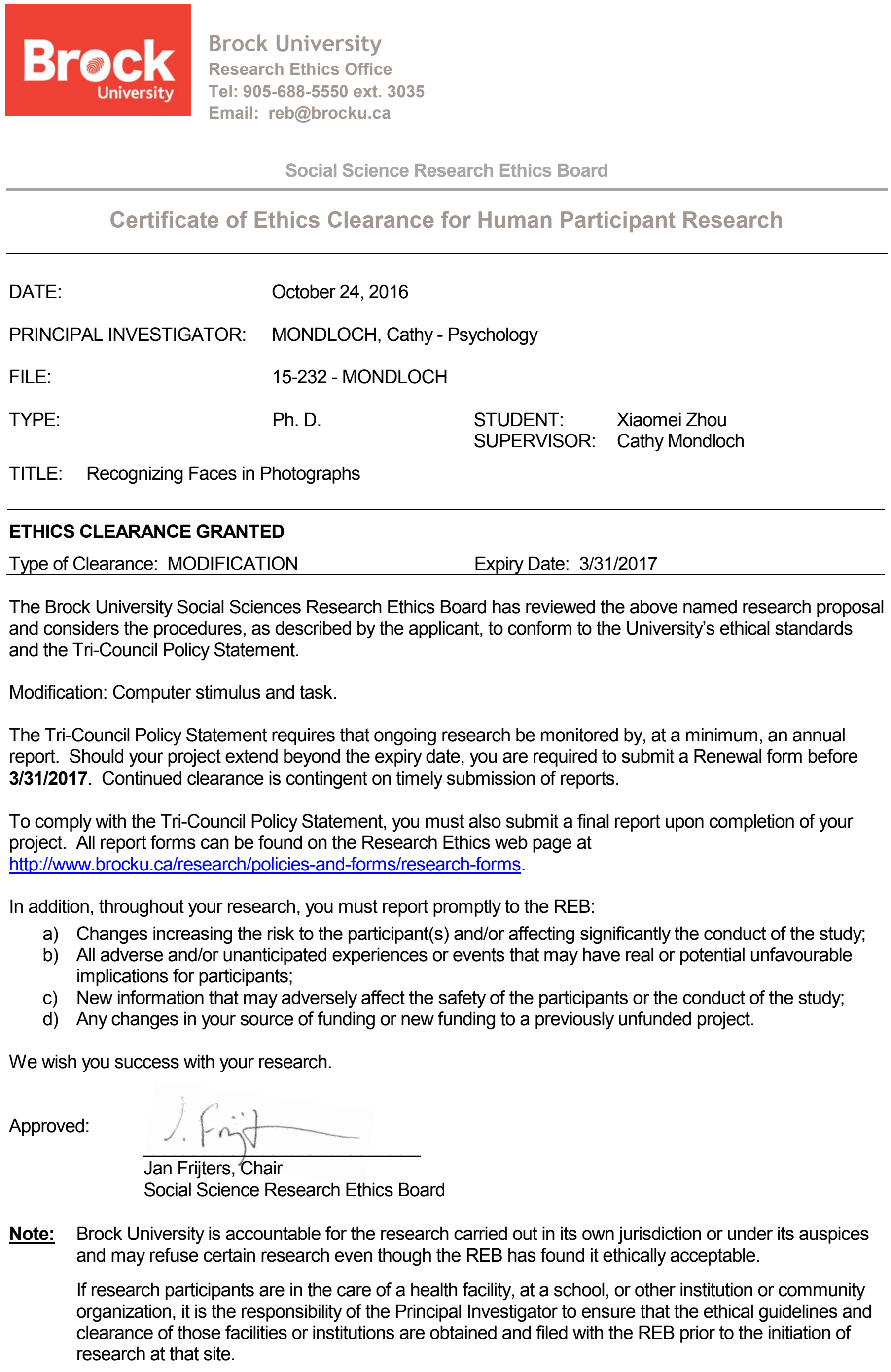
Appendix 1



Brock University
Research Ethics Office
Tel: 905-688-5550 ext. 3035
Email: reb@brocku.ca

Social Science Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE: October 24, 2016

PRINCIPAL INVESTIGATOR: MONDLOCH, Cathy - Psychology

FILE: 15-232 - MONDLOCH

TYPE: Ph. D.

STUDENT: Xiaomei Zhou
SUPERVISOR: Cathy Mondloch

TITLE: Recognizing Faces in Photographs

ETHICS CLEARANCE GRANTED

Type of Clearance: MODIFICATION

Expiry Date: 3/31/2017

The Brock University Social Sciences Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement.

Modification: Computer stimulus and task.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before **3/31/2017**. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at http://www.brocku.ca/research/policies-and-forms/research-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved: ________________________________
Jan Frijters, Chair
Social Science Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.

Appendix 2

Participant #______

DOT ________________

QUESTIONNAIRE: RACE

Thank you for participating in our research. We recognize that individuals may differ in their ability to recognize faces. Some of these differences may be attributable to how much we experience different kinds of faces on a daily basis. Please take a few moments to complete the following questionnaire.

Your responses will be confidential.

PERSONAL INFORMATION

1. **Date of birth**: …………………………………..……………………………….

2. **Mark your ethnic group:**

   - ☐ Caucasican
   - ☐ Asian
   - ☐ Aboriginal
   - ☐ African Canadian
   - ☐ Other (Please specify) ___________________________

3. How many people live in your household (<u>including</u> yourself):

   a) Home _________
   b) University __________

4. Please indicate how many of those people (both at home and at University) are in each of the following groups:

   a) Caucasian _________
   b) East Asian __________

5. Think about family members with whom you have regular contact (at least once per month). How many of those people are in each of the following ehtnic groups:

   a) Caucasian _________
   b) East Asian __________

6. Please estimate how many hours you usually spend per week interacting with people in each of the following groups:

a) Caucasian __________
b) East Asian ___________

7. With how many East Asian adults do you have contact in a typical week?

____

8. In your opinion, in the last 5 years, how much experience have you had with East Asian individuals?

1	2	3	4	5
minimal	some	moderate	a lot	extensive

9. Think of up to 10 friends with whom you spend the most time. Of these 10 friends:

How many are Caucasian? ________
How many are East Asian? ________
How many are any other race outside of Caucasian and East Asian? ________

10. Please write down the FIRST NAME (only) of up to 10 East Asian friends:

____

____

____

11. Please provide any additional information that would indicate extensive experience with East Asian individuals.

Appendix 3

Familiarity Questionnaire

a) Demographic Information

Age (in years): _________

Sex (circle one): Female Male

Ethnicity (e.g. White, Black, Asian): _________________________________

First Language: _________________________________

b) Familiarity Information

Were any of the faces in the experiment familiar? Please circle
Yes / No
If yes, please indicate the name/s* of the individual/s that you recognised:

____

____

*If you can't recall a name then please write down other information related to that person e.g. actor from a Harry Potter film.

Appendix 4

Participant #______

QUESTIONNAIRE: AGE

DOT _______________

Thank you for participating in our research. We recognize that individuals may differ in their ability to recognize faces. Some of these differences may be attributable to how much we experience different kinds of faces on a daily basis. Please take a few moments to complete the following questionnaire.

Your responses will be confidential.

PERSONAL INFORMATION

1. **Date of birth**: …………………………………..……………………………….

2. **Mark your ethnic group:**

☐ Caucasican
☐ Asian
☐ Aboriginal
☐ African Canadian
☐ Other (Please specify) ___________________________

3. How many people live in your household (<u>including</u> yourself):

a) Home _________

b) University _________

4. Please indicate how many those people are in each of the following age groups:

a) Child (< 10) ____________
b) Adolescent (11 – 17) ________
c) Young adult (18 – 35) _________
d) Middle adult (35 – 55) __________
e) Older adult (56 – 80) __________

5. Think about family members with whom you have regular contact (at least once per month). How many of those people are in each of the following age groups:

a) Young adult (18 – 35) __________
b) Middle adult (35 – 55) ___________
c) Older adult (56 – 80) ___________

6. Please estimate how many hours you usually spend per week interacting with people in each of the following age groups:

a) Young adult (18 – 35) __________
b) Middle adult (35 – 55) ___________
c) Older adult (56 – 80) __________

7. How many older adults (60 to 90 years old) you have contact with in a typical week?

____

8. In your opinion, in the last 5 years, how much experience have you had with people between the ages of

60 and 90 years?

1	2	3	4	5
minimal	some	moderate	a lot	extensive

9. Please provide any additional information that would indicate extensive experience with older adults (ages 60 to 90).

Appendix 5

Occupation list used in Study 4

Accountant	Lawyer
Architect	Librarian
Artist	Mechanic
Athlete	Musician
Biologist	Nurse
Carpenter	Optometrist
Cashier	Pharmacist
Photographer	CEO
Chef	Politician
Custodian	Professor
Dentist	Psychiatrist
Director	Receptionist
Salesperson	Doctor
Editor	Scientist
Electrician	Soldier
Engineer	Teacher
Journalist	Veterinarian
Judge	Writer