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Serial dependence of facial identity for own- and other-race faces

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Abstract

It is well established that individuals are better at recognising faces of their own-race compared with other-races; however, there is ongoing debate regarding the perceptual mechanisms that may be involved and therefore sensitive to face-race. Here, we ask whether serial dependence of facial identity, a bias where the perception of a face's identity is biased towards a previously presented face, shows an other-race effect. Serial dependence is associated with face recognition ability and appears to operate on high-level, face-selective representations, like other candidate mechanisms (e.g., holistic processing). We therefore expected to find an other-race effect for serial dependence for our Caucasian and Asian participants. While participants showed robust effects of serial dependence for all faces, only Caucasian participants showed stronger serial dependence for own-race faces. Intriguingly, we found that individual variation in own-race, but not other-race, serial dependence was significantly associated with face recognition abilities. Preliminary evidence also suggested that other-race contact is associated with other-race serial dependence. In conclusion, though we did not find an overall difference in serial dependence for own- versus other-race faces in both participant groups, our results highlight that this bias may be functionally different for own- versus other-race faces and sensitive to racial experience.

Keywords

Serial dependence; facial identity; other-race effect; face recognition

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Individuals are significantly better at recognising own-race faces compared with other-race faces, a phenomenon called the other-race effect (for a meta-analysis, see Meissner & Brigham, 2001). The other-race effect is typically assessed via unfamiliar face recognition memory (Meissner & Brigham, 2001); however, other race-effects have also been found in tasks that do not involve memory, such as face discrimination (Walker & Tanaka, 2003), face matching (Megreya et al., 2011), face categorisation (Thorup et al., 2018), and even judgements of eye gaze direction (Collova et al., 2017), highlighting that this effect is common throughout unfamiliar face perception. The other-race effect can also have real-world implications. For example, within the criminal justice system, wrongful convictions have been found to occur due to incorrectly identifying an individual of a different race (Dioso-Villa, 2015; Gross et al., 2017). Day-to-day, the other-race effect can also impact socialisation between individuals from different races. McKone et al. (2021) recently found that Asian individuals who were international students at a predominantly Caucasian university reported problems in recognising Caucasian individuals as well as being recognised by Caucasian individuals, both of which contributed to socialisation difficulties. These real-world implications of the other-race effect mean that it is important to understand the underlying causes of this effect in face perception.

Two types of theories have been put forward as potential (though not mutually exclusive) explanations for the other-race effect: social–motivational theories and experience-based perceptual theories. Social–motivational theories suggest that other-race faces are not as socially important as own-race faces, therefore, despite being able to, individuals do not individuate other-race faces (Hugenberg et al., 2007; Meissner et al., 2005; Sporer, 2001). These types of theories predict that the other-race

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effect could be overcome in situations where motivation to individuate other-race individuals is the same as own-race individuals (Wan et al., 2015). However, the other-race effect has still been found to be present in cultural settings in the absence of a social-motivational discrepancy between races, suggesting that social-motivational theories cannot purely account for the other-race effect in face perception (Wan et al., 2015).

In contrast to social-motivational theories, experience-based perceptual theories suggest that we have greater perceptual expertise for own-race faces compared with other-race faces (Lebrecht et al., 2009; Rossion & Michel, 2011; Tanaka et al., 2013). It is argued that we gain this expertise for own-race faces through experience, which tunes the perceptual mechanisms underlying face processing to more selectively respond to own-race faces (De Heering et al., 2010; Lee et al., 2011; Rossion & Michel, 2011). Consistent with this, research has found that greater other-race experience is associated with a smaller other-race effect in face perception (Chiroro & Valentine, 1995; Hancock & Rhodes, 2008; Rhodes et al., 2009; Thorup et al., 2018; Walker & Hewstone, 2006). Further, when motivation is consistent towards own- and other-races, an other-race effect has been observed that is purely due to a lack of perceptual expertise with other-race faces (Wan et al., 2015). Therefore, it is likely that the other-race effect is, at least in part, due to perceptual expertise.

Researchers have therefore examined the mechanisms that might be tuned by experience to operate more selectively for own-race faces. While various factors could be associated with the other-race effect (e.g., sensitivity to feature shape and spacing, Mondloch et al., 2010; and visual working memory, Nishimura et al., 2021; Zhou et al., 2018), researchers have generally focused on perceptual mechanisms that have been shown to be functional in face-processing, like holistic processing and adaptive norm-based coding. The perceptual expertise account also predicts that these face-processing mechanisms would be sensitive to face-race and racial experiences, in that they would be more specialised for own-race faces due to our greater experience with own-race faces. Overall, the majority of research examining the perceptual mechanisms that may be contributing to the other-race effect has examined holistic processing. Holistic processing, the processing of a face as a single perceptual representation instead of a collection of individual features (Rossion, 2008, 2009), is suggested to underlie face expertise and has previously been found to contribute to face recognition abilities, such that greater holistic processing is associated with better (own-race) face recognition (DeGutis, Wilmer, et al., 2013; Engfors et al., 2017; Richler et al., 2011; Wang et al., 2012). Further, holistic processing is found to be greater for own-race faces compared with other-race faces (Degutis, Mercado, et al., 2013; Michel, Caldara, & Rossion, 2006; Michel, Rossion, et al., 2006; Tanaka et al., 2004), leading to suggestions that weaker holistic processing for other-race faces leads to poorer recognition of these faces (Rossion & Michel, 2011). However, the role of holistic processing both in face recognition and the other-race effect is still somewhat debated (Hayward et al., 2013; Konar et al., 2010; Richler et al., 2014, 2015; Zhao et al., 2014). Some researchers have found that holistic processing shows no sensitivity to face-race (e.g., Mondloch et al., 2010), while others have instead suggested that the other-race effect in holistic processing may only be observed in Caucasian participants (e.g., Crookes et al., 2013). Therefore, the research is mixed as to the exact role of holistic processing in the other-race effect.

Another face-processing mechanism examined in relation to the other-race effect is adaptive norm-based coding, whereby subtle variations in the attributes of faces are coded relative to norms reflecting the average of previously encountered faces (Rhodes & Leopold, 2011; Valentine, 1991). Like holistic processing, adaptive norm-based coding (as measured through face identity aftereffects) is found to be associated with face recognition abilities (Engfors et al., 2017; Rhodes et al., 2014; Turbett et al., 2019). Opposite aftereffects have been found to occur for own- and other-race faces, whereby the perception of own- and other-race faces was simultaneously biased in opposing directions, suggesting the existence of race-specific norms (Jaquet et al., 2007, 2008). Research has also suggested that faces are coded relative to race-specific norms and not a more general norm (Armann et al., 2011), indicating that adaptive norm-based coding is sensitive to face-race. Further, adaptive norm-based coding for own-race faces has also been found to be associated with own-race face expertise (Rhodes et al., 2014), suggesting that this process may also play a role in the other-race effect.

Given there is evidence suggesting that perceptual mechanisms found to be important to face recognition (like holistic processing and adaptive norm-based coding) may be sensitive to race, this raises the question of whether other face-mechanisms similarly show an other-race effect. Here we asked whether serial dependence, a mechanism recently found to contribute to face recognition (Turbett et al., 2019), operates differently for other-race faces. In serial dependence, current perception is biased towards prior visual input (Fischer & Whitney, 2014). This bias is suggested to have a functional role in vision, increasing the perceptual stability of visual input through the integration of information over brief periods of time (Cicchini et al., 2018; Fischer & Whitney, 2014) and is found for a variety of visual characteristics and objects, including faces. For faces in particular, serial dependence has been observed for a variety of characteristics including attractiveness (Taubert & Alais, 2016; Taubert, Van der Burg, & Alais, 2016; Xia et al., 2016), gender (Taubert, Alais, & Burr, 2016) and identity (Hsu & Lee, 2016; Liberman et al., 2014; Turbett et al., 2019; Turbett, Palermo, et al., 2021).

Serial dependence of facial identity occurs where the perceived identity of a face is biased towards the identity of a previously presented face, such that the second face appears to look more like the first (Liberman et al., 2014). Though serial dependence appears to be ubiquitous in visual perception (Kiyonaga et al., 2017) and may operate at various levels of the visual hierarchy, serial dependence of facial identity appears to operate on high-level face representations and may reflect a face-selective coding mechanism (Liberman et al., 2014; Turbett et al., 2019; Turbett, Palermo, et al., 2021). Two aspects of serial dependence of facial identity have been examined, the strength and the tuning. The strength of serial dependence refers to the magnitude of this bias towards the previous face, where stronger serial dependence indicates that there is a greater bias towards the previously seen face. Tuning instead refers to how the strength of serial dependence varies depending on stimuli similarity. Generally, serial dependence of facial identity appears to be narrowly tuned (i.e., this bias is strongest when sequential faces are *more* similar to one another); however, individual differences are present with some individuals showing serial dependence of facial identity for all faces, regardless of their similarity (broadly tuned; Turbett et al., 2019). It is unknown, however, whether serial dependence of facial identity strength and/or tuning is sensitive to face race.

There are several reasons to expect that serial dependence of facial identity would be sensitive to other-race effects. First, this bias is found to contribute to face recognition abilities (Turbett et al., 2019). Specifically, stronger and more narrowly tuned serial dependence of facial identity has been found to be associated with better face recognition abilities (Turbett et al., 2019). It is plausible, therefore, that serial dependence would operate more optimally (i.e., is stronger and/or more narrowly tuned) for own-race faces compared with other-race faces, given the relatively greater recognition performance for own-race faces (Meissner & Brigham, 2001).

Second, serial dependence of facial identity is sensitive to face inversion, such that this bias is stronger and more narrowly tuned for upright than inverted faces (Turbett, Palermo, et al., 2021). Sensitivity to inversion is argued to arise due to face-coding mechanisms becoming selective for the face configuration most commonly experienced (i.e., near upright; Rossion, 2008, 2009). The sensitivity of serial dependence to inversion may indicate that this perceptual mechanism is likewise tuned by our experience, showing selectivity for the faces that we see typically see. Therefore, serial dependence of facial identity may also be sensitive to race and operate more optimally for own-race faces, given we have greater experience with these faces.

The third reason to expect that serial dependence of facial identity may show an other-race effect is that this bias is sensitive to stimuli similarity (Alexi et al., 2018; Cicchini et al., 2018; Liberman et al., 2018). Typically, serial dependence is narrowly tuned and is therefore strongest when faces are more similar to one another and becomes weaker as stimuli differ more substantially. Therefore, factors that affect the similarity (discriminability) of faces are likely to affect serial dependence. This is illustrated by the finding that serial dependence for inverted faces, which are more difficult to discriminate between than upright faces (Diamond & Carey, 1986; Yin, 1969), is more broadly tuned (i.e., greater integration of more dissimilar faces) compared with this bias for upright faces (Turbett, Palermo, et al., 2021). As other-race faces are also more difficult to discriminate between and appear more similar to one another than own-race faces (Byatt & Rhodes, 2004; Walker & Tanaka, 2003), it is plausible that serial dependence may therefore also be sensitive to face–race. Consistent with this view is evidence that assimilation effects in judgements of facial attractiveness are more robust to stimulus differences (changes in gender) for other-race compared with own-race faces (Kramer et al., 2013).

The present study examined the effects of face-race on serial dependence of facial identity in Caucasian and Asian individuals. We used a previously developed serial dependence task that features Caucasian faces (Turbett et al., 2019) and developed a new version featuring Asian faces. To date, serial dependence of facial identity has not yet been tested using other-race faces as stimuli. Given that serial dependence is argued to reflect a general visual processing principle (Kiyonaga et al., 2017), we expected this bias to be present in participants for both own- and other-race faces. Furthermore, if serial dependence of facial identity is sensitive to race, we expected the strength and/or tuning of this bias to differ between own- and other-race faces.

It is less clear, however, whether serial dependence strength would be stronger or weaker for own-race versus other-race faces. Serial dependence could be stronger for *own*-race faces, consistent with evidence that stronger serial dependence is associated with better face recognition performance (Turbett et al., 2019) and that own-race faces are better recognised that other-race faces (Meissner & Brigham, 2001). Such a finding would be in line with the suggestion that stronger serial dependence of facial identity facilitates face perception (Turbett et al., 2019). Alternatively, serial dependence could be stronger for *other*-race faces, consistent with evidence that serial dependence is strongest for more similar stimuli (Cicchini et al., 2018; Liberman et al., 2018; Turbett et al., 2019) and that other-race faces are perceived as more similar to one another and are more difficult to discriminate between than own-race faces (Byatt & Rhodes, 2004; Walker & Tanaka, 2003). Such a result would be consistent with Kramer et al. (2013), who found greater assimilation across gender for attractiveness judgements for other-race compared with own-race faces.

Our predictions regarding the effect of race on serial dependence *tuning* were clearer. We expected narrower tuning for own- than other-race faces for two reasons. First, narrower tuning is associated with better face recognition abilities and we are better able to recognise own-race faces. Second, other-race faces are more difficult to discriminate between, so we expected individuals to integrate the identity of less physically similar other-race faces, compared with own-race faces, resulting in broader tuning of other-race faces.

We also included measures of face recognition abilities and racial contact, to ensure that our participant samples showed typical other-race effects in face recognition and differed in their experience with Caucasian and Asian faces. Inclusion of these measures additionally allowed us to replicate the previous finding that serial dependence of Caucasian faces is associated with face recognition ability in participants who had lived in a Caucasian country for at least 10 years (and therefore had sufficient experience with Caucasian faces; Turbett et al., 2019), and to test whether this finding extends to Asian participants viewing Asian faces. Inclusion of the other-race questionnaire allowed us to ask whether other-race contact was associated with serial dependence of facial identity. Previous research has found that greater other-race contact reduces the magnitude of other race-effects in face perception (Chiroro & Valentine, 1995; Hancock & Rhodes, 2008; Rhodes et al., 2009; Thorup et al., 2018; Walker & Hewstone, 2006; Wan et al., 2015). We measured own- and other-race face recognition abilities, using a Caucasian (McKone et al., 2011) and Asian (McKone et al., 2012) version of the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006) and a measure of racial contact that was developed by Hancock and Rhodes (2008).

Method

Participants

Overall, moderate effect sizes have previously been found when examining the other-race effect in face recognition (Meissner & Brigham, 2001). Therefore, an a priori power analysis (conducted using G*Power 3; Faul et al., 2007) determined that a sample of 52 participants per ethnicity group would be sufficient for within-subjects analyses to detect moderate effects of $d=0.40$ at 80% power. Within each ethnicity, additional participants beyond this were tested to ensure an adequate sample size was maintained should some participants fail to recognise the stimuli sufficiently to allow successful completion of both the own- and other-race serial dependence of facial identity tasks.

Sixty-five Caucasian undergraduate students from the University of Western Australia (UWA) participated in the current experiment for course credit. Nine participants were removed from the final analyses: three because they reported non-Caucasian ethnicity and six because they were unable to learn the Asian faces ($n=5$) or both the Caucasian and Asian ($n=1$) faces at the beginning of the serial dependence tasks (an a priori determined criterion of performing at less than 75% during training; as in Turbett et al., 2019). The final Caucasian sample consisted of 56 participants (37 female, $M=19.83$ years, $SD=3.22$). All reported Caucasian ethnicity and were aged between 16 and 32 years old.

Sixty-five Chinese participants were recruited in Hong Kong by researchers at the University of Hong Kong (HKU). Of these participants, 55 were undergraduate students from HKU who participated for course credit and 10 were adult participants paid HK$75 for their participation. One participant was removed from the final analyses because they were unable to learn the Asian faces at the beginning of the serial dependence task. The final Asian sample consisted of 64 participants (48 female, $M=19.59$, $SD=2.72$). All reported Chinese ethnicity and were aged between 17 and 28 years old.

Tasks

Serial dependence of Caucasian Facial Identity Task. This task has been used previously to examine the strength and tuning of serial dependence of facial identity for Caucasian faces (Turbett et al., 2019; Turbett, Jeffery, et al., 2022; Turbett, Palermo, et al., 2021). Some of the following detail regarding the task methodology and variable calculation was taken from Turbett et al. (2019). Participants were first trained to identify four faces, two male ("Tim" and "Jon") and two female ("Mel" and "Sue"), from a left 1/4 profile and frontal view (stimuli from the Radboud Faces Database; Langner et al., 2010). Within each gender pair, the faces were morphed together, using Abrosoft FantaMorph 5 Deluxe (version 5.4.8), to produce a continuum of 23 faces, with each face differing from the next by 4% (face morphs ranged from 6% to 94%). Higher percentages reflect faces that were more like Jon and Sue (for male and female faces, respectively). After participants had learnt the target faces, they were trained on weaker strength versions of each face (faces ±20% from the average, 50%, face). These weaker faces were presented as "siblings" to highlight the similarity between the four identities and the corresponding weaker strength version.

On each trial of the serial dependence task (for trial schematic, see Figure 1a), participants were presented with a face (300 ms), followed by a visual noise mask (500 ms), an inter-stimulus interval (500 ms), a second (target) face (300 ms), and finally a second visual noise mask (500 ms). Participants were then asked to identify the second (target) face as either Tim, Jon, Mel, or Sue by pressing one of four labelled keys. Following their

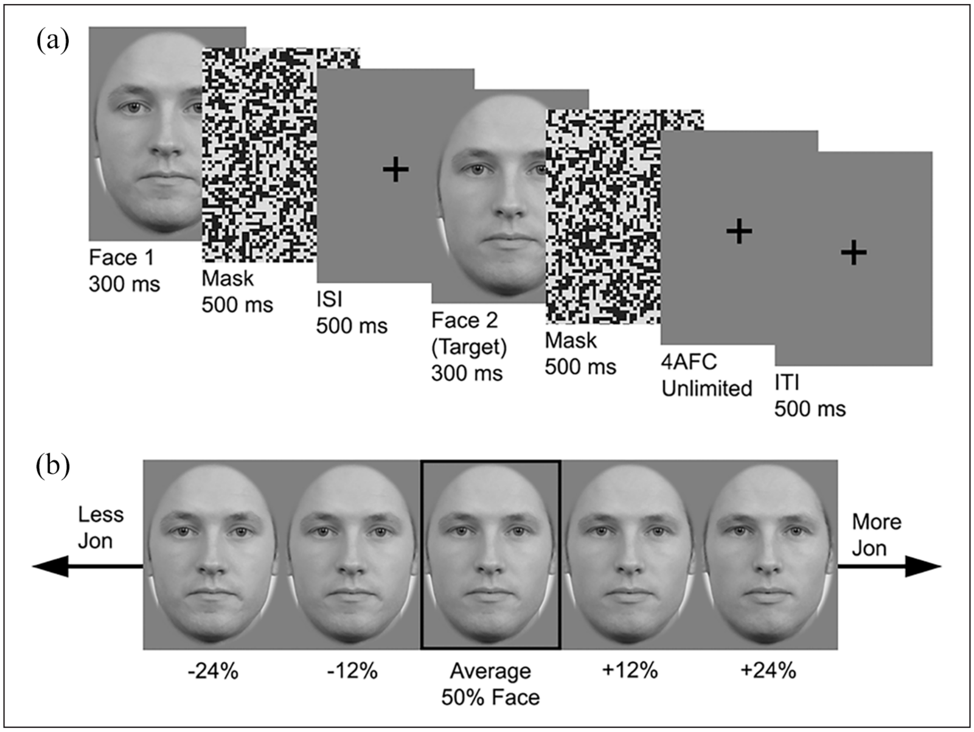

Figure 1. Experiment trial sequence and possible differences between Face 1 and Face 2.
(a) Schematic showing one trial. On each trial, participants were presented with a face (300 ms), followed by a visual noise mask (500 ms) and inter-stimulus interval (500 ms). Participants are then presented with a second face (300 ms) that, following a visual noise mask (500 ms), they are asked to identify. Following their response, there was an inter-trial interval (500 ms). (b) Example differences between Face 1 and Face 2. In Figure 1b, the centre face in the black box is the average 50% face which could appear as Face 2. The images surrounding it are the four possible Face 1 stimuli for when Face 2 was the average 50% face. The two faces to the left are less Jon (−24% or −12%) and the two faces to the right are more Jon (+12% and +24%). In this example, it would be expected that the proportion of Jon responses to the average 50% centre face would decrease when Face 1 is less Jon and increase when Face 1 is more Jon. Morph identities were created using images obtained with permission from the Radboud Faces Database (Langner et al., 2010). Figure and caption from Turbett et al. (2019), licenced under CC BY 4.0.

response, a fixation cross was presented (500 ms) prior to the start of the next trial. Within each trial, Face 2 was one of the 11 faces from the middle of the morph continuum that ranged between 30% and 70% in morph identity strength. On each trial, Face 1 differed from Face 2 in one of four ways: −24%, −12%, +12%, or +24%, with each of these differences occurring in a quarter of the trials (see Figure 1b, for example). Face 1 could be any of the 23 morphs between the two identities.

There were 176 trials, presented in a pseudorandom order so that the expected perceived identity of Face 2 was not the same for more than four consecutive trials. Gender and viewpoint did not vary within a trial. Half of the trials used male faces and half of the trials were forward-facing. The trials were divided into 4 blocks of 44 trials to provide participants with regular breaks. Overall, the task (including the training stage) took approximately 25 min to complete.

Face 1 subtended an average visual angle of 9.1° (v) × 6.7° (h) when viewed from approximately 60 cm while Face 2 was smaller, 8.2° (v) × 6.0° (h), to reduce low-level retinotopic effects. The visual noise masks following each face were 16 unique, binary noise images, 12° (v) × 12° (h), luminance balanced relative to the grey screen and scaled to match the minimum and maximum luminance of the faces used within the study. These masks were included to reduce the visible persistence of the test stimuli.

Serial dependence of Asian facial identity. This task was designed for the current study and was identical to the Caucasian task; however Chinese faces from the HKU Visual Cognition Lab Face Database were instead used as stimuli. The pairs of male and female faces were selected to be as similar to each other for Asian individuals as the Caucasian faces were for Caucasian individuals (see Supplementary Materials for stimuli selection). The male faces were named "Peng" and "Kun" and the female faces were "Wen" and "Lu." These names were selected by a Chinese speaker as they were common, one syllable names that each began with a different letter.

Similarity ratings of Caucasian and Asian stimuli. The stimuli for the Asian serial dependence task were chosen based on similarity ratings from a pilot sample to match the similarity of the Caucasian and Asian pairs for own-race perceivers (see Supplementary Materials). We sought to confirm that the similarity of the stimuli was also matched in the study proper. Participants rated the similarity of the male and female face pairs used in the Caucasian and Asian serial dependence of facial identity tasks. Participants viewed the faces for an unlimited time and rated the similarity of each pair using a seven-point Likert-type scale, ranging from *not at all similar* to *very similar*. For each participant, an average similarity rating for Caucasian and Asian faces was calculated.

CFMT for Caucasian Australian faces. The CFMT for Caucasian Australian Faces (CFMT-Caucasian) is a measure of face recognition ability based on the original CFMT (Duchaine & Nakayama, 2006) and includes faces that are better matched to the European ethnicity typical in Australia (McKone et al., 2011). In this task, participants learn to identify six male faces from three viewpoints. Over three test stages, participants are then presented with three faces and asked to select which face they had previously seen (one target and two distractors). In the first test stage, the target faces were identical to the originally learnt faces. In the second stage, the target faces were presented in differing lighting conditions or viewpoints. The final stage was identical to the second, however with visual noise added to the faces. Percentage accuracy on the CFMT-Caucasian was used as an estimate of Caucasian face recognition ability.

CFMT for Asian Chinese faces. The CFMT for Asian Chinese Faces (CFMT-Asian) is identical to the CFMT-Caucasian; however Asian (Chinese) faces are used instead of Caucasian (Australian) faces (McKone et al., 2012). Percentage accuracy on the CFMT-Asian was used as an estimate of Asian face recognition ability.

Race Contact Questionnaire. This self-report questionnaire measured contact with Caucasian and Asian individuals (and therefore exposure to faces from theseraces; Hancock & Rhodes, 2008). The questionnaire included 14 statements, half assessing contact with Caucasian individuals and half assessing contact with Asian individuals, for example, "I know lots of Asian[/Caucasian] people." Participants rated each item using a six-point Likert-type scale, ranging from *very strongly disagree* to *very strongly agree*. For each individual, the average response to Caucasian and Asian items was taken as the measure of own- and other-race contact.

Procedure

The Caucasian participants were tested at UWA. They were seated approximately 60 cm from a 21.5-in. iMac (1,920 × 1,080 resolution). The Asian participants were tested at HKU. They were seated approximately 65 cm from a 19-in. PC (1,440 × 900 resolution). Participants were tested individually in a 1 to 1.5-hr session with regular breaks. After informed consent had been obtained, participants first completed the two serial dependence tasks (both programmed and presented via SuperLab 4.5, Cedrus Corp), with the order of the own- and other-race tasks counterbalanced across participants. Following this, participants then completed the two face recognition tasks, with the order again counterbalanced across participants. Finally, participants completed a demographic questionnaire, similarity ratings of the faces used in both serial dependence tasks, and the racial contact questionnaire. Participants were debriefed at the end of the session. The experimental procedure was approved by the University of Western Australia's Human Research Ethics Committee and was performed in accordance to their guidelines and regulations.

Results

Calculation of serial dependence values

Serial dependence of facial identity strength and tuning were calculated the same for both the Caucasian and Asian versions of the task. Using the example of the Caucasian task, within each trial, differences of −24% and −12% between Face 1 and Face 2 indicate Face 1 was less like Jon/Sue, while differences of +12% and +24% indicate that Face 1 was more like Jon/Sue. Serial dependence was expected to bias perception of identity towards the previously seen face, we therefore expected a larger proportion of Jon/Sue responses to Face 2 when Face 1 was more like Jon/Sue (i.e., differed by +12% and +24%) and a smaller proportion of Jon/Sue responses to Face 2 when Face 1 was less like Jon/Sue (i.e., differed by −24% and −12%).

Serial dependence is typically strongest when stimuli are more similar (Alexi et al., 2018; Cicchini et al., 2018; Turbett et al., 2019), therefore to calculate the strength of serial dependence of facial identity, a linear regression (as in Alexi et al., 2018; Cicchini et al., 2014, 2018; Turbett et al., 2019; Turbett, Jeffery, et al., 2022; Turbett, Palermo, et al., 2021) was fit to the ±12% trials (trials where Face 1 and Face 2 were closer together on the morph continuum and more similar to one another, see Figure 2). A positive gradient indicated individuals were biased towards the previous identity consistent with serial dependence, a value of zero indicated no bias, while a negative value indicated that individuals were biased away from the previous identity, consistent with adaptation.

We calculated a tuning value for serial dependence to characterise the range that each individual used serial dependence, depending on how similar Faces 1

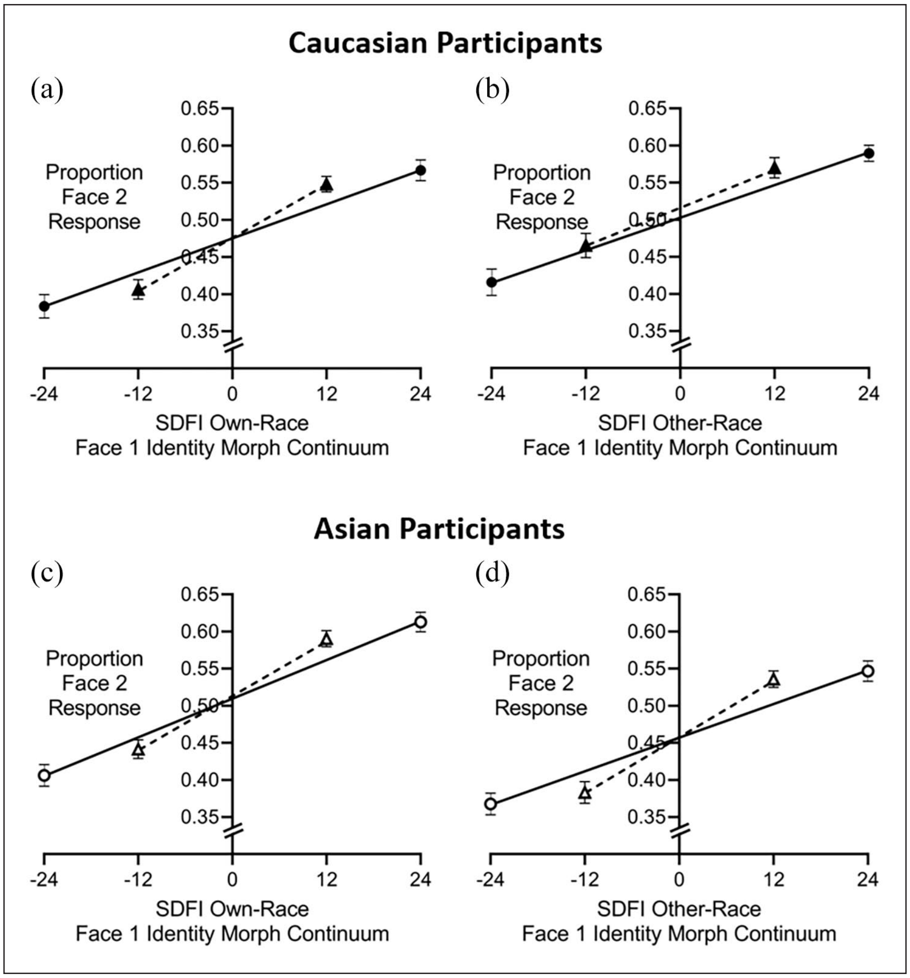

Figure 2. Group mean responses as a function of the percentage difference between Face 1 and Face 2 separately for the same and different orientation trials.

(a) Caucasian participant's linear regressions for own-race faces (±12% slope = .006; ±24% slope = .004). (b) Caucasian participant's linear regressions for other-race faces (±12% slope = .004; ±24% slope = .004). (c) Asian participant's linear regressions for own-race faces (±12% slope = .006; ±24% slope = .004). (d) Asian participant's linear regressions for other-race faces (±12% slope = .006; ±24% slope = .004). Regression slopes fit to the group means for illustrative purposes. Error bars represent standard error of the mean. A linear regression was fit separately for when Face 1 and 2 were more similar (±12%; inner triangle data points and dashed line) and for when they were less similar (±24%; outer circle data points and solid line). A larger, positive gradient indicates stronger serial dependence.

and 2 were. This value quantified whether serial dependence was greatest for more similar stimuli, or whether it was used across a broader range of faces and the extent that this occurred. The tuning value was calculated by subtracting the gradient for the dissimilar faces (calculated by fitting a linear regression to the ±24 trials) from the gradient for the similar faces (as in Turbett et al., 2019; Turbett, Jeffery, et al., 2022; Turbett, Palermo, et al., 2021, see Figure 2). A larger, positive tuning value indicates greater serial dependence for similar faces than dissimilar faces (narrower tuning) while a value closer to zero or a negative value indicates that serial dependence increased as dissimilarity increased (broader tuning).

Distribution

No univariate outliers (scores 2.2 times the interquartile range, as suggested by Hoaglin & Iglewicz, 1987) were identified. All variables were normally distributed (skew less than |2| and kurtosis less than |9|; Gignac, 2019). Descriptive statistics are reported in Table 1, see Supplementary Materials (Table S5) for descriptive statistics collapsed across participant ethnicity.

Preliminary analyses

Racial contact for own- and other-races. Overall, participants showed significantly greater own-race than

Table 1. Descriptive statistics for all measures for both the Caucasian and Asian participants.

Task	Min	Max	*M*	*SD*	Skew	Kurtosis
Caucasian participants (*N*=56)						
Own SDFI strength	−0.007	0.014	0.006	0.005	−0.521	−0.260
Other SDFI strength	−0.009	0.014	0.004	0.005	−0.289	−0.405
Own SDFI tuning	−0.011	0.011	0.002	0.005	−0.527	0.163
Other SDFI tuning	−0.010	0.010	0.001	0.005	−0.202	−0.682
Own CFMT	43.06	94.44	76.02	11.55	−0.519	0.221
Other CFMT	48.61	98.61	72.47	11.16	−0.060	−0.063
Own SDFI stimuli similarity	1.13	5.25	3.53	0.930	−0.225	−0.550
Other SDFI stimuli similarity	2.00	6.63	4.72	0.966	−0.558	0.005
Own contact	3.86	6.00	5.32	0.593	−0.891	−0.163
Other contact	1.00	4.29	2.79	0.820	−0.368	−0.582
Other high school contact	1.00	6.00	3.53	1.526	−0.378	−0.873
Asian participants (*N*=64)						
Own SDFI strength	−0.004	0.015	0.006	0.004	0.056	−0.398
Other SDFI strength	−0.008	0.018	0.006	0.005	−0.239	0.693
Own SDFI tuning	−0.008	0.009	0.002	0.004	0.015	−0.782
Other SDFI tuning	−0.006	0.012	0.003	0.004	0.209	0.008
Own CFMT	56.94	94.44	77.73	11.58	−0.153	−1.366
Other CFMT	44.44	87.50	70.46	11.53	−0.472	−0.739
Own SDFI stimuli similarity	2.25	6.13	4.12	0.838	−0.008	−0.333
Other SDFI stimuli similarity	1.75	5.63	3.64	0.909	0.109	−0.246
Own contact	2.29	6.00	5.18	0.765	−1.391	2.393
Other contact	1.00	5.43	2.47	1.027	0.463	−0.070
Other high school contact	1.00	6.00	2.52	1.662	0.818	−0.565

SD: standard deviation; SDFI: Serial Dependence of Facial Identity Task; CFMT: Cambridge Face Memory Test.

other-race contact, $t(118)=20.936$, $p<.001$, $d=1.919$. Numerically, Caucasian participants showed greater other-race contact than Asian participants, and while not significant, $t(117)=1.875$, $p=.063$, $d=0.345$, we note that this difference was moderate in size.

Other-race effects on the CFMT. Participants showed the expected other-race effect in face recognition abilities, with accuracy on own-race CFMT greater than other-race CFMT, $t(119)=6.460$, $p<.001$, $d=0.590$. Better performance on the own-race CFMT was found to be associated with better performance on the other-race CFMT, $r=.665$, $p<.001$. Greater other-race contact was associated with a significantly smaller difference in performance between own- and other-race face recognition abilities, $r\text{s}>-.182$, $p\text{s}<.039$, consistent with previous research (Hancock & Rhodes, 2008; Zhao et al., 2014; see Supplementary Materials, Table S3, for further details).

Serial dependence of facial identity for own- and other-race faces. To determine that serial dependence was present in both participant groups for both tasks we compared the mean gradient from the ±12% trials to zero (which would indicate no bias). Both Caucasian and Asian participants showed significant serial dependence of facial identity for both own- and other-race faces, $t\text{s}>6.562$, $p\text{s}<.001$, $d\text{s}>0.877$, indicating that the Caucasian and Asian serial dependence tasks both produced a significant bias in each participant group.

Stimuli similarity. Overall, both Caucasian and Asian participants rated the Asian faces to be significantly more similar to each other than the Caucasian faces, resulting in a significant difference in how each participant group rated the similarity of their own-race faces, $t(118)=-2.310$, $p=.023$, $d=-0.423$. Mean similarity ratings of Caucasian faces by Caucasian participants ($M=3.53$, $SD=0.93$) were 14% less similar than the mean similarity ratings of Asian faces by Asian participants ($M=4.12$, $SD=0.82$). This was unexpected, given pilot testing data originally found no significant difference in similarity ratings for own-race faces between Caucasian and Asian participants (see Supplementary Materials). It is possible that this discrepancy could be due to differences in sample size ($n=50$ in pilot sample and $n=120$ in current study, though we note the direction of the effect is different in our pilot and current study samples) or participants in the current study having completed the similarity ratings following the serial dependence task.

Does serial dependence differ for own- versus other-race faces?

Our first aim was to examine whether serial dependence differed for own-race versus other-race faces. We first examined serial dependence *strength* (Figure 3a). In Caucasian participants, serial dependence was significantly stronger for own-race faces than for other-race faces, $t(55)=2.152$, $p=.035$, $d=0.288$. However, there was no significant difference between serial dependence strength for own- and other-race faces in Asian participants, $t(63)=-.226$, $p=.822$, $d=-0.028$.

Next, we examined serial dependence of facial identity *tuning* (Figure 3b). In Caucasian participants, no significant difference was found in the tuning of serial dependence for own- versus other-race faces, $t(55)=1.678$, $p=.099$, $d=0.224$, although the direction of the effect was consistent with narrower tuning for own-race faces. Again, no significant differences in the tuning of serial dependence were found in Asian participants, $t(63)=-1.080$, $p=.284$, $d=-0.135$. Instead, Asian participants trended towards showing the opposite pattern to Caucasian participants, where tuning was numerically narrower for other-race faces.[1]

Is serial dependence associated with face recognition abilities?

Our next aim was to examine whether there was a relationship between serial dependence of facial identity and face recognition abilities for own-race and other-race faces. Both Caucasian and Asian participants showed small to large,[2] positive relationships between own-race serial dependence and own-race face recognition abilities (rs $>$ .185, ps $<$ .171; see Table 2). However, only the relationship between own-race tuning and face recognition in Caucasian participants was significant ($r=.343$, $p=.010$). Given the small to medium effects previously found between serial dependence and face recognition abilities (rs $>$ .157; Turbett et al., 2019), we note that the current study is underpowered to detect a significant effect within each of the participant ethnicities.

As both Caucasian and Asian participants showed positive relationships between serial dependence and face recognition, we collapsed across ethnicity. When Caucasian and Asian participants were combined, the relationships between own-race face recognition abilities and both strength ($r=.195$, $p=.033$) and tuning ($r=.259$, $p=.004$) were significant. This result suggests that for own-race faces, both stronger and more narrowly tuned serial dependence is associated with better face recognition abilities. We next examined the relationship between serial dependence and face recognition abilities for other-race faces. No significant relationships were found when examining Caucasian, Asian, or all participants combined (all rs $<$ |.088|, ps $>$ .491), suggesting that other-race serial dependence is not associated with other-race face recognition. This pattern suggests a different relationship between serial dependence and face recognition ability for own- versus other race faces.

To examine this further, we compared the correlations between serial dependence and face recognition abilities for own- versus other-race faces. The Pearson r values were transformed into Z-scores which were compared using one-tailed tests for non-overlapping correlations in dependent groups (Silver et al., 2004). The correlation between serial dependence *strength* and face recognition abilities was not significantly, stronger for own-race faces compared with other-race faces, $Z=1.426$, $p=.077$, but that correlation between *tuning* and face recognition was significantly stronger for own-race than other-race faces, $Z=2.218$, $p=.013$. These results indicate that own-race serial dependence contributes to own-race face recognition abilities to a significantly greater extent than other-race serial dependence does to other-race face recognition abilities.

We additionally examined the relationship between own-race serial and other-race face recognition as well as other-race serial dependence and own-race face recognition abilities (see Table 2). Although we had no hypotheses for these relationships, we found that when collapsed across participant ethnicity there was a medium, positive relationship between own-race serial dependence tuning and other-race face recognition abilities ($r=.214$, $p=.019$). Specifically, narrower tuning of serial dependence for own-race faces was associated with better other-race face recognition abilities. The relationship found for serial dependence strength was not significant, though we note it was also positive and small to medium in size ($r=.146$, $p=.111$). In contrast to this, the relationships between other-race serial dependence and own-race face recognition abilities were both not significant (rs $<$ .070, ps $>$ .449). These results suggest that own-race serial dependence may play a role in face recognition abilities for both own- and other-race faces, whereas serial dependence of other-race faces does not.

Is other-race contact associated with serial dependence?

Finally, our last aim was to examine whether other-race contact is associated with other-race serial dependence. For Caucasian participants, greater other-race contact was significantly associated with both stronger and more narrowly tuned serial dependence for other-race faces (rs $<$ .388, ps $>$ .003; see Table 3). Asian participants, however, showed no relationship between other-race contact and other-race serial dependence strength or tuning (rs $<$ .022, ps $>$ .864).

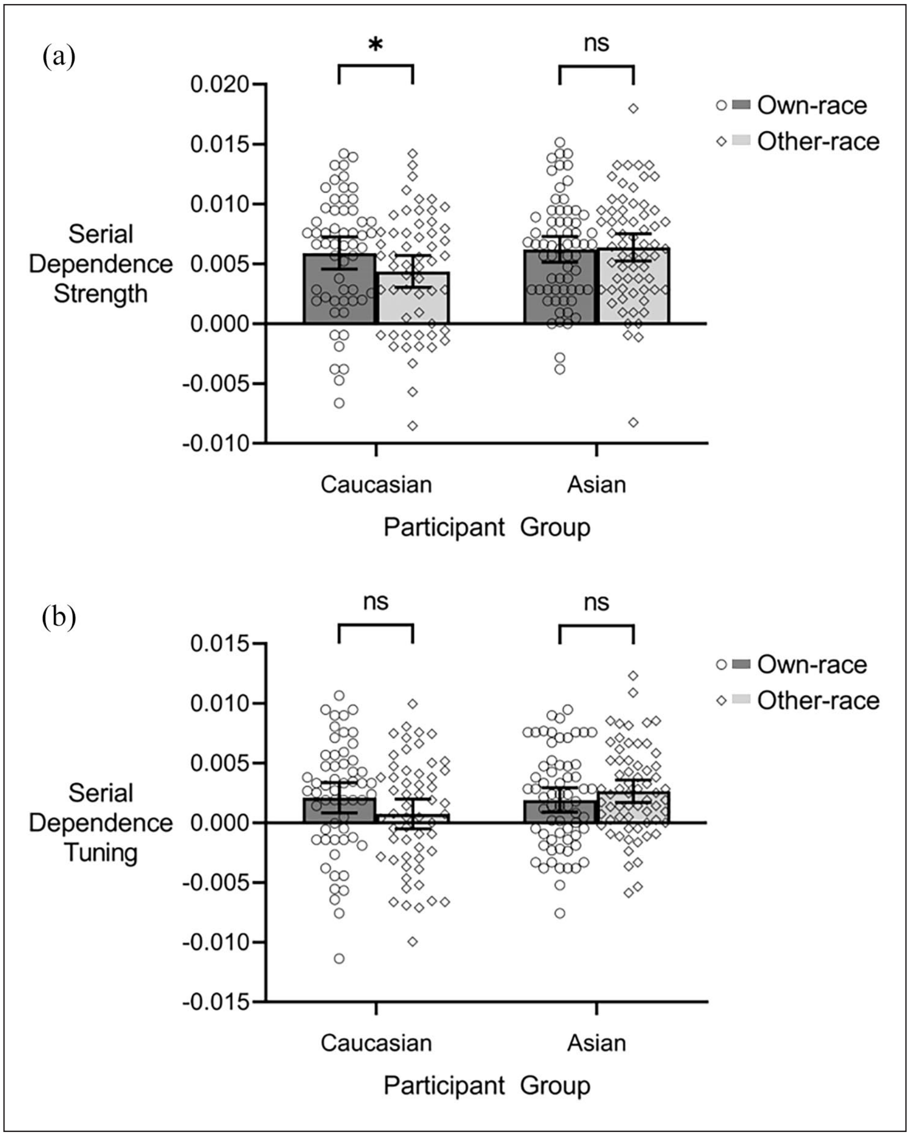

Figure 3. Mean serial dependence of facial identity strength and tuning for own and other-race faces.
(a) Mean serial dependence of facial identity strength for own- and other-race faces. (b) Mean serial dependence of facial identity tuning for own- and other-race faces. Circles and diamonds represent individual participants' serial dependence for own-race faces and other-race faces, respectively. Serial dependence was significantly stronger for own-race faces in Caucasian participants only. No other significant differences between serial dependence for own- and other-race faces were found. Error bars represent 95% confidence intervals.
*$p < .05$.

Recent research has suggested that only childhood other-race experience is associated with improved other-race face recognition, and not adult contact (McKone et al., 2019). Given our questionnaire predominantly assessed current racial contact (Hancock & Rhodes, 2008), we performed follow-up, exploratory analyses using the one item on the questionnaire assessing other-race high school racial contact, "I went to a high school where I interacted with Asian[/Caucasian] students." We note that Caucasian participants had significantly greater other-race high school contact compared with Asian participants, $t(117) = 3.438$, $p < .001$, $d = 0.632$.

When examining high school other-race contact, both Caucasian and Asian participants showed small to large associations between high school other-race contact and other-race serial dependence of facial identity, r_ss > .121, ps < .339 (see Table 3). When we collapsed across participant ethnicity, there was a significant, positive, medium association between other-race high school contact and serial dependence of facial identity *strength*, r_ss = .239, $p = .009$, while the relationship with serial dependence *tuning* was also positive and small to medium in size, although not significant, r_ss = .157, $p = .089$. Overall, these results provide preliminary evidence that greater other-race

Table 2. Pearson correlations between serial dependence of facial identity and face recognition abilities for both own- and other-race faces for Caucasian and Asian participants and collapsed across ethnicity.

	Own CFMT	Other CFMT
Caucasian participants (*N* = 56)		
Own SDFI strength	.185	.180
Own SDFI tuning	.343**	.368**
Other SDFI strength	.082	.074
Other SDFI tuning	.053	−.062
Asian participants (*N* = 64)		
Own SDFI strength	.189	.144
Own SDFI tuning	.185	.088
Other SDFI strength	.039	−.007
Other SDFI tuning	.064	.088
Total sample (*N* = 120)		
Own SDFI strength	.195*	.146
Own SDFI tuning	.259**	.214*
Other SDFI strength	.070	.023
Other SDFI tuning	.070	−.012

Note. SDFI: Serial Dependence of Facial Identity Task; CFMT: Cambridge Face Memory Test.
*$p < .05$, **$p < .01$.

Table 3. Pearson and Spearman's rank correlations between other-race contact and serial dependence of facial identity split for Caucasian and Asian participants and collapsed across ethnicity.

	Other-race contact (*r*)	Other-race contact high school (r_ss)
Caucasian participants (*N* = 56)		
Other SDFI strength	.388**	.315*
Other SDFI tuning	.334*	.349**
Asian participants (*N* = 64)		
Other SDFI strength	.022	.223
Other SDFI tuning	.018	.143
Total sample (*N* = 120)		
Other SDFI strength	.162	.239**
Other SDFI tuning	.126	.167

Note. SDFI: Serial Dependence of Facial Identity Task.
*$p < .05$, **$p < .01$.

contact during high school is associated with stronger, and potentially more narrowly tuned, serial dependence of facial identity for other-race faces.

Discussion

Overall, we found evidence that serial dependence of facial identity is present for both own- and other-race faces in Caucasian and Asian individuals. However, only Caucasian participants showed an expected other-race effect, where serial dependence of facial identity was significantly stronger for own-race faces compared with other-race faces. Caucasian participants also showed a trend for more narrowly tuned serial dependence for own-race faces; however, this was not significant. In contrast to this, no differences in either the strength or tuning of this bias were found in Asian participants. Therefore, our results suggest that serial dependence of facial identity may be sensitive to race in Caucasian, but not Asian, participants (potential reasons for this difference are discussed further below). We additionally found evidence that own-race serial dependence of facial identity is associated with both own- and other-race face recognition abilities and preliminary evidence indicating that other-race contact is associated with serial dependence for other-race faces. These results suggest that serial dependence may operate differently for own- versus other-race faces and that this bias might be sensitive to racial experience.

Importantly, the results here replicate our previous findings of stronger and more narrowly tuned serial dependence of facial identity being associated with better face recognition abilities (Turbett et al., 2019). Further, here we show for the first time that this extends beyond Caucasian stimuli and participants with sufficient experience with Caucasian faces. Here, when we collapsed across ethnicity, own-race serial dependence strength and tuning was significantly associated with own-race face recognition abilities in our overall sample. These results suggest that this relationship is not specific to Caucasian participants, but instead is also present in an Asian sample of participants as examined using Asian face stimuli. Interestingly, in our overall sample when collapsing across participant race, narrower tuned serial dependence of own-race faces was also found to be associated with better *other*-race face recognition abilities. These results indicate that serial dependence of facial identity for own-race faces may play a functional role in both own- and other-race face recognition abilities. In contrast to this, other-race serial dependence was not found to contribute to face recognition abilities for either own- or other-race faces. These results highlight that although serial dependence of facial identity for other-race faces was present, it does not appear to play a functional role in face recognition for either own- or other-race faces. Overall, this suggests that face recognition for both own- and other-race faces may be relying on processes, like serial dependence of facial identity, that are more selective and tuned for own-race faces.

We also found preliminary evidence indicating that other-race contact during high school was associated with stronger, and potentially more narrowly tuned, other-race serial dependence of facial identity. Initially, when overall other-race contact was examined, only Caucasian participants showed significant associations. One potential explanation for this finding is recent suggestions that there is a critical period for faces, where only childhood social contact improves other-race face recognition, while adult social contact does not (McKone et al., 2019). The questionnaire used in the current study primarily focused on *current* adult social contact and included only one question examining *earlier* life other-race contact during high school (Hancock & Rhodes, 2008). While overall there were no significant differences in other-race contact, Caucasian participants had significantly more other-race contact in high school and this may have accounted for the significant relationship found only in Caucasian participants. When we examined the relationship between other-race high school contact and serial dependence in our overall sample, we found that greater contact was associated with stronger and potentially more narrowly tuned other-race serial dependence. This finding suggests that serial dependence of facial identity may be sensitive to prior visual experience, in that this bias becomes more specialised (i.e., stronger and more narrowly tuned) for the types of faces we have greater experience with. Other-race serial dependence of facial identity being more specialised in individuals with greater other-race contact is also consistent with the perceptual expertise account for the other-race effect, as this account suggests that our greater experience with own-race faces is what leads to the perceptual mechanisms underlying face processing becoming more specialised for own-race faces (De Heering et al., 2010; Lee et al., 2011; Rossion & Michel, 2011). The small to moderate relationships found here between other-race contact and other-race serial dependence of facial identity are consistent with a recent meta-analysis examining the relationship between other-race contact and the other-race effect in face recognition (Singh et al., 2022). However, it is important that this finding be replicated as the relationship between early life other-race contact and serial dependence was not originally predicted. Given this, it is recommended that future research measure both primary and high school other-race contact to further examine the relationship between racial contact and serial dependence of facial identity.

As mentioned earlier, the presence of an other-race effect was only found in Caucasian participants. One potential explanation for this is that in previous research examining holistic processing, it is not uncommon to only find a significant other-race effect in Caucasian participants. Specifically, Caucasian participants are typically found to show stronger holistic processing for own-race faces compared with other-race face, whereas Asian participants often show similar holistic processing for both own- and other-race faces (Crookes et al., 2013; Michel, Caldara, et al., 2006; Tanaka et al., 2004). Therefore, it is possible that our finding of significantly stronger serial dependence of facial identity might reflect an effect only present in Caucasian participants.

One caveat to this suggestion is that the perceived similarity of the own- and other-race stimuli was not matched in the current participants. In our study, all participants (regardless of ethnicity) perceived the Asian stimuli to be more similar to one another, despite matching the stimuli based on similarity in initial pilot testing. As serial dependence of facial identity is typically stronger for more similar stimuli (Turbett et al., 2019), it is possible that the greater similarity of the Asian stimuli may have resulted in the lack of effect found in Asian participants or even contributed to the significant effect found in Caucasian participants. However, the direction of the current results is not consistent with this suggestion, as greater stimuli similarity would instead predict stronger serial dependence for Asian faces. Given this, the greater similarity of the Asian stimuli cannot account for either the significant other-race effect in Caucasian participants as serial dependence was stronger for Caucasian faces, or the lack of an other-race effect in Asian participants as this would instead have inflated any potential race effect and no significant effect was found. Therefore, it is unlikely that our current results can be explained as having occurred due to differences in the similarity of the Asian and Caucasian stimuli. Overall, future research would benefit from further examining the contributions of stimuli and participant race to serial dependence of facial identity to better determine whether the effects found here are driven by stimuli similarity or reflect effects only present in Caucasians.

Our current results do highlight two key methodological considerations in other-race face research. First is the importance of obtaining ratings from the participants in the study proper and not solely relying on ratings obtained from a pilot sample, given here we found that these ratings differed. By obtaining ratings from the current participants, we were better able to understand potential stimulus effects on our current results and attempt to control for them. We note, however, that the way the stimuli were presented to obtain the similarity ratings differed from the format the stimuli were presented during the serial dependence task. Specifically, similarity ratings were obtained from participants simultaneously viewing two faces for an unlimited amount of time, whereas during the serial dependence task participants were presented with two faces sequentially for 250 ms. Therefore, future research may benefit from obtaining similarity ratings in a similar format to the task design. Second is that it is crucial to have a cross-cultural comparison to determine whether any effects found extend beyond one group of participants tested. By including a cross-cultural comparison group, this allowed us to more appropriately interpret that the effects found in the current study may be only present in Caucasian participants.

Overall, future research should further examine whether serial dependence of facial identity is sensitive to race using better matched stimuli and a larger sample size. While moderate effect sizes have previously been found in the other-race face recognition literature (Meissner & Brigham, 2001), the effect sizes found in the current study were predominantly small to moderate in size, and therefore smaller than anticipated. Due to this, we were underpowered for analyses within each participant group. While our overall sample was sufficient to detect smaller effects, it was insufficient when we examined Caucasian and Asian participants separately. While our current results suggest that face-race may only have a small to moderate effect on serial dependence of facial identity, future research should use larger sample sizes to further examine the sensitivity of this bias to face–race and the relationships between serial dependence and both face recognition and other-race contact within each ethnicity.

In conclusion, we found an expected other-race effect in Caucasian, but not Asian, participants of stronger serial dependence for own-race faces. This finding is consistent with the suggestion that stronger serial dependence of facial identity facilitates face perception. We also found evidence indicating that own-race serial dependence of facial identity is a functional process for recognition of both own- and other-race faces, whereas other-race serial dependence does not contribute to recognition abilities. Finally, we found preliminary evidence indicating that other-race contact during high school is associated with more specialised other-race serial dependence, suggesting that this bias is altered by our perceptual experiences. Therefore, our results highlight that serial dependence of facial identity may be functionally different for other-race faces and be sensitive to early life racial experiences.

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Supplementary material

The supplementary material is available at qjep.sagepub.com

Notes

1. See Supplementary materials for analyses scaling for differences in stimuli similarity and collapsed across participant ethnicity. In these analyses, no significant differences were found in serial dependence strength or tuning between own- and other-race faces.
2. For individual differences research, it is recommended that correlations of $r = .10$, $r = .20$, and $r = .30$ be considered small, medium, and large, respectively (Gignac & Szodorai, 2016).

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