Received: 9 May 2021 | Accepted: 28 December 2022

DOI: 10.1111/bjop.12629

SPECIAL ISSUE PAPER

Do they 'look' different(ly)? Dynamic face recognition in Malaysians: Chinese, Malays and Indians compared

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Abstract

Previous cross-cultural eye-tracking studies examining face recognition discovered differences in the eye movement strategies that observers employ when perceiving faces. However, it is unclear (1) the degree to which this effect is fundamentally related to culture and (2) to what extent facial physiognomy can account for the differences in looking strategies when scanning own- and other-race faces. In the current study, Malay, Chinese and Indian young adults who live in the same multiracial country performed a modified yes/no recognition task. Participants' recognition accuracy and eye movements were recorded while viewing muted face videos of own- and other-race individuals. Behavioural results revealed a clear own-race advantage in recognition memory, and eye-tracking results showed that the three ethnic race groups adopted dissimilar fixation patterns when perceiving faces. Chinese participants preferentially attended more to the eyes than Indian participants did, while Indian participants made more and longer fixations on the nose than Malay participants did. In addition, we detected statistically significant, though subtle, differences in fixation patterns between the faces of the three races. These findings suggest that the racial differences in face-scanning patterns may be attributed both to culture and to variations in facial physiognomy between races.

KEYWORDS

culture, eye tracking, face recognition, multi-ethnicity, other-race effect

BACKGROUND

Recognizing a familiar face in a crowd is something most people can do effortlessly in a fraction of a second. However, this ability, which we take for granted, is actually so complex that despite many years devoted to the problem its underlying mechanisms are still debated and even robots sometimes cannot readily outperform and replace humans in certain situations (Phillips & O'Toole, 2014; Phillips et al., 2015; Zhao et al., 2003; but see O'Toole et al., 2012; Phillips et al., 2018). Converging evidence from neuroimaging studies has suggested that humans may have evolved specialized perceptual and neural mechanisms devoted to face processing (Eimer, 2011; Kanwisher, 2010; Kanwisher & Yovel, 2006; Kleinschmidt & Cohen, 2006). Despite the adeptness with which facial information can be processed, human recognition accuracy for unfamiliar faces can easily be affected by race.

The own-race bias (ORB; also known as the other-race effect and cross-race effect) refers to the well-documented phenomenon that recognition of own-race faces is more accurate than recognition of other-race faces (Goldinger et al., 2009; Meissner & Brigham, 2001; Sporer, 2001; Walker & Hewstone, 2006; Wright et al., 2003). This is a common phenomenon among individuals who live in primarily mono-racial societies and it emerges not only in adults (Caharel et al., 2011; Tanaka & Pierce, 2009; Walker & Tanaka, 2003) but also in children (Anzures et al., 2014; de Heering et al., 2010) and infants as young as 3 months old (Bar-Haim et al., 2006; Hayden et al., 2007; Kelly et al., 2005, 2008). The robustness of the ORB has also been recently reported in children (Su et al., 2017; Tham et al., 2018) and young adults (Wong et al., 2020, 2021) from a multiracial population. One widely accepted explanation for superior recognition of own-race group faces is interracial contact. Most people have higher levels of contact with their own-race group. This variation in exposure can contribute to the development of visual expertise for own-race faces (Fioravanti-bastos et al., 2014; Goodman et al., 2007). Such visual expertise developed for recognizing individuals of one race group, however, does not necessarily transfer effectively to recognizing individuals of other-race groups. This is supported by the accumulated evidence that the amount of contact that an individual has with another race is positively correlated with their ability to recognize faces of that race (e.g. Chiroro et al., 2008; Kelly et al., 2008; Zhao et al., 2014). In particular, contact at primary school age seems to be key (McKone et al., 2019).

Although different levels of exposure to own- and other-race faces have been widely accepted as a precursor to the ORB, researchers are still attempting to elucidate the specific cognitive mechanisms through which own- and other-race faces are differentially processed. It has been suggested that extensive experience with own-race faces and a relative lack of experience with other-race faces leads to different looking patterns for own- and other-race faces (Liu et al., 2012; Tanaka et al., 2004; Xiao, Xiao, et al., 2013). For example, Liu et al. (2012) demonstrated that when viewing Chinese and Caucasian faces, Chinese infants' fixation duration on the Chinese nose had no significant change, whereas their fixation duration on the Caucasian nose decreased significantly with age. The authors argued that with more experiences with own-race faces, individuals may learn looking strategies that encode and extract critical individuating information from particular features, optimizing recognition ability for own-race faces but not for other-race faces. Most studies claiming to discover cross-race differences in face processing have focused on populations that show a significant separation of culture and geography (e.g. Kelly, Liu, Rodger, et al., 2011; Sangrigoli et al., 2005). Yet, the generalization of results from these studies to other populations living in largely multiracial societies is relatively unknown.

Ethnic differences in face processing

Investigating the underlying attentional strategies people deploy in order to distinguish faces is of specific interest for human social behaviour. Like many basic visual processes, the mechanism underlying face recognition was first considered to be common and universal to all humans until the emergence of eye-tracking methodology. Blais et al. (2008) discovered that Western and East Asian adults who have been raised in different cultural backgrounds exhibit dissimilar-looking patterns during face-processing tasks. More specifically, they found that East Asian adults tended to fixate on the central region of the face, in the nose region, potentially reflecting a holistic face processing style. On the other hand, Western Caucasian adults showed triangular fixation patterns (shifting between the mouth and eye regions) when perceiving faces, suggestive of featural processing of individual features. Differential preferences for holistic versus featural processing styles between East Asians and Westerners were later replicated in a younger population (children aged between 7 and 12 years; Kelly, Jack, et al., 2011). Taken together, these findings support the *enculturation hypothesis* (Blais et al., 2008; Fu et al., 2012) which suggests that the strategies used for face recognition are reflective of a broader cognitive style dominant in their respective cultures (Caldara et al., 2010), which could stem from several sources, including differences in experience, expertise and socialization.

To further assess the extent to which diversity in eye movements is shaped by cultural factors, Kelly, Liu, et al. (2011) investigated looking strategies in a population of British-born Chinese adults by employing face recognition and expression classification tasks. Their results showed that most British-born Chinese observers employed 'Eastern' looking strategies while about 25% of observers used 'Western' strategies. More interestingly, British-born Chinese participants performed equally well at recognizing East Asian and Western Caucasian faces, indicating that increased familiarity with other-race faces enhances recognition abilities. Kelly and colleagues argued that culture alone could not directly account for the diversity in looking patterns; instead, differential experience with faces of different races – in this case, the Caucasian and Chinese faces – during development might also be another critical factor in driving such perceptual differences. It would seem somewhat premature to claim that the key factor that explains the diversity in eye movement strategies is the culture to which participants have been primarily exposed. Not only has recent research demonstrated that exposure to variations in facial physiognomy could drive the differences in face processing (Fu et al., 2012; McKone et al., 2012), but also some studies have failed to detect racial differences in eye movements during face recognition (e.g. Rayner et al., 2007), especially when the individual differences were taken into account (e.g. Chuk, Chan, & Hsiao, 2017; Chuk, Crookes, et al., 2017; Or et al., 2015).

Three major race groups in Malaysia: Malay, Chinese and Indian

Malaysia is a multiracial country. Its population comprises three major race groups: Malay (50.1%), Chinese (22.6%), Indian (6.7%), as well as indigenous groups that primarily live in rural areas (11.8%), other (0.7%) and non-citizens (8.2%; The World Factbook, 2015). The high degree of racial diversity in Malaysia is indicated by the Ethnic Fractionalisation Index which measures the racial (phenotypical), linguistic and religious cleaves in society (Yeoh, 2001; see Supporting Information). It should be noted that there are discernible variations of facial features between these major race groups in the country (Ngeow & Aljunid, 2009; Wai et al., 2015). Anthropometric studies of facial morphology between Chinese, Malay and Indian adults found major cross-racial differences in craniofacial characteristics. That is, Malaysian Indian faces tend to have narrower noses and relatively lower upper lip height to mouth width index as compared to Malay and Chinese faces, exhibiting some North American White Caucasian features in most regions (Ngeow & Aljunid, 2009). Compared to Indian and Malay faces, Chinese faces tend to have wider noses and smaller mouth width (Wai et al., 2015). These between-group differences of face morphologies in terms of the physiognomic features allow us to test the extent to which differential face scanning patterns are driven by the physical features of faces.

Despite a long history of interaction among the Malays, Chinese and Indians, a common culture did not emerge, and each group more or less holds to their own religion, culture, language and tradition (Embong, 2002). The low level of interracial contact during infancy and childhood in Malaysians is commonly reflected through the same-race primary caregivers (Tham et al., 2018) and the racially diversified educational systems in primary and secondary schools (Kawangit et al., 2012). For instance, the Chinese usually sent their children to Chinese schools with their syllabus adopted from mainland China; Malays sent their children to *Madrasa* (religious schools) and Indians to Tamil schools. Therefore, opportunities for Malaysians (Malays, Chinese and Indian) to integrate and interact with other-race individuals as a community in early childhood may not be as frequent as expected as compared to adulthood. This claim is supported by Wong et al.'s (2020) quantitative measures of interracial contact in Malaysian young adults, showing that they seem to mostly grow in relatively homogeneous groups at a young age but then are regularly exposed to other-race groups when older. Moreover, according to the Marriage and Divorce Statistics Report released by the Department of Statistics Malaysia (2019), the number of interracial marriages has increased over the years, such that in 2018, 9% of all marriages in Malaysia were interracial (see also Dava, 2021).

Dynamic face recognition

While the majority of existing research has investigated face recognition using static faces, the faces we typically encounter outside of the laboratory are moving. Hence, it is important to examine face processing with dynamic stimuli that are as close as possible to what we experience in the real world. Behavioural studies have consistently demonstrated improved recognition performance for both familiar (Knight & Johnston, 1997; Lander et al., 1999) and unfamiliar faces (Lander & Bruce, 2003; Lander & Davies, 2007) when dynamic stimuli, rather than static stimuli, are used. Moreover, eye-tracking studies comparing between these two types of stimuli have shown differences in facial information extraction. As compared to static faces, dynamic faces are more likely to receive longer fixations on the mouth (Xiao et al., 2014b) and more fixations on the centre of faces (Bindemann et al., 2009; Vo et al., 2012), but fewer fixations on the eyes (Xiao et al., 2013a).

Considering the issue of ecological validity, Tan et al. (2015) conducted a face recognition study by using dynamic stimuli with facial motions. Compared with what was found in their previous static face recognition study (Tan et al., 2012), the ORB appeared to be less evident. When dynamic stimuli were used, Malaysian Chinese observers recognized East Asian, Western Caucasian, and African faces equally well. Even more unexpectedly, they failed to replicate the previous report where Malaysian Chinese primarily fixate on the eye and nose regions. Instead, participants fixated most on the nose, followed by the mouth then the eyes when perceiving dynamic face stimuli. The authors proposed that the use of facial motion in the dynamic face stimuli might have rendered the faces easier to recognize and led to different eye movement patterns between static and dynamic stimuli. Taken together, these findings highlight the importance of involving dynamic aspects of facial information in face processing research as the faces may provide distinctive identifying information (e.g. eye gaze, facial expression and lip movement) for recognition (Haxby et al., 2000), especially when static information is difficult to access (Burton et al., 1999; O'Toole et al., 2002).

The current study

Most of the previous eye-tracking studies on dynamic face processing involved participants of a single race when investigating cross-race face perception (Tan et al., 2012, 2015), and relatively little work has directly investigated the relative contribution of culture and facial physiognomy in accounting for between-race differences in face-scanning pattern. To address this shortfall, in a yes/no face recognition task, we presented naturalistic stimuli that closely represent a typical social situation (i.e. videos of models briefly introducing themselves) to compare the eye movement strategies between Malay, Chinese and Indian young adults when perceiving own- and other-race faces. Meanwhile, we also assessed their ability to recognize own- and other-race faces. More specifically, we tested whether the ORB would be attenuated following persistent natural exposure to faces of different races in the multiracial country and explored how prolonged real-life exposure to multiple races of faces could modulate looking patterns.

Here, we tested two non-mutually exclusive hypotheses. First, if the differential racial experience and/or cultural background shape how Malaysians look at faces, the face scanning pattern would differ depending on the race of observer. Recent studies have found that people from different cultures may allocate visual attention to facial features differently (e.g. Blais et al., 2021; Caldara, 2017), even within a shared environment. We conjectured that, although Malay, Chinese and Indian participants have grown up in the same Southeast-Asian country, their different levels of exposure to faces of different races (Tham et al., 2018; Wong et al., 2020) and cultures (Embong, 2002) suggest that face processing styles – and therefore eye movement patterns – may differ between them.

Despite the constant and permanent exposure to a common other-race face (i.e. Chinese and Malay faces are highly usual for Malaysian Indians), Malaysians' levels of meaningful interracial contact might vary at different life stages, especially during the critical period of enhanced plasticity in childhood (Su et al., 2017; Tham et al., 2018; see also McKone et al., 2019). The perceptual experience account – that the size of the ORE will vary with the amount of interracial contact experienced in everyday life – would predict observation of group differences in looking strategy with the ORB in face memory, reflecting the development of an optimal (intermediate) looking strategy in a top-down manner for recognizing faces with which they are more familiar (Tan et al., 2015). Second, if the facial physiognomy hypothesis – that bottom-up facial physiognomic information contributes to face scanning – is supported, participants' gaze patterns would differ according to the race of face. Given the paucity of existing studies comparing between the three race groups, we had no specific predictions about the fixation patterns of Malay and Indian observers. However, one prediction, derived from previous studies on Malaysian Chinese (e.g. Tan et al., 2015) and Western Caucasians (e.g. Blais et al., 2008), is that Malaysian Chinese would make more fixations on the nose than on the mouth and the eyes when perceiving dynamic face stimuli. If both hypotheses were supported, we should observe a three-way interaction between face race, race of observer and facial features. For instance, Chinese participants adopted a more nose-centric scanning pattern for own-race faces than other-race faces whereas Indian participants attended more to the mouth region of own-race faces than other-race faces. If none of the hypotheses was true, no scanning difference should be observed at all.

METHOD

Participants

A total of 66 young Malaysian adults attending a branch campus of a British University participated in the study. Data from three participants were excluded due to the issue of inaccurate calibration and excessive eye-tracking data loss (total recorded gaze samples under 50%) during data collection. Finally, 63 participants (32 males, 31 females) were kept for the present study. Races of participants were as follows: 21 Chinese (11 males and 10 females; mean age = 19.57 years, *SD* = 1.69), 22 Malay (11 males and 11 females; mean age = 19.91 years, *SD* = 1.51) and 20 Indian (10 males and 10 females; mean age = 19.35 years, *SD* = 1.54). None of them was racially mixed (i.e. having parents or grandparents belonging to two different racial groups). All participants self-reported normal or corrected-to-normal vision and were given chocolates or course credit for their participation. Written informed consent was obtained from all participants, and the protocol was approved by the Faculty of Science Ethics Committee. Our current sample size was five times more than the estimated sample size based on Blais et al.'s (2008) effect size where $\eta_p^2 = 0.33$. A priori power analysis using G*Power 3 (Faul et al., 2007) indicated that a total number of 12 participants are enough to detect a significant ORB (i.e. an interaction between participant race and face race), assuming $\alpha = 0.05$ and power $(1 - \beta) = 0.80$.

Apparatus

A Tobii T120 eye tracker was used to record participants' eye movements. This uses infrared technology to measure corneal reflections without the use of a head-mounted device. The on-screen remote eye-tracking system has an integrated infrared camera located beneath a 17" display monitor with a resolution of 1280 × 1024 pixels. The eye tracker performs binocular tracking at 120 Hz sampling rate by measuring the *X* and *Y* coordinates of the participants' pupils while viewing the monitor and is accurate to within 0.4° visual angle. The minimum fixation duration and saccade thresholds were set to 100 ms and 6 pixels/ms during the recordings. Tobii Studio™ software was used for stimuli presentation, gaze data recording and preliminary gaze data extraction.

Materials

Face videos were collected from 54 young adults (27 male, 27 female; age range: 18–24 years old) from three different race ethnic groups (Chinese, Malay and Indian) living in Malaysia. The face stimuli were dynamic videos of ‘normal appearing’ (no major facial lesions or deformities) young adults. Individuals appearing in the videos consented to the use of their videos in research settings. All the videos fulfilled the same criteria: controlled studio lighting (non-flash), full head with upper body, frontal view, wearing a uniform grey shirt and light grey background. Individuals were videotaped with all jewellery, makeup and spectacles removed. While being video recorded, individuals were asked to look straight at the camera and to maintain a neutral, natural and pleasant expression while verbally expressing a few sentences (i.e. introducing themselves briefly in English). All individual videos were recorded with a Panasonic HDC-TM300 digital video camera. Videos were muted to avoid participants using voice matching to recognize the individuals.

To avoid trivial matching strategies for memorizing faces, videos were edited using Sony Vegas™ Pro software to different segments (i.e. one segment was presented in the learning phase, and another was presented in the recognition phase) and were cropped to two different extents – one set of videos included the face and upper body, while the other included only the face and neck. Both sets were randomized to the learning and recognition phase separately for each participant. All edited video clips were 1280 × 720 pixels with a 32-bit colour depth.

Procedure

Participants were then tested individually in a quiet eye-tracking room. They were asked to sit comfortably and approximately 60 cm away from the monitor. Prior to testing, calibration was performed using a standard 9-point grid as implemented in the Tobii Studio software to ensure accurate tracking of eye gaze. Recalibration was performed when necessary and until the optimal calibration criterion was achieved. At the beginning of the experiment, participants were told beforehand that they would be presented with a series of videos to learn and subsequently recognize. By employing a yes/no recognition paradigm, the experiment involved three phases: learning phase, distracter task and recognition phase. The presentation order of trials was randomized for each participant. To avoid fixation bias, each trial started with a fixation cross presented randomly in each of the four quadrants of the computer screen for 1 s. Subsequently, a face video was displayed in the centre of the screen for 5 s. The stimulus presentation was always the same for the learning and recognition phases.

During the face-learning task, they were shown videos of 36 individuals, one at a time. After watching each video, they rated the face for attractiveness on a seven-point Likert scale, 7 being ‘very attractive’ and 1 being ‘very unattractive’. This rating task was to ensure that participants actively viewed and attended to the stimuli.

After the learning phase, participants were presented with 20 videos of inanimate objects (e.g. floating boat, ticking clock and moving car), with each presented for 5 s. To keep them focused throughout the task, participants were asked to rate how much they like each video on a 7-point Likert scale. This 3-min distracter task played a role in distracting them from immediately recalling the learned faces so that the long-term memory could be assessed.

During the recognition phase, participants were shown videos of 36 individuals (half previously learned faces and half novel faces). The order of presentation was random for all participants and each video lasted for 5 s, preceded by a 1-s fixation cross. After each short video, participants were asked to indicate if they had seen the face during the recognition phase by selecting either a 'Yes' or 'No'. Their behavioural performance was assessed by average per cent correct recognition (out of 36 trials).

Eye movement data analysis

The eye movement data for just the face stimuli were analysed using area-of-interest (AOI) analysis. AOIs were drawn for each target stimulus frame by frame in advance using Tobii Studio software so that the eye-tracking system could capture and calculate the average total number of fixations and average total fixation time within each of these predefined AOIs. A general template of AOIs was created for each face stimulus, outlining the nose, mouth and eyes region (see Figure 1). Indices of fixation count and fixation duration over the predefined AOI within each face were collected during each trial. For every face presentation, durations and number of fixations on each AOI were summed and then averaged across faces to provide average total measures of fixation count and fixation duration on each AOI. Since preliminary analyses showed no effects of experimental phase (Figure S1), the data were collapsed across the learning and recognition phase.

Bayesian analyses

To avoid Type II error, additional Bayesian analyses were conducted using the statistical software JASP (v0.14.0.0, https://jasp-stats.org/) with default Cauchy prior, $r = 0.707$ (JASP Team, 2020). Bayesian analysis has the pragmatic benefit that it is not based on the evaluation of significance levels that can be interpreted inaccurately, especially when the results are non-significant. The Bayes Factor (BF_{10}) provides the likelihood ratio of the probability of the data given the alternative hypothesis (H_1) divided by the probability of the same data given the null hypothesis (H_0). A BF10 value between 1 and 3 provides anecdotal evidence for H1; a value between 3 and 10 provides moderate evidence for H1; a value above 10 provides strong evidence for H_1; a value between 1 and 1/3 provides anecdotal evidence for H_0; a value between 1/10 and 1/3 provides moderate evidence for H_0; a value less than 1/10 provides strong evidence for H0 (Jeffreys, 1961; Lee & Wagenmakers, 2013). In addition to the conventional frequentist approach, Bayesian analyses (see Dienes, 2011; Kelter, 2020) were performed with participants' accuracy performance and eye movement patterns to assess to determine the likelihood of each alternative

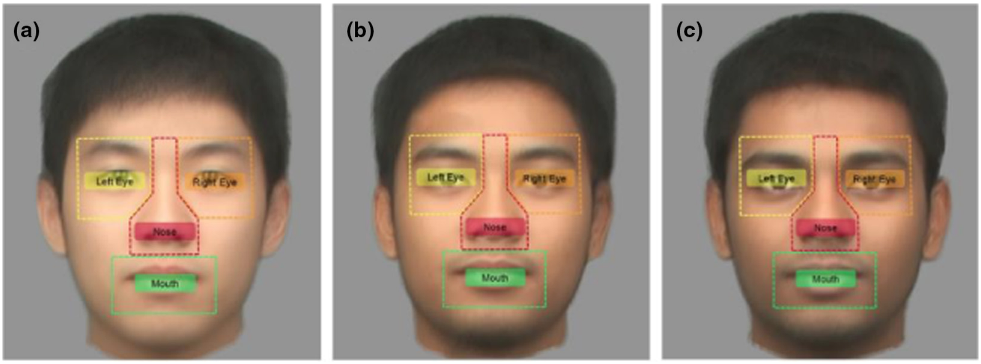

FIGURE 1 Average faces of (a) Chinese, (b) Malay and (c) Indian are shown for illustrative purposes. The predefined areas of interest (AOI) were used to analyse eye gaze. During the experiment, AOIs were never visible to participants.

hypothesis in relation to its corresponding null hypothesis as reflected by Bayes Factor BF_{10}. The exact BF values are reported in the following results section. Results showed that, albeit with a decent sample size of 66, the data consistently supported the outputs derived from the analyses of variance. Hence, it is unlikely that the lack of main effects in accuracy performance and eye movements was merely due to insufficient statistical power. Results showed that the data consistently support the robust main effect of facial features and its interaction with face race on the fixation patterns, with BF10 ranging from 4.20 to 512.57. In contrast, participants' performance in the face recognition task revealed modest support for the ORB effect – that the frequentist approach concludes there is very strong evidence for the ORB ($p < .001$) while the Bayesian concludes there is a smidgen of support for the ORB (BF10 = 2.12) – indicating more observations are needed to reach a definite conclusion.

RESULTS

Recognition accuracy

A 3 (Race Group: Chinese, Malay, Indian) × 3 (Race of Face: Chinese, Malay and Indian) mixed factorial ANOVA performed on averaged percent correct scores revealed that participants' recognition accuracy did not differ significantly between races of faces, F (2,120) = 0.37, p = .69, $\eta_p{}^2 = 0.01$, $BF_{10} = 0.45$, or between race groups, F (2, 60) = 4.12, p = .76, $\eta_p{}^2 = 0.009$, $BF_{10} = 0.88$. However, there was a significant interaction between race group and race of face (Figure 2), F (4,120) = 14.34, $p < .001$, $\eta_p{}^2 = 0.32$, $BF_{10} = 2.12$, suggesting the ORB in recognition accuracy. Simple main effect analysis showed that Chinese recognized own-race faces better than Malay ($p < .001$) and Indian faces ($p < .001$). Malay participant performed better for own-race faces than for Chinese ($p < .001$) and Indian faces (p = .009). Indian participants recognized own-race faces better than Chinese ($p < .001$) and Malay faces (p = .07).

Eye tracking results

Average total fixation counts

A 3 (Race Group: Chinese, Malay, Indian) × 3 (Race of Face: Chinese, Malay, Indian) × 3 (Facial Feature: Eyes, Mouth, Nose) mixed factorial ANOVA was performed on the total fixations directed to each AOI.

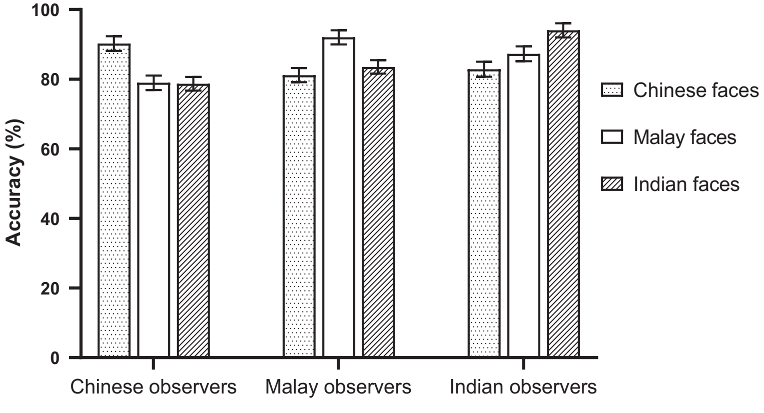

FIGURE 2 Chinese, Malay and Indian participants' average recognition accuracy scores for own-race and other-race faces. Error bars represent standard error of the mean.

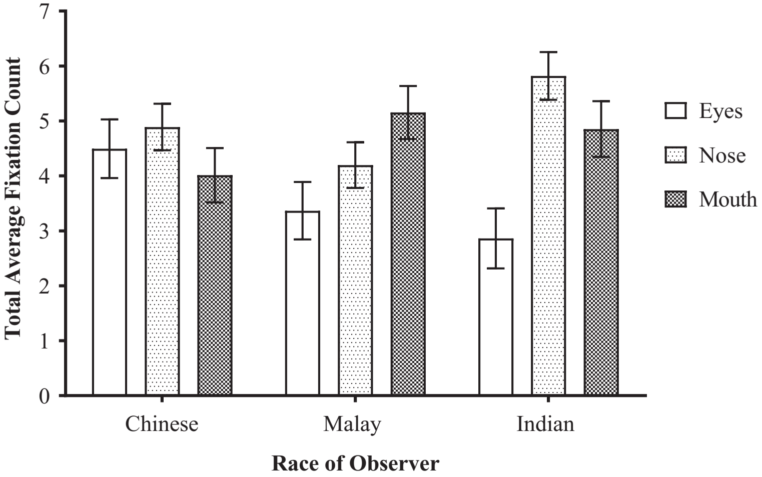

FIGURE 3 Average total number of fixations on the nose, mouth and eyes for the three race groups during the face recognition task. Error bars represent standard error of the mean.

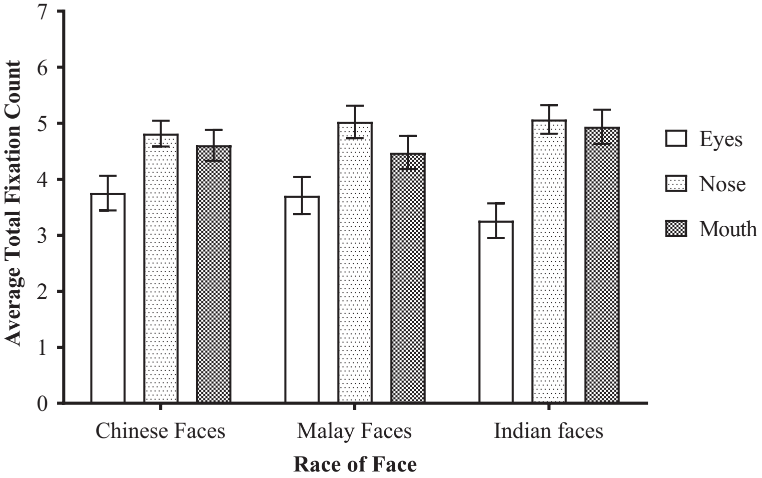

FIGURE 4 Average total number of fixations on the nose, mouth, eyes for Malaysian Chinese, Malaysian Malay and Malaysian Indian faces. Error bars represent standard error of the mean.

There was a significant main effect of Feature, F (1.71, 102.56) = 5.23, p = .01, $\eta_p^2 = 0.08$, $BF_{10} = 4.20$, Greenhouse–Geisser corrected. Post-hoc Bonferroni-corrected pairwise comparisons for the main effect of Feature revealed that participants generally looked more at the nose than at the eyes (p = .001). However, the average total number of fixations landing on the mouth did not differ significantly from those on the eyes (p = .13) and nose (p = 1). The main effect of Race Group was not significant, F (2, 60) = 0.71, p = .50, $\eta_p^2 = 0.02$, $BF_{10} = 0.28$, indicating that the amount of attention directed towards each face did not differ between the three groups. Importantly, there was a significant interaction between Race Group and Feature (Figure 3) (*3*), F (4,120) = 2.64, p = .037, $\eta_p^2 = 0.08$, $BF_{10} = 3.18$. Simple main effect analysis demonstrated that Indian participants showed a greater number of fixations towards the nose than Malay participants did (p = .027), while Chinese participants showed a tendency to fixate more on the eyes than Indian participants did (p = .07).

There was also a significant interaction between Race of Face and Feature (Figure 4), F (4,240) = 4.63, $p < .001$, $\eta_p^2 = 0.12$, $BF_{10} = 423.33$, indicating that participants adjusted their looking strategies to some degree according to the race of faces. Indian faces received more mouth fixations than Chinese ($p = .015$) and Malay faces ($p = .001$). However, Indian faces received fewer eye fixations compared to Chinese ($p = .001$) and Malay ($p = .003$) faces. The three-way interaction between Race Group, Race of Face and Feature failed to reach statistical significance, $F\ (8, 240) = 0.51, p = .85, \eta_p^2 = 0.02, \mathrm{BF}_{10} = 0.03$.

Average total fixation duration

A 3 (Race Group: Chinese, Malay, Indian) × 3 (Race of Face: Chinese, Malay, Indian) × 3 (Facial Feature: Eyes, Mouth, Nose) mixed factorial ANOVA was also conducted on the average total fixation durations directed to the nose, mouth and eyes for each participant. There was a significant main effect of Feature, $F\ (2,120) = 12.43, p < .001, \eta_p^2 = 0.17, \mathrm{BF}_{10} = 512.57$, providing strong evidence for. Post-hoc Bonferroni-corrected pairwise comparisons for the main effect of Feature showed that the average total viewing time for each facial feature was significantly different from each other (all $p < .05$). Participants spent most time looking at the mouth, followed by the nose and then the eyes. There were also significant interactions between Race Group and Feature, $F\ (4, 120) = 2.52, p = .04, \eta_p^2 = 0.08, \mathrm{BF}_{10} = 75.76$, and between Race of Face and Feature, $F\ (4, 240) = 8.13, p < .001, \eta_p^2 = 0.11, \mathrm{BF}_{10} = 89.10$. Analyses of simple main effects indicated that Chinese participants looked at the eyes for significantly longer than Indian participants ($p = .02$), while a non-significant trend suggested that Indian participants tended to look at the nose longer than Malay participants ($p = .09$; see Figure 5).

The interaction between Race of Face and Feature was mainly due to the fact that Indian faces received longer fixations to the nose than Chinese faces ($p = .01$) but shorter fixations to the mouth than Malay faces ($p = .04$). Additionally, Chinese and Malay faces received longer fixations to the eyes compared to Indian faces (both $p < .001$; see Figure 6). The three-way interaction between Race Group, Race of Face and Feature failed to reach statistical significance, $F\ (8, 240) = 0.83, p = .57, \eta_p^2 = 0.03, \mathrm{BF}_{10} = 0.001$. This pattern of results was consistent with the fixation count analysis.

DISCUSSION

The present study investigated Malaysian Malay, Malaysian Chinese and Malaysian Indian participants' recognition accuracy and eye movement strategies when viewing muted videos of own- and other-race

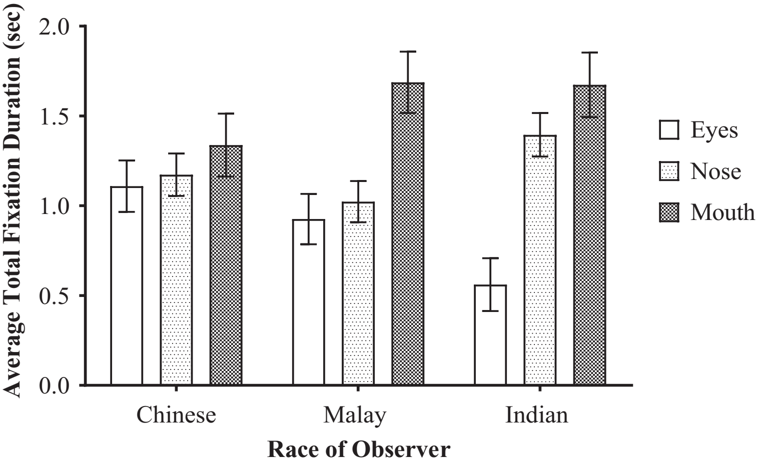

FIGURE 5 Average total fixation duration (in seconds) on the eyes, nose and mouth region made by observers from the three different race groups. Error bars represent standard error of the mean.

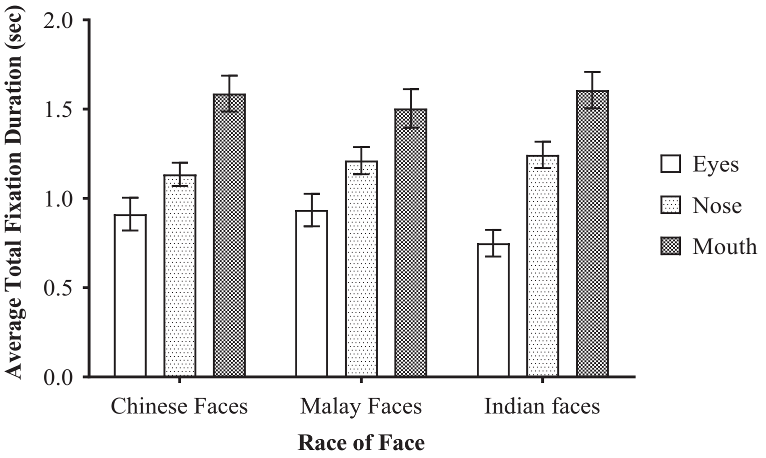

FIGURE 6 Average total fixation duration on the nose, mouth, eyes for Malaysian Chinese, Malay and Indian faces. Error bars represent standard error of the mean.

identities introducing themselves. Across race groups, participants displayed a better performance in recognizing own-race faces (i.e. a presence of ORB), as demonstrated by the significant interaction between race of participant and race of face. Although dynamic information may have conferred additional visual cues (e.g. facial motion) that are beneficial for face recognition (Knight & Johnston, 1997; Lander et al., 1999; Xiao, Perrotta, et al., 2014), in the current study, the ORB did not seem to be eliminated. Hence, the deficits in other-race recognition performance may lie within ineffective extraction of facial information (i.e. resource limits) rather than the insufficient information within the faces per se (i.e. data limits). The observation of ORBs in the three race groups is in accordance with our previous findings derived from static face stimuli (Wong et al., 2020), further strengthening our claim that increased contact with other-race groups in a racially diverse country, especially during adulthood (McKone et al., 2019), does not necessarily abolish the ORB. The mechanism underlying the ORB may be attributed to rigidity in face processing in adulthood (McKone et al., 2019) and an inability to extract the most diagnostic visual features on other-race faces (Michel et al., 2013). In a face-memory test, we used eye-tracking to investigate whether the gaze patterns differ between Malay, Chinese and Indian young adults who were routinely exposed to multiple races in their social environments.

Eye-tracking results showed that participants generally tend to fixate on the nose (i.e. central) region more than the eye and mouth regions. It is interesting to note, however, that certain features seemed to be processed with different weights depending on the *race of observer*. Indian participants showed a different looking pattern compared with Chinese and Malays. More specifically, they made more and longer fixations on the nose than Malay participants did, but preferentially attended more to the eyes than Chinese participants did. We speculate that the higher number of nose fixations by Indians may have functional significance associated with a greater likelihood of processing configural information (i.e. holistic processing; Blais et al., 2008; Caldara et al., 2010). Moreover, Indians were less likely to attend to the eye region possibly because, in Indian cultural norms, direct prolonged eye contact may be seen as intrusive, especially towards the opposite gender (Corbett, 2014). These race-dependent looking patterns provide support to the enculturation hypothesis that different races may be socialized to scan faces differently due to cultural conventions.

The multiracial characteristic of Malaysia in conjunction with the physiognomic differences and interracial contact among race groups offer cognitive researchers a unique environment for studying human face processing. The majority of Malaysian (South) Indians are genetically a subset of Europeans (Zainuddin et al., 2006) that happen to have anthropological (i.e. bone structure) similarity but with a dark skin tone due to living near the equator (Ngeow & Aljunid, 2009). Although Malaysian Chinese and Malays also come from a collectivist Asian culture (Hofstede et al., 2010), they are both racially and genetically different from Indians and have relatively flat features (Wai et al., 2015). Consistent with the physiognomy hypothesis, our eye-tracking results showed that, at least to some extent, the looking strategies employed by participants were modulated by the race of input faces, highlighting the engagement of bottom-up perceptual mechanisms during face processing. It appears that the Indian faces received more fixations on the mouth and longer fixations on the nose, but fewer fixations with shorter durations on the eyes, compared with Chinese and Malay faces. This pattern of results indicates that the diversity of fixation patterns may also be partially due to race-specific diagnostic cues provided by specific regions of the faces whereby reliance on particular facial features could be attributable to perceptual experience with faces (Hills & Lewis, 2006). For example, a Chinese individual would look at larger mouth widths and narrower noses on Indian faces that are more salient than typical own-race faces (see also Wai et al., 2015).

Of particular note in the present study was the high number of fixations directed at the mouth, consistent with Tan et al.'s (2015) finding. Recent studies investigating eye movements have consistently found that differences in the processing of static and dynamic stimuli are typically observed when moving or speaking faces are displayed (Bindemann et al., 2009; Xiao, Quinn, et al., 2013), with dynamic faces more likely to receive longer fixations on the mouth (Xiao et al., 2014b) and the centre of the face (Bindemann et al., 2009; Vo et al., 2012), but less on the eyes. Facial motions in dynamic videos likely convey changes in the actors' expression, and even subtle movements of one's eyes and mouth contain a rich source of social information. Therefore, the relatively larger number of fixations on the mouth region observed could have resulted from the use of the dynamic face stimuli which involved mouth movements. Moving lips involved in the muted face video stimuli might result in relatively increased attention drawn towards the highly informative mouth region trying to identify emotions (Tan et al., 2015) or decode the speech based on visual cues (Watanabe et al., 2011; but see Vo et al., 2012 and Tan et al., 2015).

A few limitations of the present study must be acknowledged. First, we did not assess levels of interracial contact in our sample; therefore, we are unable to affirm that our participants were drawn from a population in which individuals of different races had significant experiences with each other. Yet, it has been well-documented that Malaysians who grew up and lived in a highly multiracial society generally had greater opportunity to be exposed to other-race faces than individuals living in communities that are relatively less racially heterogeneous (e.g. UK, China and Japan; Yeoh, 2001; Wong et al., 2020). Given that our participants were students from a university that is racially diverse, they almost certainly have had extensive exposure to the other-race faces in their daily life. Future research could provide a more definitive test by quantifying the amount of interracial contact at an individual level.

Second, the use of predefined AOIs in eye movement data analysis for face recognition has been criticized since the AOI definition is arbitrary and involves experimenter biases, and differences in AOI definition can change the analysis results. More recent studies have discarded this contemporary idea and used more distribution-based approaches by taking individual differences and temporal information of eye movements into account, such as the use of hidden Markov models (see Chuk, Chan, & Hsiao, 2017; Chuk, Crookes, et al., 2017).

In addition, the current study adopted the conventional AOI analysis for ease of comparison with the past studies. The limitation of AOI approaches caused caveats with the preceding interpretation. As evidence of the task-dependent eye movement patterns has accrued in the literature (e.g. Hsiao et al., 2021; Kanan et al., 2015), our results showed that participants' eye movements did not differ between the two phases (learning vs. recognition). The use of predefined AOI in eye movement data analysis for face recognition has been criticized since the AOI definition is arbitrary and could involve experimenter biases, and an unstandardised AOI definition may change the outcome of data analysis. Further research is required to use more distribution-based approaches, as well as to take individual differences and temporal information of eye movements into account, such as the use of hidden Markov models (see Chuk, Chan, & Hsiao, 2017; Chuk, Crookes, et al., 2017) to substantiate hypotheses.

In conclusion, the current yes/no face recognition task wherein faces was displayed dynamically, revealed the ORBs in Malay, Chinese and Indian participants living in a profoundly multiracial society, replicating previous findings derived from static face stimuli (Wong et al., 2020). Additionally, eye-tracking results showed that not only did participants from these three racially distinct groups living in close proximity adopt dissimilar looking patterns but also their looking patterns appeared to be modulated by the race of face, to a lesser extent. In line with the perceptual-experience account, these findings indicate that the facial cues that have the highest diagnostic value for identifying faces in the local population may differ between the three major groups in a racially diverse society.

AUTHOR CONTRIBUTIONS

Hoo Keat Wong: Conceptualization; data curation; formal analysis; investigation; methodology; resources; software; validation; visualization; writing – original draft; writing – review and editing. **David R. T. Keeble:** Conceptualization; investigation; supervision; validation; visualization; writing – review and editing. **Ian D. Stephen:** Conceptualization; data curation; formal analysis; investigation; methodology; project administration; software; supervision; validation; visualization; writing – review and editing.

ACKNOWLEDGEMENTS

The authors received no specific funding for this work.

CONFLICT OF INTEREST

All authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Wong, H. K., Keeble, D. R. T., & Stephen. I. D. (2023). Do they 'look' different(ly)? Dynamic face recognition in Malaysians: Chinese, Malays and Indians compared. *British Journal of Psychology*, *114*(Suppl. 1), 134–149. https://doi.org/10.1111/bjop.12629