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Eye-tracking the own-race bias in face recognition: Revealing the perceptual and socio-cognitive mechanisms

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ABSTRACT

Own-race faces are recognised more accurately than other-race faces and may even be viewed differently as measured by an eye-tracker (Goldinger, Papesh, & He, 2009). Alternatively, observer race might direct eye-movements (Blais, Jack, Scheepers, Fiset, & Caldara, 2008). Observer differences in eye-movements are likely to be based on experience of the physiognomic characteristics that are differentially discriminating for Black and White faces. Two experiments are reported that employed standard old/new recognition paradigms in which Black and White observers viewed Black and White faces with their eye-movements recorded. Experiment 1 showed that there were observer race differences in terms of the features scanned but observers employed the same strategy across different types of faces. Experiment 2 demonstrated that other-race faces could be recognised more accurately if participants had their first fixation directed to more diagnostic features using fixation crosses. These results are entirely consistent with those presented by Blais et al. (2008) and with the perceptual interpretation that the own-race bias is due to inappropriate attention allocated to the facial features (Hills & Lewis, 2006, 2011).

1. Introduction

Own-race faces are recognised more accurately than other-race faces: this is the own-race bias (ORB) in face recognition (e.g., Meissner & Brigham, 2001). It is a highly reliable effect (Chance & Goldstein, 1996) across various races (Ng & Lindsay, 1994) and has implications in eyewitness recognition (Leippe, 1995). There are many theories of the ORB but these can be broadly separated into socio-cultural accounts and perceptual models. Levin (1996, 2000) proposed that the ORB is due to the depth of encoding. Specifically, when presented with an own-race face, effortful and deep processing is engaged in leading to individuation. However, when presented with other-race faces, shallower processing is employed involving categorisation processes (Meissner, Brigham, & Butz, 2005): participants process race as a visual feature (Levin, 2000). Similarly, Sporer (2001) proposed the in-group/out-group model, in which own-race faces are automatically processed deeply, whereas other-race faces are processed to a shallow level. That is, people have the motivation to process own-race faces deeply, but not other-race faces.

Perceptual accounts of the ORB, however, are based on the idea that we employ some form of expert perceptual or cognitive mechanisms to encode and store own-race faces. Expert face processing has been suggested to be based on relational (distances between features) or holistic (analysing the face as a whole) processing (e.g., Tanaka & Farah, 1993). This is in contrast with the inexpert featural processing (where each feature is processed independently; for a review, see Maurer, Le Grand, & Mondloch, 2002). Holistic processing is based on our visual experience (Carey, de Schonen, & Ellis, 1992; Le Grand, Mondloch, Maurer, & Brent, 2001). Hancock and Rhodes (2008) have suggested that own-race faces are processed more holistically than other-race faces, and this leads to the ORB

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(Hugenberg & Corneille, 2009; Michel, Rossion, Han, Chung, & Caldara, 2006).

Another perceptual model of the ORB is based upon Valentine's (1991) face-space model of face memory. In this model, all faces are stored in some form of multidimensional space in which the dimensions represent physiognomic features. The dimensions are diagnostic for the most frequently encountered faces (Lewis, 2004) as a result of development (Hills, Holland, & Lewis, 2010). This means that physiognomic differences across races (McClelland & Chappell, 1998) are implicitly represented in the face-space: the dimensions used for encoding and recognition of own-race faces will be more diagnostic and appropriate, but are unlikely to be as diagnostic for the processing of other-race faces (Hills & Lewis, 2006, 2011). Thus, other-race faces are stored closer together in face-space making them more confusable (Valentine & Endo, 1992). Furthermore, the dimensions of face-space guide how well faces are encoded (Hills & Lewis, 2006).

Hills and Lewis (2006) used this face-space metaphor to train White participants to use the features typically described by Black participants when recognising faces. Ellis, Deregowski, and Shepherd (1975) found that Black and White participants describe faces using different features: White participants describe faces using the hair colour, texture, and iris colour more so than Black participants, whereas Black participants tend to use the hair position, eye size, eyebrows, chin, ears, nose, and lips more so than White participants (see also, Shepherd & Deregowski, 1981). Hills and Lewis' (2006) training removed the ORB in White participants. This was interpreted as the training altered the dimensions of the face-space that were used to encode the faces. Hills and Lewis (2011) devised a related method for reducing the ORB in White participants. They presented faces preceded by a fixation cross that either drew White participants' attention to the eyes or to the tip of the nose. Recognition of White faces was better when the fixation cross preceded the eyes, but the recognition of Black faces was better when the fixation cross preceded the nose.

Hills and Lewis (2006, 2011) interpreted these results within the face-space metaphor: faces of different races are processed more accurately using different physiognomic features. Black faces are easier to distinguish based on the nose, whereas White faces are more distinguishable from the eyes (Ellis, 1975). The ORB is due to participants not attending to these most diagnostic visual features. This interpretation is only based on behavioural data however it is consistent with the differential feature hierarchy for Black and White observers (whereby the eyes are the most diagnostic visual feature for White participants processing faces and other features are less diagnostic, e.g., Haig, 1985, 1986; Hills, Ross, & Lewis, 2011). Eye-tracking evidence is required to confirm this conclusion.

The socio-cognitive theories (e.g., Levin, 2000; Sporer, 2001) of the ORB and the holistic/featural processing (Hancock & Rhodes, 2008) perceptual theory make the assumption that we view own- and other-race faces differently. If these theories are correct, then you would expect to find that there are eye-tracking differences when viewing own- and other-race faces. However, these theories do not predict that there would be any eye-movement differences across participants of different races.

There is a problem with the suggestion above: eye-movements are relatively slow and face perception is fast. The face-sensitive Event-Related-Potential occurs 170 ms after the stimulus has been presented (e.g., Joyce & Rossion, 2005) and ERPs as early as N250 show familiarity effects (e.g., Tanaka, Curran, Porterfield, & Collins, 2006) implying face recognition occurs within 200 ms. The first fixation typically lasts about 200–300 ms (e.g., Guzman-Martinez, Leung, Franconeri, Grabowecky, & Suzulo, 2009; Sæther, van Belle, Laeng, Brennen, & Øvervoll, 2009), suggesting that only one fixation is required to accurately recognise faces. Indeed, Hsiao and Cottrell (2008) have shown that face recognition is accurately performed with only one central fixation and is not much improved with three or more fixations beyond the level obtained with two fixations. This would suggest that any processing differences observed for own- and other-race faces are not likely to be due to eye-movement differences, rather they will be due to coding differences subsequently. However, there is evidence that with longer exposure durations to faces, recognition accuracy is increased (e.g., Bruce, 1982; Ellis, 1981; Laughery, Alexander, & Lane, 1971; Shepherd, Gibling, & Ellis, 1991), though this is not due to more features being sampled (Coin & Tiberghien, 1997). Potentially, therefore, coding differences may be revealed through eye-movements following these first two fixations.

The other perceptual theories of the ORB (based on the face-space, Valentine, 1991), however, make a contrasting prediction to the socio-cultural and holistic/featural processing accounts: namely that there would be observer differences in eye-movements based on cultural exposure and experience. Given the physiognomic differences of faces of different races, and the experience of looking at these faces, the features explored by one race will be different than the features explored by a different race. However, there would be no effect of race of face, because the observer would simply use their native scan-path for all faces and the deficits to recognition are caused by the fact it is not expert enough because it does not focus on the most diagnostic features.

Given the clear predictions made by these theories, we should explore what the experimental data shows us. There have not been many studies employing eye-tracking and the ORB. One of the first was conducted by Blais et al. (2008) who found that Western Caucasian observers fixated upon each eye more so than East Asian observers. Conversely, East Asian observers fixated upon the nose more than Western Caucasian observers. This pattern of results was observed when the observers were viewing both own- and other-race faces in both a race categorisation task and an old/new recognition paradigm. Thus, this suggests that culture affects the way people view faces and that people use the same eye-movements when viewing all faces. Similar results were obtained by Caldara, Zhou, and Miellet (2010) using an old/new recognition paradigm.

Contrasting with the findings of Blais et al. (2008), Caldara et al. (2010), Goldinger et al. (2009) reported a recognition experiment in which there were eye-tracking differences when observers viewed faces of different races. However, the pattern of eye movements was the same for Caucasian and Japanese observers (though Goldinger et al. did not directly or statistically test this). Their results revealed that participants tended to fixate upon the eyes, forehead, and hair more for own-race faces than other-race faces. Conversely, the nose and mouth received more fixations for other-race faces than own-race faces. It must be noted that there were some differences depending on the duration the faces were on screen for: when the faces were on screen for 5 s, the difference in fixations to the eyes was not significant. Thus, participants viewed own- and other-race faces differently (see also Wu, Laeng, & Magnussen, 2012, who found more active scanning for own-race faces than other-race faces).

These studies may indicate variations in eye-movements, which may indicate coding differences. However, there may be differences in the first fixation given the concept of the preferred landing position (Rayner, 1979). For White participants, the preferred landing position for faces is typically between the eyes (Sæther et al., 2009; Tyler & Chen, 2006). If the first fixation is between the eyes face recognition accuracy is higher than if the first fixation is not between the eyes (Hills, Cooper, & Pake, 2013). The preferred landing position for non-White participants has yet to be explored.

The present work thus aimed to address a number of theoretically important questions. The first is whether there are eye-movement differences across faces of different races (as predicted by the socio-cognitive explanations of the ORB). The second is whether there are eye-movement differences across different observer races (as predicted by the face-space model of the ORB). If the feature-hierarchy is different across different observer races, then it should be possible to alter the nature of the ORB by altering which features are being fixated upon. Based on previous work (Hills & Lewis, 2011), we shall use fixation crosses to do this in Experiment 2.

2. Experiment 1

The purpose of Experiment 1 was to establish whether there are eye-tracking differences when recognising Black and White faces by Black and White participants. We employed a standard old/new recognition paradigm. We measured participants' eye-movements during both the learning and test phases and recorded their recognition accuracy using the Signal Detection Theory (e.g., Swets, 1966) measure of d'. Statistically, the interaction between the race of face and feature viewed will be significant if the social-cognitive theories of the ORB have explanatory power. However, perceptual theories of the ORB based on face-space predict an observer race by feature viewed interaction.

2.1. Method

2.1.1. Participants

Forty-eight (26 male) staff and students from Anglia Ruskin University (mean age 25 years) volunteered to take part in this study. All self-reported they had normal or corrected-to-normal vision. Twenty-four participants (11 male) self-reported that they had been brought up in the UK and were ethnically White. Twenty-four participants (15 male) self-reported that they were from an African country and were ethnically Black. These participants had been in the UK for a maximum of 4 months and were on study visits. All participants reported that they were fluent in English and understood all of the instructions. Participants were paid £3 for their participation.

2.1.2. Materials

A total of 120 faces from the Minear and Park (2004) database were used. These were full frontal faces, with no extraneous features (e.g., beards, make-up or jewelry) and were on the same plain white background. All clothing was removed using Adobe PhotoShop. Half were male and half were female aged between 18 and 30: half of each were ethnically Black and half were ethnically White. The images were displayed in full colour. All images were constrained to the proportions 350 pixels high by 275 pixels wide (subtending 8.80° high and 6.91° wide in visual angle) with a resolution of 72 dpi. Two images of each face were used, with a slightly different expression displayed (smiling and neutral). One was presented at learning and one was presented at test. This was counterbalanced.

These stimuli were extensively pretested by 20 participants (10 Black and 10 White) who did not take part in the main experiment. These participants rated all the faces (and additional faces: there were more faces that were pretested to form the 120 used in the experiment) on two scales while they were on screen. The first was a distinctiveness rating in which participants rated each face for how easy it would be to spot in a crowd where 1 was difficult and 9 was easy (Light, Kayra-Stuart, & Hollander, 1979). Because participants rated other-race faces as less distinctive than own-race faces, all pretesting was done between subjects (i.e., by each race individually). All highly distinctive (mean rating above 7.5) or highly typical (mean rating below 2.5) faces or those faces that were inconsistently rated (with an SD above 4) were removed. Finally, faces were randomly selected such that the set of Black faces had the same mean and SD distinctiveness rating as the White faces as rated by own-race participants. Secondly, participants judged the ethnicity of each face by categorising them as either Black, White, Mixed, or other. All the faces used were rated as the appropriate race by both own- and other-race participants.

Eight areas of interest (AOIs, similar to e.g., Goldinger et al., 2009) were mapped out on the stimuli (see Fig. 1). These were: hair, forehead, eyes, nose, mouth, chin, cheeks, and screen. The areas mapped out were not visible to participants. We ran analyses using different AOIs (such as including the eyebrows within the eye region): All results were broadly consistent with the approach taken here. During the experiment, the stimuli were displayed on a white background, in the centre of a 17″ (1280 × 1024 pixels) LCD colour monitor. The stimuli were presented and recognition responses were recorded using E-Prime Professional 2, and eye movements were recoded using a Tobii 1750 eye-tracker (Falls Church, VA), with embedded infra-

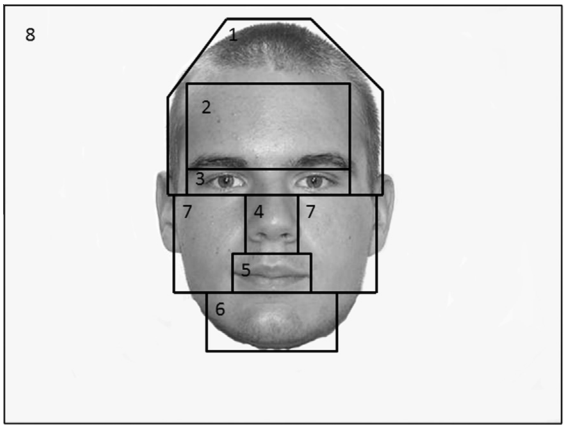

Fig. 1. An example of the AOIs: 1. Hair; 2. Forehead; 3. Eyes; 4. Nose; 5. Mouth; 6. Chin; 7. Cheeks; and 8. Screen. This image is from the Minear and Park (2004) database.

red cameras with a sampling rate of 50 Hz. The eye-tracker emits near infra-red light, which reflects off a person's eyes, which is then detected by the eye-tracker's camera. A fixation was defined as the eyes remaining in the same 30 pixel area for 100 ms (see Goldinger et al., 2009). If the eyes left the region, but returned within 100 ms, it was considered to be the same gaze. These settings were based on the defaults for the Tobii eye-tracker. Participants' heads were restrained using a standard chinrest.

2.1.3. Design

A 2 × 2 within-subjects design was employed with the factors race of face (Black and White) and observer race (Black and White). Recognition accuracy (measured using the Signal Detection Theory, e.g., Swets, 1966, measure, d'), reaction time and eye-tracking measures (number of fixations, duration of fixations, and location of first fixation) were recorded. Complete counterbalancing was employed such that each face appeared in each condition (as a target and a distractor) an equal number of times.

2.1.4. Procedure

Participants were tested individually in a quiet, fully lit, laboratory. They were seated 60 cm in front of the eye-tracking monitor and keyboard, with their head placed comfortably on a chin rest to keep head movements to a minimum. Once informed consent was given, participants' eyes were then calibrated to the eye-tracker using Clear-View software 2.7.0, which required them to follow a moving blue circle around a white screen with their eyes. The blue circle went to five pseudo-random locations on the screen including approximately the centre, and into the four quadrants. The calibration process could start in any of these five locations. The blue circle moved in a random order and did not return to any location. The eye-tracker was successfully calibrated for all participants reported in the participants section; four participants (all White) could not be calibrated and did not take part. From this point, there were three consecutive phases: the learning phase, distractor phase, and the test phase.

In the learning phase, participants were shown 60 faces, of which 30 were Black and 30 were White. Each face was displayed in the centre of the screen until the participant responded. Participants were required to rate each face for distinctiveness whilst the face was on screen. This was done by asking participants how easy each face would be to spot in a crowd where 1 was difficult and 9 was easy (Light et al., 1979). Participants were encouraged to use all the numbers in the scale. Participant responded using the numerical keypad on the standard computer keyboard, but were encouraged not to look down at the keypad (i.e., their fingers were positioned over the key-pad before the experiment began). The faces were presented sequentially in a random order. Before each face, a fixation cross appeared in one of four locations around the screen (top middle, bottom middle, left middle, right middle). Participants had to look at this for 150 ms before the fixation cross would disappear and the face appear. Thus, participants' first fixation was to the face (see Bindemann, Scheepers, & Burton, 2009).

Once the learning phase was completed, participants were required to complete a distractor task. This task was a short demographic questionnaire asking participants to provide information regarding their age, gender, and other characteristics. All responses were made using the computer keyboard. Once completed, participants were told that they had not been assessed on the distractor task.

In the test phase, participants were shown the 60 faces previously seen in the learning phase (the targets), along with a further 60 new faces (distractors). The 120 faces were presented sequentially in a random order. Again, each face was displayed until the participant responded. Participants were required to indicate, whilst the face was on screen, whether they recognised the face or not. Participants were required to press '*Z*' on the keyboard if they recognised a face, and press '*M*' if they did not recognise a face. Half of the distractor faces were Black and half were White. As in the learning phase, a fixation cross was presented in one of four randomly selected locations before each face and had to be fixated on for 150 ms before the face would appear. Once all the faces had been shown, participants were thanked and debriefed.

2.2. Results

2.2.1. Behavioural

The Signal Detection Theory (e.g., Swets, 1966) measure of stimulus discriminability, d', was calculated using the Macmillan and Creelman (2005) method from the hit and false alarm rate. d' typically ranges from 0 to 4 where 0 is chance-level recognition accuracy and 4 is near-perfect recognition accuracy. Mean recognition accuracy is presented in Table 1. These data were subjected to a 2 × 2 Mixed factorial ANOVA with the factors: race of face (Black and White) and Observer race (Black and White). Neither main effect was significant. Crucially, the interaction was significant, $F(1, 46) = 113.71$, $MSE = 0.24$, $p < .001$, $\eta_p^2 = .71$. This interaction was revealed through own-race faces being more accurately recognised than other-race faces for both Black (mean difference = 1.17, F(1,

Table 1
Mean (and standard error in parentheses) recognition accuracy (d'), hit rate, false alarm rate, and reaction time (ms) for Black and White faces by Black and White observers for Experiment 1.

			Race of face	
			Black	White
Recognition accuracy (d')	Observer race	Black	2.24 (0.13)	1.07 (0.10)
		White	0.98 (0.08)	1.96 (0.11)
Hit rate	Observer race	Black	.77 (.02)	.62 (.02)
		White	.65 (.02)	.81(.02)
False alarm rate	Observer race	Black	.15 (.02)	.27 (.02)
		White	.27 (.02)	.12 (.02)
Reaction time (ms)	Observer race	Black	903 (22)	1091 (31)
		White	1056 (43)	823 (28)

23) = 72.36, MSE = 0.23, $p < .001$, $\eta_p^2 = .76$) and White participants (mean difference = 0.98, $F(1, 23) = 44.19$, MSE = 0.26, $p < .001$, $\eta_p^2 = .66$). The effects on accuracy were paralleled in both its constituent parts (hit rate and false alarm rate).

A parallel analysis was run on the response time, presented in Table 1. This revealed no significant main effects, although there was a trend for White participants to respond faster than Black participants, $F(1, 46) = 3.95$, MSE = 20,168, $p = .053$, $\eta_p^2 = .08$. There was a significant interaction, $F(1, 46) = 36.57$, MSE = 28,905, $p < .001$, $\eta_p^2 = .44$. Own-race faces were responded to faster than other-race faces for both Black (mean difference = 187 ms, $F(1, 23) = 20.40$, MSE = 20,651, $p < .001$, $\eta_p^2 = .47$) and White participants (mean difference = 232 ms, $F(1, 23) = 17.43$, MSE = 37,159, $p < .001$, $\eta_p^2 = .43$).

2.2.2. Eye-tracking

All eye-tracking data recorded was to the participants' response during both the learning and the recognition phase of the experiment. Thus, for all analyses, proportions were calculated. An analysis of both the learning and test phases was conducted. There was no difference in eye-movements during the learning and test phases so all analyses were collapsed across this variable (similar to Blais et al., 2008). Analysis of mean duration of fixation, mean number of fixations, and location of first fixation are presented independently here. Due to the fact that the AOIs were of unequal sizes, area-normalised scores were calculated by dividing the proportion of fixations (or durations) by the proportion of the screen the AOI occupied (see Bindemann et al., 2009). This transformation means that a score of one is random scanning, whereas a score significantly higher than one indicates that the region is specifically targeted (Fletcher-Watson, Findlay, Leekam, & Benson, 2008). Given the relatively arbitrary nature of defining an AOI (for example, whether to include the eye-brows in the eye region or not), an analysis on the raw data was conducted and is presented in the Appendix. This analysis produced an identical pattern of results to this for the internal features but larger proportion of fixations to external features (though no differences across participant groups). The analysis based on proportions is preferred due to the fact that the AOIs are of very different sizes. It is important for eye-tracking studies to check both raw data and normalised data to ensure consistency. The variability of the data (as indicated by relative sizes of SDs is unaffected by this technique). Here, we present only theoretically important and relevant results. In all cases involving the variable feature, Mauchly's test of sphericity was significant (Epsilon values ranging between .3 and .4). Thus, the Greenhouse and Geisser (1959) correction was applied. Here, we report the corrected p value and the uncorrected degrees of freedom. Where appropriate, simple main effects were subject to a Bonferroni correction.

2.2.2.1. Total duration of fixations. Area-normalised total duration of fixation to each AOI is presented in Fig. 2. These data were subjected to a $2 \times 2 \times 8$ Mixed subjects ANOVA with the factors: race of face, observer race, and feature (AOI). The interaction between feature and race of face was not significant, $F(7, 322) = 0.96$, MSE = 2.06, $p > .46$, $\eta_p^2 = .02$. Crucially, as predicted by face-space, the interaction between feature and observer race was significant, $F(7, 322) = 9.78$, MSE = 19.52, $p < .001$, $\eta_p^2 = .18$. This interaction was revealed through a different pattern of features scanned by different observer races. Specifically, Black observers looked at the mouth and cheeks more than White observers ($p < .01$), whereas White observers looked at the eyes and hair more than Black observers ($p < .01$).

A parallel analysis was run on the area-normalised mean number of fixations to each AOI. This produced an identical pattern of results. The feature by race of face interaction was not significant, $F(7, 322) = 0.69$, MSE = 0.72, $p > .68$, $\eta_p^2 < .02$. However, the feature by observer race interaction was significant, $F(7, 322) = 2.75$, MSE = 9.67, $p = .009$, $\eta_p^2 = .06$. This interaction was revealed in the same way as for the duration of fixation.

2.2.2.2. Location of first fixation. Location of first fixation was subjected to a similar analysis, however, neither screen nor chin were entered into the analysis since there were no first fixations to these locations. Thus, a $2 \times 2 \times 6$ mixed ANOVA was employed with the factors: observer race; race of face; and feature (AOI). The data are summarised in Fig. 3. The analysis revealed that the interaction between feature and race of face was not significant, $F(5, 230) = 0.80$, MSE = 7.78, $p > .55$, $\eta_p^2 < .02$. Crucially, the interaction between feature and observer race was significant, $F(5, 230) = 3.46$, MSE = 32.61, $p = .005$, $\eta_p^2 = .07$. For Black participants, the nose received more first fixations

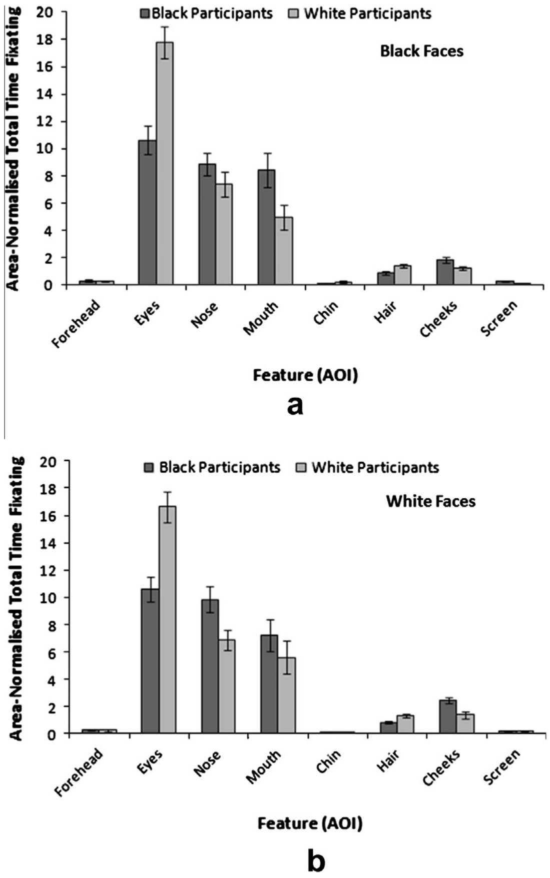

Fig. 2. Area-normalised total fixation duration to each AOI for Black and White Observers for a. Black faces and b. White faces (Experiment 1). Error bars represent standard error.

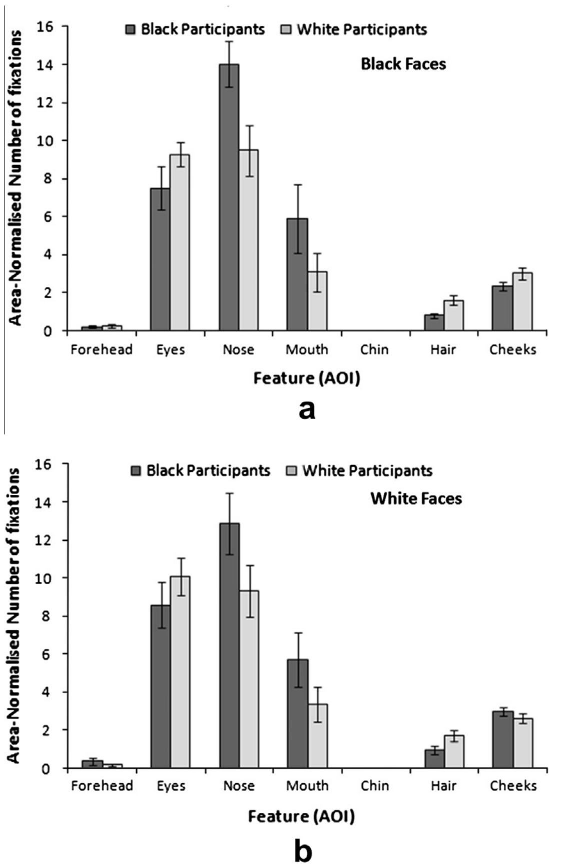

Fig. 3. Area-normalised proportion of first fixations to each AOI for Black and White Observers for a. Black faces and b. White faces (Experiment 1). Error bars represent standard error.

than any other feature (all $ps < .05$), whereas for White participants, the eyes and nose received a similar proportion of first fixations, but more than any other feature.

We also conducted an analysis of the exact location of the first fixation in pixels for Black and White participants for Black and White faces. A gaze plot is presented in Fig. 4 that shows the mean gaze plots for the first three fixations collapsed across race of face. The mean exact location for the first fixation was Cartesian co-ordinates (510,588) for Black participants and (497,489) for White participants. White participants' first fixations were significantly higher (measured in the Y axis) than Black participants fixations, $F(1,\ 46) = 97.27$, $MSE < .01$, $p < .001$, $\eta_p^2 < .68$. The main effect of race of face was not significant, nor was the interaction (both $ps > .35$). There was no significant effects in X co-ordinates, largest $F = 2.04$, smallest $p = .16$. We calculated the Euclidean distance between the average vector of first fixation for Black and White participants using the formula $d\ (p,\ q) = \sqrt{[(p_1 - q_1)^2 + (p_2 - q_2)^2]}$, where $d\ (p,\ q)$ is the distance between point p and point q. First fixations of Black participants were, on average, 10 pixels away from the first fixations of White participants on the face images shown on screen. This equates to 2.50 cm physical separation on a real face.

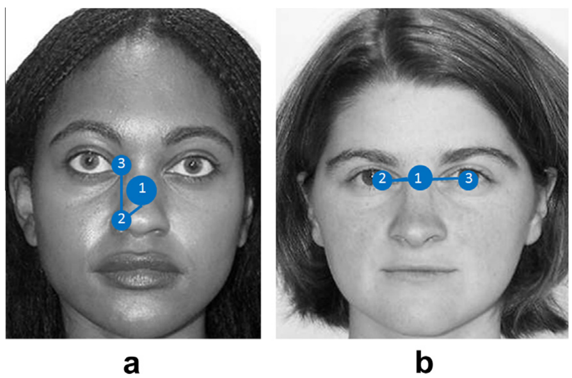

Fig. 4. Mean gaze plot for Black (a) and White (b) participants, edited to show the first three fixations (mean number of fixations was 3.10).

2.3. Discussion

The results from Experiment 1 provide support for an explanation of the ORB based on face-space (Valentine, 1991). That is, there were significant interactions between observer race and features looked at first, for the longest duration, and the most number of times. That is, Black and White participants tend to scan different features. At no point was the interaction between race of face and feature significant, as would be predicted by socio-cognitive models of the ORB. These data are consistent with those presented by Blais et al. (2008) and Caldara et al. (2010) but are inconsistent with Goldinger et al. (2009). This shall be explored in the general discussion.

Given that these data indicate that observers from different races look at different features, it seems plausible to hypothesise that this is due to implicit understanding of the physiognomic differences between races (McClelland & Chappell, 1998). Specifically, Black participants' first fixations were typically 2.50 cm of a life-size face below that of White participants' first fixations; this located Black participants' first fixation on the nose and White participants' first fixation between the eyes. Indeed, it is typical for the first fixation to an image to be directed to its centre of gravity (Findlay, 1982; Findlay & Gilchrist, 1997). The centre of gravity and preferred landing position for White faces when viewed by White participants is between the eyes (Bindemann et al., 2009), whereas for Black faces when viewed by Black participants it is over the nose. The present results indicate that participants' first fixation is to the same location on all faces irrespective of their race, even though the centre of gravity maybe different for each race. An alternative suggestion is that one group of participants may not direct their first fixation to the centre of gravity for any face. If the former, it may be possible to alter the nature of the ORB by encouraging participants to scan the more appropriate features of other-race faces (see Hills & Lewis, 2006, 2011). If this procedure is effective, the method with which it works may be through an alteration of eye-movements. Thus, Experiment 2 was conducted to see whether the manipulation of Hills and Lewis (2011), fixation crosses, do actually affect eye movements.

3. Experiment 2

Experiment 2 employed a very similar procedure to Hills and Lewis (2011, Experiment 1) except that the no fixation cross condition was not run (given that we would expect the same results as in Experiment 1 here). Thus, Experiment 2 presented Black and White participants with a series of Black and White faces that were preceded by a fixation cross. The fixation cross either preceded the bridge of the nose (between the eyes) and is consistent with the first fixation for White participants (Hills et al., 2013; Hsiao & Cottrell, 2008) or the fixation cross preceded the nose which is consistent with the first fixation for Black participants. We can make this claim for a number of reasons: firstly, in Experiment 1, we have shown that the first fixation of Black participants is indeed on the nose. Secondly, when describing faces, Black participants tend to describe the nose more frequently than other features (Ellis et al., 1975; Shepherd & Deregowski, 1981) and there is more physiognomic variability around the nose in Black faces than White faces (McClelland & Chappell, 1998). Furthermore, when the first fixation is to the most diagnostic feature, recognition accuracy is increased (Hills et al., 2013).

If the theory that the ORB is caused by not scanning the most appropriate features is valid, then a fixation cross preceding the bridge of the nose will improve the encoding and recognition of White faces (see Hills et al., 2013) irrespective of the observer race. Similarly, a fixation cross preceding the nose will improve the encoding and recognition of Black faces irrespective of the observer race. Thus, we would predict an interaction between position of the fixation cross and race of face, but no interactions with observer race.

3.1. Method

3.1.1. Participants and materials

Forty-eight (22 male) staff and students from Anglia Ruskin University (mean age 27 years) volunteered to take part in this study. All self-reported they had normal or corrected-to-normal vision. Twenty-four participants (12 male) self-reported that they had been brought up in the UK and were ethnically White. Twenty-four participants (10 male) self-reported that they were from an African country and were ethnically Black. These participants had been in the UK for a maximum of 4 months and were on study visits. All participants reported that they were fluent in English and understood all of the instructions. Participants were paid £3 for their participation. The same materials used in Experiment 1 were used in Experiment 2.

3.1.2. Design and procedure

A $2 \times 2 \times 2$ Mixed design was employed, with the between-subjects factor observer race (Black and White) and the within-subjects factors race of face (Black and White) and position of the fixation cross (preceding the bridge of the nose or preceding the tip of the nose). Counterbalancing was employed such that each face appeared as a target and a distractor an equal number of times in each fixation cross condition. An additional eye-tracking measure was also analysed: location of the second fixation. This was recorded to see whether the effect of the fixation cross (if there is one) lasts more than one fixation (given that the first fixation immediately follows the fixation cross). All other design aspects were identical to Experiment 1.

The procedure was similar to Experiment 1, except for the fixation cross location. In Experiment 1, the fixation cross could appear in one of four locations on the screen. In the present Experiment, the fixation cross always appeared on the centre line in horizontal axis of the screen but could appear in one of two locations in the vertical axis. The fixation cross either preceded between the eyes or the tip of the nose. It still had to be fixated upon for 150 ms before the face would appear. Fixation cross position was matched from learning to test.

3.2. Results

3.2.1. Behavioural

The d', recognition accuracy, scores were subjected to a $2 \times 2 \times 2$ Mixed-subjects ANOVA and are summarised in Table 2. This revealed a significant position of the fixation cross by race of face interaction, $F(1, 46) = 234.45$,

Table 2
Mean (and standard error in parentheses) recognition accuracy (d'), hit rate, false alarm rate, and reaction time (ms) for Black and White faces by Black and White observers split by the position of the fixation cross, for Experiment 2.

				Race of face	
				Black	White
Recognition accuracy (d')	Observer race	Black	High fixation cross	1.14 (0.10)	1.86 (0.11)
			Low fixation cross	1.82 (0.10)	0.92 (0.06)
		White	High fixation cross	1.04 (0.06)	1.88 (0.10)
			Low fixation cross	1.84 (0.12)	0.97 (0.06)
Hit rate	Observer race	Black	High fixation cross	.64 (.02)	.79 (.02)
			Low fixation cross	.80 (.03)	.65 (.02)
		White	High fixation cross	.61 (.02)	.80 (.02)
			Low fixation cross	.75 (.03)	.61 (.02)
False alarm rate	Observer race	Black	High fixation cross	.24 (.02)	.18 (.02)
			Low fixation cross	.18 (.02)	.30 (.02)
		White	High fixation cross	.24 (.02)	.19 (.02)
			Low fixation cross	.14 (.02)	.25 (.02)
Reaction time (ms)	Observer race	Black	High fixation cross	1069 (15)	1072 (25)
			Low fixation cross	995 (25)	1264 (17)
		White	High fixation cross	1209 (45)	845 (20)
			Low fixation cross	904 (25)	1150 (38)

$MSE = 0.14$, $p < .001$, $\eta_p^2 = .84$. This interaction was revealed through Black faces being better recognised when the fixation cross preceded the tip of the nose (mean difference = 0.74, $F(1, 47) = 61.38$, $MSE = 0.22$, $p < .001$, $\eta_p^2 = .57$) and White faces being more accurately recognised when the fixation cross preceded the bridge of the nose (mean difference = 0.92, $F(1, 47) = 144.39$, $MSE = 0.14$, $p < .001$, $\eta_p^2 = .75$) than the converse. No other effects nor interactions were significant. A parallel analysis was conducted on the reaction time summarised in Table 2. This revealed a significant observer race by face race interaction, $F(1, 46) = 41.25$, $MSE = 11{,}133$, $p < .001$, $\eta_p^2 = .47$, in which responses were made quicker to own-race faces than other-race faces for both Black observers (mean difference = 136 ms, $F(1, 23) = 38.10$, $MSE = 5833$, $p < .001$, $\eta_p^2 = .62$) and White observers (mean difference = 60 ms, $F(1, 23) = 8.03$, $MSE = 5300$, $p = .009$, $\eta_p^2 = .23$). In addition, there was a significant position of the fixation cross by race of face interaction, $F(1, 46) = 90.81$, $MSE = 25{,}415$, $p < .001$, $\eta_p^2 = .66$, in which responses to Black faces were faster when the fixation cross preceded the nose (mean difference = 190 ms, $F(1, 23) = 32.45$, $MSE = 26{,}605$, $p < .001$, $\eta_p^2 = .41$) and responses to White faces were faster when the fixation cross preceded the bridge of the nose (mean difference = 249 ms, $F(1, 23) = 78.51$, $MSE = 18{,}935$, $p < .001$, $\eta_p^2 = .63$). Surprisingly, there was a significant three-way interaction, $F(1, 46) = 14.00$, $MSE = 25{,}415$, $p = .001$, $\eta_p^2 = .23$, in which the fixation cross by race of face interaction pattern was most strongly observed for White participants than for Black participants. The same pattern was observed for hit rate and the opposite pattern was observed for false alarm rate.

3.2.2. Eye-tracking

All eye-tracking analyses followed the same protocol as that described in Experiment 1.

3.2.2.1. Total duration of fixations. The area-normalised total duration of fixations to each AOI is presented in Fig. 5 (for an analysis on the nonarea-normalised data, see the

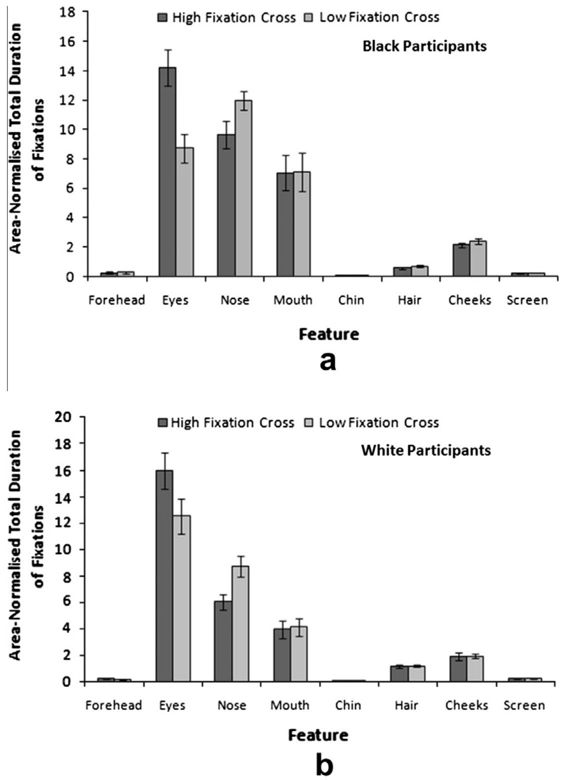

Fig. 5. Area-normalised total fixation duration to each AOI for (a) Black and (b) White observers for faces preceded by a high fixation cross (between the eyes) and a low fixation cross (tip of the nose). This figure collapses across the race of face as no effect nor interactions with this factor were significant (Experiment 2). Error bars represent standard error.

Appendix). These data were subjected to a $2 \times 2 \times 2 \times 8$ Mixed-subjects ANOVA with the factors: observer race; race of face; position of the fixation cross; and feature (AOI). This revealed a significant feature by observer race interaction, replicating Experiment 1, $F(7, 322) = 5.03$,

$MSE = 37.88$, $p < .01$, $\eta_p^2 = .10$. Bonferoni corrected simple effects showed that Black observers viewed the nose more so than White observers ($p < .05$) and White observers viewed the eyes more than Black observers. Crucially, there was an interaction between the position of the fixation cross and the feature, $F(5, 230) = 38.86$, $MSE = 4.58$, $p < .001$, $\eta_p^2 = .46$. Bonferoni corrected simple effects showed that when the fixation cross preceded the bridge of the nose (between the eyes) the eyes received more fixation time than when the fixation cross preceded the tip of the nose ($p < .05$). Conversely, when the fixation cross preceded the tip of the nose, fixation duration was longer to the nose than when the fixation cross preceded the bridge of the nose ($p < .05$). No other comparisons were significant. In addition, no other effects nor interactions were significant.

A parallel analysis was conducted on the number of fixations and revealed an identical pattern of results: A significant feature by observer race interaction, replicating Experiment 1, $F(7, 322) = 4.07$, $MSE = 22.04$, $p = .02$, $\eta_p^2 = .08$ and a significant interaction between feature and position of the fixation cross, $F(7, 322) = 12.08$, $MSE = 0.49$, $p < .001$, $\eta_p^2 = .21$.

3.2.2.2. Location of the first and second fixations. A parallel analysis on the location of first fixation, as presented in Fig. 6 (left panel), except that the screen was not entered into the analysis as no first fixations were made to the screen. This revealed a feature by fixation cross position interaction, $F(6, 276) = 15.17$, $MSE = 17.65$, $p < .001$, $\eta_p^2 = .25$, whereby the eyes received more first fixations when the fixation cross preceded them and the nose received more first fixations when the fixation cross preceded it (all $ps < .05$). No other effects or interactions were significant.

A final analysis was conducted on the location of the second fixation and is presented in Fig. 6 (right panel). Screen was not entered into this analysis since no second fixations were to the screen. This revealed no significant effects nor interactions consistent with any other measures.

3.3. Discussion

results for both the experiments!!!

The results of Experiment 2 extend those of Experiment 1 in two important ways. Firstly, we have replicated the interactions between observer race and features fixated upon; Black observers tend to fixate upon the nose more so than the White observers, whereas the White observers tend to fixate upon the eyes. Secondly, the fixation crosses do appear to attract the first fixation to the relevant features. This matches the behavioural data in that low fixation crosses preceding Black faces caused them to be recognised more accurately than White faces for both Black and White observers. White faces, however, were recognised more accurately when they were preceded by a high fixation cross by both Black and White observers. This replicates Experiment 1 in Hills and Lewis (2011). The second fixation seems to be more random and poten-

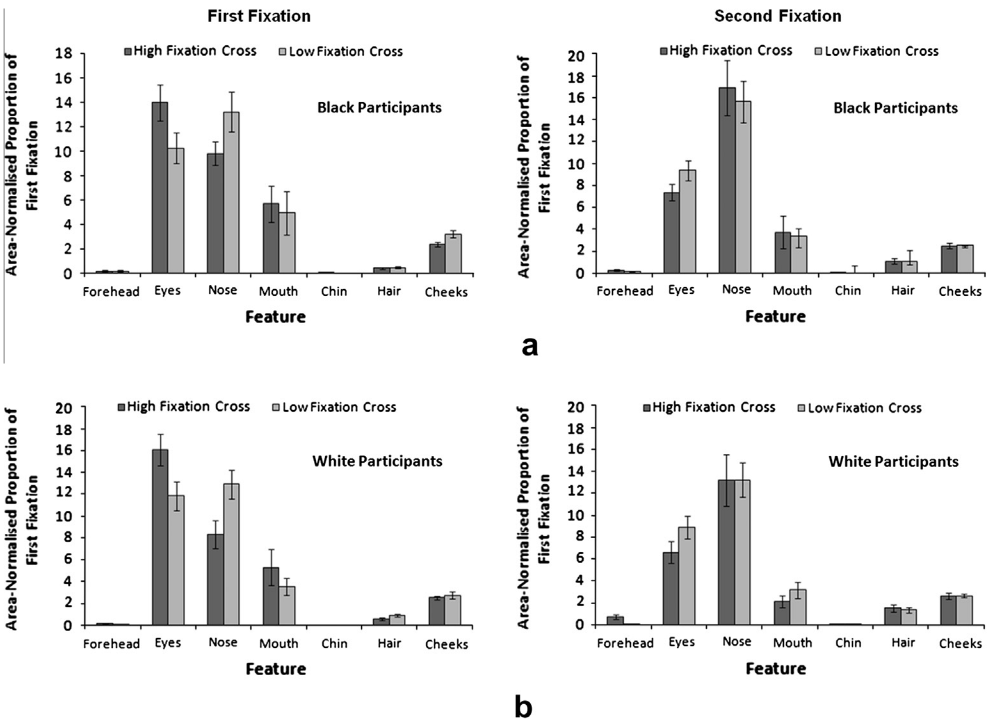

Fig. 6. Area-normalised proportion of first (left panel) and second (right panel) fixations to each AOI for (a) Black and (b) White observers for faces preceded by a high fixation cross (between the eyes) and a low fixation cross (tip of the nose). This figure collapses across the race of face as no effect nor interactions with this factor were significant (Experiment 2). Error bars represent standard error.

tially reverting to the native scanpath. The suggestion that fixations tend to revert to the native scanpath after the first fixation is implied by the fact that the first fixation is guided by the fixation cross, but the overall number of fixations and total fixation duration are somewhat guided by the observers' race and potentially their expert face recognition system.

4. General discussion

In two experiments, we have shown that Black and White observers view faces differently – they sample different features and crucially look at different features first. In addition and critically, they view own- and other-race faces in the same manner. Thus, these results are not consistent with Goldinger et al.'s (2009) findings but are entirely consistent with Blais et al.'s (2008) and Caldara et al.'s (2010) findings. Thus, these results are not consistent with a socio-cognitive account of the ORB because this predicts that participants view own- and other-race faces differently (Levin, 2000; Sporer, 2001). These results are also not consistent with any perceptual account which suggests that we view own- and other-race differently (such as the configural/featural account, e.g., Hancock and Rhodes, 2008). However, these results are entirely consistent with the face-space account of the ORB (Valentine, 1991; Valentine & Endo, 1992): Participants encode faces according to those physiognomic features that discriminate between the most frequently encountered faces. The allocation of attention is based on prolonged interaction with the visual environment (Leonards & Mohr, 2009; Leonards & Scott-Samuel, 2005) and may be directed by the dimensions of face-space which have developed to process own-race faces (Furl, Phillips, & O'Toole, 2002).

Although the results seem to be inconsistent with the configural/featural processing account of the ORB, this account is too popular to simply disregard: it is worth considering how the present results can be interpreted within this account. It has been suggested that own-race faces are encoded configurally whereas other-race faces are encoded featurally (Michel, Caldara, & Rossion, 2006; Michel, Rossion, et al., 2006). Our manipulation could be interpreted as configural or holistic information is better extracted from different features by Black and White observers given that the preferred landing position (location of first fixation) is relatively central for both Black and White observers. Alternatively, only the first two fixations are actually critical to face recognition (Hsiao & Cottrell, 2008) and eye-tracking differences following this are a quirk and do not reflect any actual processing differences. This cannot be discounted given that there is no one-to-one relationship between eye-movements and attention or encoding. It could be, for example, that participants can extract configural information from one fixation for own-race faces but not extract it for other-race faces. This possibility cannot be discounted by the data and highlights a limitation of the eye-tracking method. However, we have made the assumption that eye-movements are functional (Henderson, WIlliams, & Falk, 2005) and ensure that critical information is attended to (Desimone & Duncan, 1995; Egeth & Yantis, 1997).

another important point!!

There are a number of issues that this research has unearthed. One is that we found results that were different to those reported by Goldinger et al. (2009) but consistent with those of Blais et al. (2008). These differences are hard to resolve. All three studies used a recognition paradigm, though ours was incidental and Goldinger et al.'s and Blais et al.'s was intentional. Thus, type of learning cannot be an explanation for this difference. However, there could be different eye movements employed for different types of facial judgements. Goldinger et al. asked participants to simply view faces. We asked participants to judge the distinctiveness of those faces. Potentially, asking participants to make distinctiveness judgements caused them to view the faces differently to simply passively viewing them. Finally, there may be race and cultural (even nationality) differences in the way participants view faces. Both Blais et al. (2008) and Caldara et al. (2010) have indicated that cultural differences may alter eye-movements, such that societal factors (for example in some East Asian and African cultures, direct eye-contact is considered rude, Argyle & Cook, 1976). Possibly differences between White British and White American participants may explain the differences between the findings of Goldinger et al. (2009), Blais et al. (2008), Caldara et al. (2010) and the present study. Potentially, the location of the fixation crosses used by these different researchers could explain the different results. Fixation crosses have surprising effects on face perception and there location needs to be carefully considered (Hills et al., 2011). There were other differences in these experiments including participant numbers, stimuli numbers, stimuli databases, stimuli size, eye-trackers used, precise nature of the AOIs, and data smoothing (normalisation procedures), though these differences are unlikely to account for the contrasting findings.

cultural differences:

This research has significant implications for research in face recognition and eye-tracking research. Specifically, there are many studies that use fixation crosses in face recognition. If these precede the eyes then recognition accuracy of non-White faces may be impaired. In terms of eye-tracking research, any study that employs a fixation cross may be affecting the first fixation, the subsequent encoding, and performance. Two methods can be employed to avoid this unintentional effect: fixation crosses outside the face image ensure that the first fixation is to the image (e.g., Experiment 1 here based on Bindemann et al., 2009); An alternative procedure is to guide fixation using boxes or images (e.g., Wu et al., 2012). These results also indicate hitherto unacknowledged individual differences in eye-movements when scanning faces. These eye-movements may be based on cultural, societal, and race differences. Furthermore, these results imply that different instructions given to participants can potentially alter their eye-movements and scanning behaviour.

In conclusion, we have found that there are race differences across participants of different races and they view own- and other-race faces in the same way. Black observers fixated more upon the nose than White observers whereas White observers tend to fixate on the eyes more than Black observers. The ORB can be reversed if participants are cued to fixate more on the features that the other-race would normally fixate upon. These results have been interpreted within the face-space metaphor of face processing (Valentine, 1991) and are entirely consistent with perceptual models of the ORB and not of socio-cognitive models.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2013.08.012.

References

Argyle, M., & Cook, M. (1976). *Gaze and mutual gaze*. Cambridge, UK: Cambridge University Press.

Bindemann, M., Scheepers, C., & Burton, A. M. (2009). Viewpoint and center of gravity affect eye movements to human faces. *Journal of Vision, 9*(2), 1–16. http://dx.doi.org/10.1167/9.2.7. 7.

Blais, C., Jack, R. F., Scheepers, C., Fiset, D., & Caldara, R. (2008). Culture shapes how we look at faces. *PLoS ONE, 3*, e3022. http://dx.doi.org/10.1371/journal.pone.0003022.

Bruce, V. (1982). Changing faces: Visual and non-visual coding processes in face recognition. *British Journal of Psychology, 73*, 105–116. http://dx.doi.org/10.1111/j.2044-8295.1982.tb01795.x.

Caldara, R., Zhou, X., & Miellet, S. (2010). Putting culture under the "*spotlight*" reveals universal information use for face recognition. *PLoS ONE, 5*, e9708. http://dx.doi.org/10.1371/journal.pone.0009708.

Carey, S., de Schonen, S., & Ellis, H. D. (1992). Becoming a face expert. *Philosophical Transaction of the Royal Society of London, 335B*, 95–103. http://dx.doi.org/10.1098/rstb.1992.0012.

Chance, J. E., & Goldstein, A. G. (1996). The other-race effect and eyewitness identification. In S. L. Sporer, R. S. Malpass, & G. Koehnken (Eds.), *Psychological issues in eyewitness identification* (pp. 153176). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc..

Coin, C., & Tiberghien, G. (1997). Encoding activity and face recognition. *Memory, 5*, 545–568. http://dx.doi.org/10.1080/741941479.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18*, 193–222. http://dx.doi.org/10.1146/annurev.ne.18.030195.001205.

Egeth, H. E., & Yantis, S. (1997). Visual attention: Control, representation, and time course. *Annual Review of Psychology, 48*, 269–297. http://dx.doi.org/10.1146/annurev.psych.48.1.269.

Ellis, H. D. (1975). Recognizing faces. *British Journal of Psychology, 66*, 409–426. http://dx.doi.org/10.1111/j.2044-8295.1975.tb01477.x.

Ellis, H. D. (1981). Theoretical aspects of face recognition. In G. Davies, H. D. Ellis, & J. W. Shepherd (Eds.), *Perceiving and remembering faces* (pp. 143202). San Diego, CA: Academic Press.

Ellis, H. D., Deregowski, J. B., & Shepherd, J. W. (1975). Descriptions of white and black faces by white and black subjects. *International Journal of Psychology, 10*, 119–123. http://dx.doi.org/10.1080/00207597508247325.

Findlay, J. M. (1982). Global processing for saccadic eye movements. *Vision Research, 22*, 1033–1045.

Findlay, J. M., & Gilchrist, I. D. (1997). Spatial scale and saccade programming. *Perception, 26*, 1159–1167. http://dx.doi.org/10.1068/p261159.

Fletcher-Watson, S., Findlay, J. M., Leekam, S. R., & Benson, V. (2008). Rapid detection of person information in a naturalistic scene. *Perception, 37*, 571–583. http://dx.doi.org/10.1068/p5705.

Furl, N., Phillips, P. J., & O'Toole, A. J. (2002). Face recognition algorithms and the other-race effect: Computational mechanisms for a developmental contact hypothesis. *Cognitive Science, 26*, 797–815. http://dx.doi.org/10.1016/S0364-0213(02)00084-8.

Goldinger, S. D., Papesh, M. H., & He, Y. (2009). Deficits in cross-race face learning: Insights from eye movements and pupillometry. *Journal of Experimental Psychology: Learning, Memory and Cognition, 35*, 1105–1122. http://dx.doi.org/10.1037/a0016548.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24*, 95–112. http://dx.doi.org/10.1007/BF02289823.

Guzman-Martinez, E., Leung, P., Franconeri, S., Grabowecky, M., & Suzulo, S. (2009). Rapid eye-fixation training without eyetracking. *Psychonomic Bulletin and Review, 16*, 491–496. http://dx.doi.org/10.3758/PBR.16.3.491.

Haig, N. D. (1985). How faces differ—A new comparative technique. *Perception, 14*, 601–615. http://dx.doi.org/10.1068/p140601.

Haig, N. D. (1986). Exploring recognition with interchanged facial features. *Perception, 15*, 235–247. http://dx.doi.org/10.1068/p150235.

Hancock, K. J., & Rhodes, G. (2008). Contact, configural coding and the other-race effect in face recognition. *British Journal of Psychology, 99*, 45–56. http://dx.doi.org/10.1348/000712607X199981.

Henderson, J. M., Williams, C. C., & Falk, R. J. (2005). Eye movements are functional during face learning. *Memory and Cognition, 33*, 98–106. http://dx.doi.org/10.3758/BF03195300.

Hills, P. J., Cooper, R. E., & Pake, J. M. (2013). First fixations in face processing: The more diagnostic they are the smaller the face-inversion effect. *Acta Psychologica, 142*, 211–219. http://dx.doi.org/10.1016/j.actpsy.2012.11.013.

Hills, P. J., Holland, A. M., & Lewis, M. B. (2010). Aftereffects for face attributes with different natural variability: Children are more adaptable than adolescents. *Cognitive Development, 25*, 278–289. http://dx.doi.org/10.1016/j.cogdev.2010.01.002.

Hills, P. J., & Lewis, M. B. (2006). Reducing the own-race bias by shifting attention. *Quarterly Journal of Experimental Psychology, 51*, 599–607. http://dx.doi.org/10.1080/17470210600654750.

Hills, P. J., & Lewis, M. B. (2011). Reducing the own-race bias in face recognition by attentional shift using fixation crosses preceding the lower half of a face. *Visual Cognition, 19*, 313–339. http://dx.doi.org/10(1080/13506285), 2010, 528250.

Hills, P. J., Ross, D. A., & Lewis, M. B. (2011). Attention misplaced: The role of diagnostic features in the face-inversion effect. *Journal of Experimental Psychology: Human Perception and Performance, 37*, 1396–1406. http://dx.doi.org/10.1037/a0024247.

Hsiao, J. H., & Cottrell, G. (2008). Two fixations suffice in face recognition. *Psychological Science, 19*, 998–1006. http://dx.doi.org/10.1111/j.1467-9280.2008.02191.x.

Hugenberg, K., & Corneille, O. (2009). Holistic processing is tuned for in-group faces. *Cognitive Science, 3*, 1173–1181. http://dx.doi.org/10.1111/j.1551-6709.2009.01048.x.

Joyce, C., & Rossion, B. (2005). The face-sensitive N170 and VPP components manifest the same brain processes: The effect of reference electrode site. *Clinical Neurophsyiology, 116*, 2613–2631. http://dx.doi.org/10.1016/j.clinph.2005.07.005.

Laughery, K. R., Alexander, J. F., & Lane, A. B. (1971). Recognition of human faces: Effects of target exposure time, target position, pose position, and type of photograph. *Journal of Applied Psychology, 55*, 477–483. http://dx.doi.org/10.1037/h0031646.

Le Grand, R. L., Mondloch, C. J., Maurer, D., & Brent, H. P. (2001). Early visual experience and face processing. *Nature, 410*, 890–891. http://dx.doi.org/10.1038/35073749.

Leippe, M. R. (1995). The case for expert testimony about eyewitness memory. *Psychology, Public Policy and Law, 1*, 909–959. http://dx.doi.org/10.1037/1076-8971.1.4.909.

Leonards, U., & Mohr, C. (2009). Schizotypal personality traits influence idiosyncratic initiation of saccadic face exploration. *Vision Research, 49*, 2404–2413. http://dx.doi.org/10.1016/j.visres.2009.07.013.

Leonards, U., & Scott-Samuel, N. E. (2005). Idiosyncratic initiation of saccadic face exploration in humans. *Vision Research, 45*, 2677–2684. http://dx.doi.org/10.1016/j.visres.2005.03.009.

Levin, D. T. (1996). Classifying faces by race: The structure of face categories. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*, 1364–1382. http://dx.doi.org/10.1037/0278-7393.22.6.1364.

Levin, D. T. (2000). Race as a visual feature: Using visual search and perceptual discrimination tasks to understand face categories and the cross-race recognition deficit. *Journal of Experimental Psychology:*

General, 129, 559–574. http://dx.doi.org/10.1037/0096-3445.129.4.559.
Lewis, M. B. (2004). Face-space-r: Towards a unified account of face recognition. *Visual Cognition, 11*, 29–70. http://dx.doi.org/10.1080/13506280344000194.
Light, L. L., Kayra-Stuart, F., & Hollander, S. (1979). Recognition memory for typical and unusual faces. *Journal of Experimental Psychology: Human Learning and Memory, 5*, 212–228. http://dx.doi.org/10.1037/0278-7393.5.3.212.
Macmillan, N. A., & Creelman, C. D. (2005). *Detection theory: A user's guide*. Cambridge, UK: Cambridge University Press.
Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences, 6*, 255–260. http://dx.doi.org/10.1016/S1364-6613(02)01903-4.
McClelland, J. L., & Chappell, M. (1998). Familiarity breeds differentiation: A subjective likelihood approach to the effects of experience in recognition memory. *Psychological Review, 105*, 724–760. http://dx.doi.org/10.1037/0033-295X.105.4.734-760.
Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy and Law, 7*, 3–35. http://dx.doi.org/10.1037/1076-8971.7.1.3.
Meissner, C. A., Brigham, J. C., & Butz, D. A. (2005). Memory for own- and other-race faces: A dual-process approach. *Applied Cognitive Psychology, 19*, 545–567. http://dx.doi.org/10.1002/acp.1097.
Michel, C., Caldara, R., & Rossion, B. (2006). Same-face faces are perceived more holistically than other-race faces. *Visual Cognition, 14*, 55–73.
Michel, C., Rossion, B., Han, J., Chung, C.-S., & Caldara, R. (2006). Holistic processing is finely tuned for faces of one's own race. *Psychological Science, 17*, 608–615. http://dx.doi.org/10.1111/j.1467-9280.2006.01752.x.
Minear, M. E., & Park, D. C. (2004). A lifespan database of adult facial stimuli. *Behavior Research Methods. Instruments and Computers, 36*, 630–633. http://dx.doi.org/10.3758/BF03206543.
Ng, W.-J., & Lindsay, R. C. L. (1994). Cross-race facial recognition: Failure of the contact hypothesis. *Journal of Cross-Cultural Psychology, 25*, 217–232. http://dx.doi.org/10.1177/0022022194252004.
Rayner, K. (1979). Eye guidance in reading: Fixation locations within words. *Perception, 8*, 21–30.
Sæther, L., van Belle, W., Laeng, B., Brennen, T., & Øvervoll, M. (2009). Anchoring gaze when categorizing faces' sex: Evidence from eye-tracking data. *Vision Research, 49*, 2870–2880. http://dx.doi.org/10.1016/j.visres.2009.09.001.
Shepherd, J. W., & Deregowski, J. B. (1981). Races and faces: A comparison of the responses of Africans and Whites to faces of the same and different races. *British Journal of Social Psychology, 20*, 125–133. http://dx.doi.org/10.1111/j.2044-8309.1981.tb00485.x.
Shepherd, J. W., Gibling, F., & Ellis, H. D. (1991). The effects of distinctiveness, presentation time and delay on face recognition. *European Journal of Cognitive Psychology, 3*, 137–145. http://dx.doi.org/10.1080/09541449108406223.
Sporer, S. L. (2001). Recognizing faces of other ethnic groups: An integration of theories. *Psychology, Public Policy and Law, 7*, 36–97. http://dx.doi.org/10.1037/1076-8971.7.1.36.
Swets, J. A. (1966). *Signal detection and recognition by human observers*. New York, NY: Wiley.
Tanaka, J. W., Curran, T., Porterfield, A. L., & Collins, D. (2006). Activation of preexisting and acquired face representations: The N250 event-related potential as an index of face familiarity. *Journal of Cognitive Neuroscience, 18*, 1488–1497. http://dx.doi.org/10.1162/jocn.2006.18.9.1488.
Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology, 46A*, 225–245. http://dx.doi.org/10.1080/14640749308401045.
Tyler, C. W., & Chen, C. C. (2006). Spatial summation of face information. *Journal of Vision, 6*, 1117–1125. http://dx.doi.org/10.1167/6.10.11.
Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion and race in face recognition. *Quarterly Journal of Experimental Psychology, 43A*, 161–204. http://dx.doi.org/10.1080/14640749108400966.
Valentine, T., & Endo, M. (1992). Towards an exemplar model of face processing: The effects of race and distinctiveness. *Quarterly Journal of Experimental Psychology, 44A*, 671–703. http://dx.doi.org/10.1080/14640749208401305.
Wu, E. X. W., Laeng, B., & Magnussen, S. (2012). Through the eyes of the own-race bias: Eye-tracking and pupillometry during face recognition. *Social Neuroscience, 7*, 202–216. http://dx.doi.org/10.1080/17470919.2011.596946.