Removing the own-race bias in face recognition by attentional shift using fixation crosses to diagnostic features: An eye-tracking study

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Abstract

Hills and Lewis (2011) have demonstrated that the own-race bias in face recognition can be reduced or even removed by guiding participants' attention and potentially eye-movements to the most diagnostic visual features. Using the same old/new recognition paradigm as Hills and Lewis, we recorded Black and White participants' eye movements whilst viewing Black and White faces following fixation crosses that preceded the bridge of the nose (between the eyes) or the tip of the nose. White faces were more accurately recognised when following high fixation crosses (that preceded the bridge of the nose) than when following low fixation crosses. The converse was true for Black faces. These effects were independent of participant race. The fixation crosses attracted the first fixation but had less effect on other eye-tracking measures. Furthermore, the location of the first fixation was predictive of recognition accuracy. These results are consistent with an attentional allocation model of the own-race bias in face recognition and highlight the importance of the first fixation for face perception (c.f. Hsiao & Cottrell, 2008).

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The own-race bias (ORB) in face recognition is typified by more accurate and faster recognition of own-race compared to other-race faces (for a review see Meissner & Brigham, 2001). The ORB has been extensively studied, yet the mechanisms underlying it are still under debate. Many researchers propose that it is caused by expert face processing mechanisms being employed for own-race faces but not for other-race faces (e.g., Michel, Rossion, Han, Chung, & Caldara, 2006; Valentine & Endo, 1992), whereas other researchers have proposed that people are more motivated to process own-race faces more accurately than other-race faces (e.g., Sporer, 2001). While these propositions are not mutually exclusive (although a participant may have the motivation to process other-race faces accurately they also need the perceptual expertise to do so, Hugenberg, Miller, & Claypool, 2007), the precise nature of the perceptual expertise requires further elucidation.

Hills and Lewis (2006) recently proposed that the reason why other-race faces are less accurately recognised than own-race faces is due to the physiognomic characteristics of faces of different races. Black African and White European faces have different physiognomic variability for different features (McClelland & Chappell, 1998): Black faces have more variability in the nose and mouth shape than the eye and hair colour, whereas White faces have the reverse pattern. Ellis, Deregowski, & Shepherd (1975) have shown that Black and White participants tend to describe faces based on these differences: White participants described the eye and hair colour more frequently than the nose and mouth shape, whereas Black participants showed the reverse pattern. Based on this evidence, Hills and Lewis (2006) used a perceptual learning paradigm to train White participants to encode the features that distinguish between Black faces (i.e., the nose and mouth) and managed to reverse the ORB and actually make their participants recognise Black faces more accurately than White faces.

Hills and Lewis (2011) extended these findings by demonstrating that extensive training was not required to alter the nature of the ORB. They used fixation crosses to guide White participants' attention to either the nose or the eyes of Black and White faces. Given that the nose is more diagnostic in differentiating between Black faces, these authors hypothesised that recognition of Black faces would be superior following a fixation cross preceding the nose, whereas recognition of White faces would be inferior. Similarly, following a fixation cross preceding the eye region, recognition accuracy of White faces would be superior to the recognition of Black faces. This is exactly what happened. The conclusion was that recognition of Black faces was more efficient if the more diagnostic features were encoded. Specifically, the nose is a more diagnostic feature for the encoding of Black faces than the eyes.

These findings are entirely consistent with the face-space model of how faces are stored in memory (Valentine, 1991). In this model, all faces are stored in a multidimensional space in which the dimensions of the space represent different physiognomic characteristics (which could include width of nose or colour of the eyes). The dimensions used to recognise faces are based on the principles of perceptual warping (Kuhl, 1994): extensive experience removes dimensions that do not discriminate between the type of faces that are most frequently encountered (Furl, Phillips, & O'Toole, 2002). Thus, the dimensions of face-space are designed to discriminate between own-race faces and the dimensions that other-race faces vary on are not used (MacLin & Malpass, 2001; Valentine & Endo, 1992). If participants use dimensions of face-space that are more diagnostic for the recognition of other-race faces, then recognition of those faces should be more accurate. Hills and Lewis (2006; 2011) interpret their findings within this framework: training participants or guiding their attention to process faces using dimensions that are diagnostic for other-race faces will lead to more stable representations of those faces and thus increase the recognition accuracy of those faces.

The interpretation of the data of Hills and Lewis (2006; 2011) must be taken with some caution given one of their findings and a related methodological flaw. In their second experiment, Hills and Lewis (2011) demonstrated that the effects of the fixation cross were not present if participants were forced to delay their recognition responses by four seconds and were markedly reduced if participants delayed their responses by two seconds. In other words, the effects of the fixation cross were moderated by the amount of time viewing the face. Based on the evidence that only the initial fixations are important for accurate recognition of faces (Hsiao & Cottrell, 2008), Hills and Lewis interpreted their results in terms of overwriting of the information encoded during the first fixation by information encoded during later fixations especially if the first fixation does not correspond to one of the typically used dimensions of face-space. This can only be confirmed if eye-tracking data reveals that the fixation cross does indeed attract the first fixation but has a smaller effect on subsequent fixations. This is what the present study aimed to address.

This study also aims to address a limitation of Hills and Lewis (2011): Only White participants were tested. This limitation caused two caveats with the above interpretation. Firstly, we cannot be sure that Black participants do indeed view faces differently to White participants, though data from Caldara, Zhou, & Miellet (2010) indicate that Asian and White participants fixate on different facial features. Secondly, the results can be explained within the configural and featural processing framework (Michel et al., 2006) if one assumes that the fixation cross preceding the nose region disrupts configural processing and enhances the encoding of relevant features. Thus, to rule this explanation out, tests on Black participants should be conducted. If the ORB is better explained by the configural-featural explanation, then we would expect the same pattern of results to be observed in Black participants (that is, Black faces would be better recognised by a high fixation cross than a low fixation cross). However, if the explanation of the ORB based on the face-space is more parsimonious, then we would expect the opposite pattern of results (where Black participants' recognition of White faces would be more accurate when the fixation cross was high than when it was low). Nevertheless, given that Black participants do tend to describe faces based on more features (Shepherd & Deregowski, 1981), we might expect a smaller effect of the fixation cross manipulation in Black participants.

Using a similar design to Experiment 1 in Hills and Lewis (2011), Black and White participants' ORB was assessed in a standard old/new recognition paradigm when viewing own- and other-race faces (Black and White faces respectively) following fixation crosses preceding either the eyes (a high fixation cross) or nose (a low fixation cross). A control condition was implemented in which there were no fixation crosses. Behavioural (recognition accuracy) and eye-tracking measures were recorded. Crucially, if fixation crosses attract the first fixation, then there should be an effect of fixation cross position on measures of first fixation but not on other eye-tracking measures (i.e., duration of fixations to other areas). In addition, there should be an interaction between fixation cross position and race of face on recognition accuracy. To test the explanation of the ORB provided by Hills and Lewis (2011), the location of the first fixation should predict recognition accuracy of faces, in that if the first fixation is to the eyes then recognition of White faces should be more accurate, whereas if the first fixation is to the nose then the recognition of Black faces should be more accurate.

Method

Participants

Fifty (25 male) staff and students from Anglia Ruskin University participated in this experiment as partial fulfilment of a course requirement. All self-reported they had normal or corrected-to-normal vision. Twenty five self-reported that they were White British aged between 18 and 26 (modal age was 19) and 25 reported that they were Black aged between 18 and 35 (modal age was 20) of which 20 were British and five were from various African or Caribbean countries and had lived in the UK for more than 2 years.

Materials

All stimuli were displayed on a white background in the centre of a 17" (1280 x 1024 pixels) LCD colour monitor. The stimuli were presented and recognition responses were recorded using ClearView software, version 2.7.0, and eye movements were recoded using a Tobii 1750 eye-tracker (Falls Church, VA), with embedded infrared cameras with a sampling rate of 50Hz. 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 at least 100 ms (see Goldinger, He, & Papesh, 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 65 cm from the monitor.

To assess the ORB, 160 faces (80 Black and 80 White) were taken from the Minear and Park (2004) face database. The faces selected were of males or females, aged between 18 and 40 and in full frontal poses. All face stimuli had a standard background and contained no extraneous features such as clothing, jewelry, or make-up. All the images were presented in 72 dpi resolution, 125 mm wide by 188 mm high. A different image of the same face was used for the learning phase to the test phase to avoid pictorial recognition (c.f., Bruce, 1982).

The fixation crosses were 5 mm high by 5 mm wide, and were 1 mm thick. Crosses were black on a white background. These were presented in the centre of the horizontal axis of the screen, but their position was varied in the vertical axis of the screen.

Design

A 2 x 2 x 2 x 3 mixed-subjects design was employed with the factors: participant race (Black and White; between-subjects); phase of the experiment (learning and test; within-subjects); race of face (Black and White; within-subjects) and position of the fixation cross (no, high, and low fixation cross; within-subjects). Recognition accuracy was measured in terms of the Signal Detection Theory (e.g., Swets, 1966) measure of stimulus discriminability, *d'*. Duration and location of fixations were also recorded. The faces were counterbalanced such that they appeared as a target and distractor an approximately equal number of times. In addition, the order of the faces presented was randomised. Fixation crosses were presented during the learning and test phases of the experiment. The position of the fixation cross was randomised by participant with the criteria that each face appeared in each fixation cross condition in an approximately equal number of trials (56 in each of the fixation cross conditions and 48 in the control condition – this difference is accounted for in the calculation of the sums of squares and does not cause any statistical concerns).

Procedure

Participants were tested individually in a dedicated eye-tracking laboratory. Participants sat facing the monitor with the keyboard directly in front of them, 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 ClearView software, which required them to track a moving blue circle around a white screen to nine pseudo-random locations on the screen. From this point, there were three consecutive phases: the learning phase, distraction, and the test phase.

In the learning phase, participants were presented with 80 faces sequentially in a pseudo-random order with the restriction that there could not be four consecutive faces of the same race. Each face was on screen for 2 s (this was chosen as the effect of the fixation cross should be observable based on Hills & Lewis', 2011, Experiment 2 and that there should be sufficient eye-tracking data to analyse, e.g., Althoff & Cohen, 1999). After each face there was a blank white screen for 150 ms, followed by a fixation cross (or another blank screen in the no fixation cross condition). Participants were to fixate on this fixation cross, or anywhere on the blank screen where the face would appear (in the no fixation cross condition) for 200 ms before the face appeared. The fixation cross position was randomised across trials with the pre-requisite that there were 28 trials where the fixation cross was high, 28 trials where the fixation cross was low, and 24 trials where there was no fixation cross. For each fixation cross position half of the faces were Black and half were White. Participants were instructed to rate each face on a 1 to 9 scale for distinctiveness by responding to the question "how easy would this face be to spot in a crowd?" (similar to Light, Hollander, & Kayra-Stuart, 1979). Participants were encouraged to use all of the numbers in the scale.

Immediately following the learning phase, participants were presented with a brief demographic questionnaire and the Modern Racism Scale (McConahay, 1982). No participant scored at a level that gave concerns of racism so was not considered further. Participants were also asked to provide their experience and contact with people of other races in a manner similar to Malpass and Kravitz (1969). There were no correlations involving self-reported measures of contact and any behavioural or eye-tracking measure. This typically lasted 5 minutes. Participants were then given the instructions for the unexpected recognition phase.

In the test phase, participants were presented with all 160 faces (80 old and 80 new) of which half were Black faces and half were White faces. Between each face was a blank white screen for 150 ms then a fixation cross (or extended blank screen) which the participants viewed for 200 ms before the face appeared. The position of the fixation cross was matched from learning to test for the old faces. For the new faces, the ratio of high, low, and no fixation crosses was the same as the learning phase and randomised in the same way. The presentation of the faces was sequential and randomised in the same way as in the learning phase. During this task, participants were required to respond as to whether they had seen the face before by pressing "z" if they had and "m" if they had not seen it in the learning phase. Faces were on screen for 2 s and participants were required to respond during that time. Once all 160 faces were presented, participants were thanked and debriefed.

Results

We present the behavioural and eye-movement data separately for clarity. For all comparisons throughout these results, when Mauchley's test of sphericity was significant, the Huynh-Feldt (1976) correction was applied. This was chosen since the sphericity estimates were typically above 0.75 (Girden, 1992). Here, we report the corrected significance levels but the uncorrected degrees of freedom. The Bonferroni correction was applied to the alpha level for post-hoc comparisons where appropriate (corrected alpha levels are reported here).

Recognition Accuracy

The sensitivity measure, *d',* was calculated using the MacMillan and Creelman (2005) method combining hit and false alarm rate. Incidentally, an analysis was run on the non-parametric *A'* and the results were identical to the *d'* analysis and so is not reported here. Macmillan and Creelman (2005) do not indicate that one statistic is more appropriate than another for the present type of data. *d'* typically ranges from 0 to 4, whereby 0 is recognition at chance levels and 4 is near-perfect recognition. Means and standard deviations are presented in Table 1. The trend of these data replicates that of Hills and Lewis (2011), whereby Black faces were recognised more accurately following a low fixation cross than a high fixation cross and the converse was true for White faces. This pattern of results was similar for both groups of participants.

The data were subjected to a 2 x 2 x 3 mixed ANOVA with the factors: participant race, race of face, and fixation cross position. Crucially, the interaction between participant race and race of face was significant, $F(1, 48) = 33.00$, $p < .001$, $\eta_P^2 = .41$. Black participants recognised Black faces (M = 1.75, SE = 0.11) more accurately than White faces (M = 1.48, SE = 0.13, $p = .004$), whereas White participants recognised White faces (M = 1.47, SE = 0.13) more accurately than Black faces (M = 1.03, SE = 0.11, $p < .001$). This is the traditional ORB.

There was also an interaction of race of face and fixation cross position, $F(2, 96) = 19.36$, $p < .001$, $\eta_P^2 = .29$. Simple effects showed that White faces (M = 1.70, SE = 0.10) were recognised more accurately than Black faces (M = 1.15, SE = 0.10) when the fixation cross was high than when the fixation cross was low ($p < .001$). When the fixation cross was low, Black faces (M = 1.63, SE = 0.11) were recognised more accurately than White faces (M = 1.30, SE = 0.10, $p = .004$).

For completeness, there was also a main effect of participant race, $F(1, 48) = 5.59$, $MSE = 1.78$, $p = .022$, $\eta_P^2 = .10$, in which Black participants (M = 1.61, SE = 0.11) were more accurate than White participants (M = 1.25, SE = 0.11), replicating Cross, Cross and Daly (1971). These patterns were replicated in the hit rate data and mirrored in the false alarm data and there were no effects in response bias. These analyses are available from the author on request.

Table 1 about here

ORB

The raw *d'* was transformed into an ORB for each participant using the formula:

$$\text{ORB} = (d'_W - d'_B) / (d'_W + d'_B) \qquad [1]$$

where d'_W is the sensitivity of recognising White faces and d'_B is the sensitivity of recognising Black faces. This measures the ORB relative to overall performance (Hills & Lewis, 2006). Incidentally, the pattern of the results is the same when using a simpler form to calculate the ORB ($d'_W - d'_B$). Using this formula, a positive number indicates an ORB, whereas a negative number indicates a bias in favour of other-race faces (that is, the opposite of the ORB). Means are presented in Table 1. These show that the ORB was removed when the fixation cross was in the lower position for White participants and was reversed for Black participants when the fixation cross was in the higher position.

These data were subjected to a 2 (participant race) x 3 (fixation cross position) mixed-subjects ANOVA which revealed a significant effect of fixation cross position, $F(2, 96) = 6.42$, $p = .002$, $\eta_P^2 = .12$. The ORB was larger when there was no fixation cross (M = 0.26, SE = 0.04) than when the fixation cross was high (M = 0.06, SE = 0.05, $p = .018$) or when the fixation cross was low, though not significantly (M = 0.13, SE = 0.03, $p = .057$). The main effect of participant race was also significant, $F(1, 48) = 7.98$, $p = .007$, $\eta_P^2 = .14$, in which Black participants (M = 0.09, SE = 0.03) showed a smaller ORB than White participants (M = 0.21, SE = 0.03).

Crucially, there was an interaction between these variables, $F(2, 96) = 14.13$, $p < .001$, $\eta_P^2 = .23$. Simple effects revealed that for Black participants, the ORB was smaller when the fixation cross was high (M = -0.17, SE = 0.06) than when the fixation cross was low (M = 0.20, SE = 0.04, $p < .001$) or when there was no fixation cross (M = 0.24, SE = 0.06, $p < .001$). For White participants, the ORB was smaller when the fixation cross was low (M = 0.06, SE = 0.04) than when the fixation cross was high (M = 0.29, SE = 0.06, $p = .018$) or when there was no fixation cross (M = 0.29, SE = 0.06, $p = .048$).

One-sample t-tests were conducted on these ORB scores in order to demonstrate whether there was a significant ORB in each of the fixation cross conditions for both sets of participants. For White participants, the ORB was significant in the no fixation cross condition, $t(24) = 4.84$, $p < .001$, and the high fixation cross condition, $t(24) = 4.23$, $p < .001$ but not the low fixation cross condition, $t(24) = 1.33$, $p > .20$. For Black participants, the ORB was significant in the no fixation cross condition, $t(24) = 4.18$, $p < .001$, and the low fixation cross condition, $t(24) = 4.79$, $p < .001$, but in the high fixation cross condition, the ORB was significantly reversed, $t(24) = 2.83$, p = .009.

Predictive Nature of First Fixation

We directly tested the hypothesis that the location of the first fixation affects the ORB by analysing recognition accuracy as a function of the location of the first fixation. The data was coded such that for each trial the location of the first fixation was either the upper half of the face (the eyes and the head) or the lower half of the face (the nose and mouth). Trials in which the first fixation was not to any of these features were excluded from the analysis (5.8% of trials). This analysis collapsed across the fixation cross condition to ensure sufficient power.

Mean recognition accuracy is presented in Figure 1 split by first feature fixated upon and the race of the face. This was subjected to a 2 x 2 x 2 within-subjects ANOVA. Critically, this revealed an interaction between the race of the face and the first feature fixated upon, $F(1, 48) = 25.53$, $p < .001$, $\eta_p^2 = .35$. Simple effects revealed that Black faces were recognised more accurately when the first fixation was to the nose or mouth (M = 7.71%, SE = 0.02) than when the first fixation was to the head or eyes (M = 6.59%, SE = 0.02, $p < .001$). The converse was true for White faces: they were more accurately recognised when the first fixation was the head or eyes (M = 7.57%, SE = 0.02) than the nose or mouth (M = 7.09%, SE = 0.03, $p = .03$). This did not depend on the participant race, $F(1, 48) = 0.35$, $p = .557$, $\eta_p^2 = .01$. Furthermore, if the nose was first fixated upon it led to greater accuracy than if the eyes were first fixated upon, $F(1, 48) = 6.90$, $p = .012$, $\eta_p^2 = .13$, suggesting that while the eyes are exclusively beneficial to the recognition of White faces, the nose seems to be beneficial to the recognition of both White and Black faces.

Figure 1 about here

Eye-tracking results

Three areas of interest (AOIs) were mapped out on to each individual stimulus independently in a similar manner as Goldinger, He, and Papesh (2009, see Figure 2), using ClearView 2.7.0. These areas mapped out were not visible to participants. The areas were based on theoretically important regions of the face (i.e., we were not expecting nor interested in differences in eye movements over the forehead, chin, cheeks, and ears) and on preliminary analyses that revealed no effects of the fixation cross or race on fixations to these areas. We analysed the duration of fixation in each AOI and proportion of first and second fixation to each AOI. All eye-tracking data was recorded until the participants' responded in both the learning and the recognition phase of the experiment. Incidentally, we also conducted an analysis on area-normalised (calculated by dividing the proportion of time spent fixating in the AOI by the proportion of the screen the AOI occupied, see Bindemann, Scheepers, & Burton, 2009; Fletcher-Watson, Findlay, Leekam, & Benson, 2008) AOIs in order to deal with the unequal sizes of the AOIs. These results were identical to the non-normalised data.

Figure 2 about here

AOI Duration

Proportion of time spent fixating in each AOI was calculated and is presented in Figure 3. These data were subjected to a 2 x 2 x 2 x 3 x 3 within-subjects ANOVA with the factors: participant race, race of face, experiment phase, fixation cross position, and facial feature. This analysis revealed a main effect of phase of the experiment, $F(1, 48) = 5.17$, $p = .028$, $\eta_P^2 = .10$, in which fixation time was 40 ms longer in the test phase of the experiment than the learning phase. This effect interacted with race of face, $F(1, 48) = 4.09$, $p = .049$, $\eta_P^2 = .08$: the pattern of this interaction suggested that there was no difference in fixation duration between Black and White faces at learning but slightly (though not significant) longer fixation for Black faces than White faces at test.

A main effect of facial feature was revealed, $F(2, 96) = 43.74$, $p < .001$, $\eta_P^2 = .48$. Bonferroni corrected pairwise comparisons revealed that participants spent longer viewing the eyes than the nose (mean difference = 140.03, $p < .001$) and the mouth (mean difference = 353.37, $p < .001$), and the longer viewing the nose than the mouth (mean difference = 182.34, $p < .001$). These results indicate that there is a distinct hierarchy of features (Haig, 1986) in terms of scanning behaviour in which the eyes receive the largest amount of attention, followed by the nose and mouth, with other features receiving minimal attention. This effect interacted with participant race, $F(2, 96) = 43.75$, $p < .001$, $\eta_P^2 = .48$, as shown in Figure 3. Simple effects revealed that White participants demonstrated the standard feature-hierarchy effect previously described. However, this effect was not observed for Black participants: Black participants viewed the nose more than the eyes (mean difference = 175, 47, $p = .05$) and the mouth (mean difference = 294.54, $p < .001$).

The main effect of fixation cross was not significant nor any interactions with this variable, largest $F = 1.98$, $p =.14$, $\eta_P^2 = .04$, indicating that the fixation crosses do not affect participants' fixation pattern significantly. There was no significant main effect of race of face nor any further interactions with this variable, largest $F = 1.78$, $p =.15$, $\eta_P^2 = .04$, indicating that a similar fixation pattern is observed when viewing Black and White faces. Incidentally, the pattern of data was identical if the number of fixations to each AOI was used as the dependent measure.

Figure 3 about here

First and Second Fixations

Given that we explicitly predicted the fixation crosses would affect the first fixation primarily, we analysed the proportion of fixations to each AOI for the first and second fixation. Crucially, the first fixation here is defined as the first fixation post-stimulus onset and is thus most likely to be affected exogenously. We also analysed the second fixation to explore any prolonged effects of the fixation cross. Only the first two fixations were analysed since two fixations are all that are required for high recognition accuracy (Hsiao & Cottrell, 2008) and we have already noted above that globally, the fixation crosses did not affect eye-movements. The data are presented in Figure 4. We only included trials in which the fixations were to the eyes, nose, or mouth and excluded the 5.4% of trials in which other features were the first fixated upon. These figures clearly show that the preferred AOIs for the second fixation are similar to that observed for overall fixations. However, preferred AOIs for the first fixation depends on the position of the fixation cross. These data were subjected to a 2 x 2 x 2 x 2 x 3 x 3 within-subjects ANOVA with the factors: participant race, race of face, experiment phase, fixation number (first or second), fixation cross position, and facial feature.

This analysis revealed a main effect of feature, $F(2, 96) = 101.75$, $p < .001$, $\eta_P^2 = .68$. Bonferroni corrected pairwise comparisons demonstrated the standard hierarchy of features: the eyes were more likely to be fixated upon, then the nose, then the mouth (all *p*s < .05). This main effect was qualified by participant race, $F(2, 96) = 37.47$, $p < .001$, $\eta_P^2 = .44$. This interaction revealed itself through the aforementioned hierarchy of features only existing for White participants. For Black participants, the nose was the most likely to be fixated upon.

Not surprisingly, there was a significant two-way interaction between fixation cross position and feature fixated upon, $F(4, 192) = 12.88$, $p < .001$, $\eta_P^2 = .21$, in which the eyes were fixated upon more so when there was no fixation cross (M = .50, SE = .03) and when it was high (M = .53, SE = .02) than when the fixation cross was low (M = .48, SE = .02), whereas the nose was fixated upon more so when the fixation cross was low (M = .42, SE = .02) than when it was high (M = .33, SE = .02) or when there was no fixation cross (M = .38, SE = .01). This two-way interaction was mediated by participant race, $F(4, 192) = 5.97$, $p < .001$, $\eta_P^2 = .11$, such that when there was no fixation cross, fixations were made to the eyes more for White participants and to the nose more for Black participants.

Crucially, the fixation cross by feature interaction was also mediated by fixation number, $F(4, 192) = 25.12$, $p < .001$, $\eta_P^2 = .34$, such that the effect of the fixation cross (as described above) was only observed for the first fixation and not the second fixation. This interaction was itself mediated by participant race, $F(4, 192) = 2.73$, $p = .049$, $\eta_p^2 = .05$. This mediation was revealed through the effects when there was no fixation cross: in these cases, the Black participants looked at the nose and mouth more than the White participants. In this analysis, there was no effect of race of face nor an effect of phase of the experiment, indicating that the effects of fixation cross are consistent across all types of faces and all parts of the experiment.

Figure 4 about here

We also measured the length of the first fixation to see if the fixation crosses altered the starting point in the scanpath with a 2 (participant race) x 2 (race of face) x 3 (fixation cross position) within-subjects ANOVA. The first fixation was longer to Black faces than to White faces (mean difference = 16 ms), $F(1, 24) = 7.34$, $MSE = 1286$, $p = .012$, $\eta_p^2 = .23$. First fixations were longer following the low fixation cross than the high fixation cross (mean difference = 41 ms, $p = .003$) and when there was no fixation cross (mean difference = 34 ms, $p = .018$), $F(2, 48) = 9.61$, $MSE = 2966$, $p = .001$, $\eta_p^2 = .29$. The interaction between these two variables was not significant, $F(2, 48) = 1.33$, $MSE = 3101$, $p > .27$, $\eta_p^2 < .05$, nor were any effects involving participant race.

Discussion

Black faces are more accurately recognised following fixation crosses that precede the tip of the nose than White faces, whereas White faces are more accurately recognised following fixation crosses that preceded the bridge of the nose (between the eyes). This effect is irrespective of race of the observer. The present results replicate Hills and Lewis' (2011) findings from their Experiment 2, 2000 ms delay condition. In other words, the fixation cross preceding the lower half of the face removed the ORB in White participants by raising the recognition performance for Black faces and lowering the recognition performance for White faces compared to the no fixation cross condition. Additionally, we found that black participants' ORB was removed when the fixation cross preceded the upper half of the face by improving recognition accuracy of White faces and lowering recognition rates for Black faces compared to the no fixation cross conditions.

The present study explored eye-movements as the potential mechanism for this effect. The effect of the fixation cross was observed in the first fixation, but not the second fixation. At first glance, this is not surprising: the presentation of a fixation cross is specifically designed to attract attention. We have provided experimental evidence that our participants complied with this intention (this in itself is an important result). What is crucial is that this exogenous cueing then affected face recognition accuracy, highlighting the importance of the location of the first fixation for accurate face encoding, processing, and recognition (see e.g., Hsiao & Cottrell, 2008) and the re-orienting of fixations to the preferred landing position (Sæther, Van Belle, Laeng, Brennen, & Øvervoll, 2009). Most importantly, the location of the first fixation did indeed predict recognition accuracy, whereby Black faces were better recognised when the first fixation was to the nose than when the first fixation was to the eyes and the converse was true for White faces. This is particularly interesting given that the location of the first fixation in the present study was exogenously caused (i.e., it was directed by the experimentation conditions rather than any internal schemas).

These results advance our understanding of the ORB and eye-movements in two important ways. Firstly, they suggest that part of the ORB is due to whether the most diagnostic facial features are encoded first or not in both Black and White participants. Secondly, these results extend the importance on the first fixation for face recognition (cf Hsiao & Cottrell, 2008). We shall address these separate theoretical issues individually.

We have convincingly demonstrated that the ORB can be reduced by forcing participants to first fixate on the most diagnostic feature for discriminating between faces of that particular race. These results are entirely consistent with the multidimensional face-space (e.g., Valentine, 1991) framework of face memory. While participants normally use the dimensions that are most diagnostic in discriminating between faces that are most frequently encountered (typically, ones of their own race, e.g., MacLin & Malpass, 2001), they can be made to use the dimensions that are diagnostic for discriminating between faces of another, less familiar, race. This results in greater encoding efficiency and recognition accuracy for those faces. This suggests that the face-space may be a more flexible system than envisioned by Lewis (2004), whereby dimensions can be selectively attended to depending on the task at hand (see e.g., Hills, Holland, & Lewis, 2011).

These results also may indicate a potential explanation for what is occurring during the individuation training employed by a number of researchers. For example, Hugenberg et al. (2007) instructed their participants to individuate faces of another race by paying "close attention to what differentiates one particular face from another face of the same race, especially when that face is not of the same-race as you." This instruction may lead to participants to process and encode features that they would not normally attend to provided they know what features are best to differentiate other-race faces. Indeed, when asked to describe what discriminates Black faces, White participants do describe the nose shape and mouth more frequently (see e.g., Bar-Haim, Saidel, & Yovel, 2009; Chiroro, Tredoux, Radaelli, & Meissner, 2008). This suggests that participants were inherently aware of the different physiognomic variability between races. This individuation instruction and training regimes employed by other researchers leads to improved perceptual processing of other-race faces (McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2011) and enhanced activation of the N250 Event-Related Potential component for other-race faces (Tanaka & Pierce, 2009) and reduced implicit racial bias (Lebrecht, Pierce, Tarr, & Tanaka, 2009) towards other-race groups.

Fixation crosses, thus, exogenously cued participants to focus on features they would not normally fixate on. Forcing participants to fixate on features in other-race faces that are typically fixated upon by observers of that particular other race leads to greater recognition accuracy. One critical source of evidence for this stems from the control conditions when there was no fixation cross. In this condition, we would expect that participants would anticipate the presentation of the next face. They would thus orientate their first fixation to its typical location. In this case, the White participants orientated their first fixation to the eye region and Black participants orientated their first fixation to the nose region, suggesting that these features offer differential diagnostic utility depending on face race. This is consistent with existing evidence concerning the fixation pattern of Asian and White participants: Asian participants tend to fixate more on the nose than White participants (Caldara et al., 2010), though this may be a result of cultural differences in holistic and analytic processing (Nisbett, Peng, Choi, & Norenzayan, 2001) - without evidence of the diagnostic features of Asian faces, neither explanation can be ruled out. Recently, however, Michel, Rossion, Bülthoff, Hayward, & Voung (in press) have demonstrated that the ORB in White participants when viewing Asian faces is primarily due to face and feature shape rather than surface texture suggesting physiognomic variability in White and Asian faces is indeed different and is involved in causing the ORB.

Given the wide acceptance of the configural and featural framework explaining the ORB (e.g., Michel, et al., 2006), we should attempt to account for these data accordingly. These results indicate that if the ORB is due to configural encoding being primarily employed for own-race faces and featural encoding employed primarily for other-race faces, then configural coding is more successful based on different features for different races. In other words, configural information is better extracted from the eyes in White faces and from the nose in Black faces. We could thus suggest that configural processing is based on the diagnosticity of the particular facial features.

While these data are consistent with the face-space account of the ORB, they do not refute the socio-cognitive models (e.g., Sporer, 2001). The socio-cognitive account of the ORB suggests that participants require the motivation *and* the relevant ability to process other-race faces accurately (Hugenberg et al., 2007). Thus, here we are suggesting that in order to process Black faces accurately, White participants need to know that they must attend to different facial features. Indeed, during the present experiment, we observed that White participants did look at Black and White faces using slightly different features: the lower features of Black faces were looked at more frequently. This may have been due to priming, since the participants were aware of the nature of the study when they participated. Thus, we are proposing a specific integration of the socio-cognitive models of the ORB with face-space, whereby when participants have the motivation to process other-race faces, then will use the most diagnostic facial features and thus the most discriminating dimensions of face-space.

These results also advance our understanding of eye-movements involved in face perception. It has already been established that the first fixations are sufficient for accurate face recognition (Hsiao & Cottrell, 2008). We have shown that if this is to the most diagnostic features, then the face will be coded more accurately than if the first fixation is to a less diagnostic feature. However, we should point out that in the present study, as in Hills & Lewis (2011), Experiment 2, we only managed to remove the ORB from our participants. If, as in Hills and Lewis' Experiment 1, participants made their recognition responses quicker, then we would have expected a reversal of the ORB. Previously, we hypothesised that this may be due to the proportion of time spent in the diagnostic region was much lower when the face is on screen for longer or that the first fixation is over-written. This may, at first, seem contradictory to the results of Hsiao and Cottrell (2008) who indicated that only the first two fixations were required. However, there is plenty of evidence that suggests that longer exposure times lead to more fixations and greater recognition accuracy (Bruce, 1982; Ellis, 1981; Laughery, Alexander, & Lane, 1971; Shepherd, Gibling, & Ellis, 1991). This is not due to a larger number of features being sampled (Coin & Tiberghien, 1997), but rather the most diagnostic features being encoded more effectively. Thus, the ORB will be affected to a greater or lesser degree depending on the number of fixations made to the most diagnostic features. Interestingly, the effect of fixation cross on eye-movements was similar at learning and at test, indicating a generalised improvement in encoding efficiency caused by the fixation crosses.

Eye-movements over a face following a fixation cross are somewhat abnormal: fixation crosses cause fixations to be more dispersed over the face following a prolonged first fixation. This suggests that forcing attention to be directed to a particular point causes the participants to delay their normal scanning pattern. Crucially, during this delay, participants are encoding the information presented to them. Delaying the initiation of the typical scanpath could be the result of feedback and comparison from endogenous and exogenous eye-movement control systems (Parkhurst, Law, & Niebur, 2002): the actual fixation (exogenously caused by the fixation cross) has to be compared to the preferred landing position (e.g., Coren & Hoenig, 1972) when looking at that particular stimulus. If there is a match, the pre-programmed scanpath (e.g., Leonards & Scott-Samuel, 2005; Yarbus, 1967) can be engaged. If there is mismatch between actual fixation and the preferred landing position, then the eye-movement control system must programme a new scanpath. This notion is based on the idea that automatic anchoring of gaze when viewing objects (Vinette, Gosselin, & Schyns, 2004) is a pre-requisite for engaging the typical scanpath. Saccadic programming takes approximately 100 ms to engage (Hanes & Schall, 1996). This is equivalent to the additional length of the first fixation following a fixation cross. The pre-programmed scanpath is typically activated within 200 – 300 ms of the termination of the exogenous cueing (Guzman-Martinez, Leung, Franconeri, Grabowecky, & Suzuki, 2009). This may be because the system is attempting to update and this process requires more time than each fixation allows causing the eye-movements to constantly be trying to catch up (c.f., the eye-movements observed in schizophrenia, Bartfai, Levander, Nybäck, Berggren, & Schalling, 1985). This is, of course, conjecture, but explains why the fixation cross caused a protracted first fixation.

We also found that Black participants recognised faces with more accuracy overall that White participants. Cross et al. (1971) reported that White participants were less accurate at face recognition tasks than Black participants. This may be explained by the fact that both Black and White faces could be recognised accurately following a first fixation to the nose and Black participants typically fixated upon the nose more. Additionally, Black participants recognised White faces relatively more accurately than White participants recognised Black faces (similar to findings in Asian participants by Valentine & Endo, 1992). This may indicate that the Black participants were exposed to and had extensive contact with both races and were able to use the appropriate strategy for the recognition of both types of faces.

One interesting implication of the present work is the apparent confliction of the present results and the face recognition studies that employ fixation crosses. In many studies that have reported significant ORBs, fixation crosses were not employed (such as Chiroro et al., 2008; Cross et al., 1971; Hugenberg et al., 2007; Lavrakas, Buri, & Mayzner, 1976; Malpass & Kravitz, 1969; Michel, Caldara, & Rossion, 2005; Valentine & Endo, 1992). Instead, between the presentation of faces there was a blank inter-trial interval. The use of fixation crosses is a more recent procedure employed to indicate the start of a trial in order that participants are prepared to look at a relevant part of a screen. These fixation crosses are often positioned centrally (e.g., Hahn, Jantzen, & Symons, 2012), though this is not always specified, and often result in significant ORBs being observed (but see Cooper & Kennett, 2013). This "central" fixation cross may be between the eyes (for example, Williams & Henderson, 2007) depending on whether the faces show hair. In these cases, White participants should show an enhanced ORB. Based on the data here, we would expect to see studies conducting on Black participants to report showing a smaller ORB if fixation crosses are used. This has not been specifically reported thus far.

The above discussion has the critical caveat that is that the participants actually attend to fixation crosses during experiments. In the present study, participants had to fixate upon them for 150 ms in order for the trial to commence. This is not typical practice in other studies: The fixation cross is a cue to the start of the trial and in some cases disappears before the face appears (e.g., Goldinger, et al., 2009) sometimes being replaced with a context image (Shriver, Young, Hugenberg, Bernstein, & Lanter, 2008). Fixation crosses are also typically on screen for longer in face recognition experiments than in the present study (for example, 500 ms in Wiese, Stahl, & Schweinberger, 2009, and 2 s in He, Ebner, & Johnson, 2011). This increased length of time may allow participants to drift their attention and eyes away from the fixation cross. Thus, there is no reason to attend to a fixation cross in most experiments and many participants in psychological studies are familiar with the testing environment and this fact. Indeed, there are many psychological effects based on participants ignoring or inhibiting irrelevant information and fixation crosses may well be ignored by many participants. Furthermore, some studies of the ORB do not test multiple races and thus the differential effects of any fixation crosses across faces of different faces would not be detected. Where fixation crosses have been used and significant ORBs have been found, the contrast to the present results may be due to the fact that fixation cross doesn't really attract attention unless participants are directed to look at them (and in this case, the trial wouldn't begin unless they did). Nonetheless, researchers should be careful about how the devise experimental procedures and minimise the use of fixation crosses and use fixation images (see e.g., Wu, Laeng, & Magnussen, 2012) or use external fixation crosses (see e.g., Bindemann et al., 2009).

To conclude, we have observed that the ORB in face recognition can be removed by forcing participants to attend to the most diagnostic facial features first using fixation crosses. Eye-tracking data showed that the first fixation was indeed directed by the fixation cross and this impacted on the other eye-tracking measures. Furthermore, the recognition of faces is predicted by the diagnostic value of the location of the first fixation: Black faces were more accurately recognised if the first fixation was to the nose, whereas White faces were more accurately recognised if the first fixation was to the eyes. Thus, the ORB can be explained as a failure to code faces according to the most pertinent dimensions of the face-space (Valentine, 1991).

References

Ackerman, J. M., ... Schaller, M. (2006). They all look the same to me (unless they're angry): From out-group homogeneity to out-group heterogeneity. *Psychological Science, 17,* 836 – 840. doi: 10.1111/j.1467-9280.2006.01790.x

Althoff, R. R., & Cohen, N. J. (1999). Eye-movement-based memory effect: A reprocessing effect in face perception. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 25,* 997-1010. doi: 10.1037/0278-7393.25.4.997

Bar-Haim, Y., Saidel, T., & Yovel, G. (2009). The role of skin colour in face recognition. *Perception, 38,* 145 - 148. Doi: 10.1068/p6307

Bartfai, A., Levander, S. E., Nybäck, H., Bergrren, B.-M., & Schalling, D. (1985). Smooth pursuit eye tracking, neuropsychological test performance, and computed tomography in schizophrenia. *Psychiatry Research, 15,* 49 – 62. 10.1016/0165-1781(85)90039-3,

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

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

Blanchard, H. E. & Iran-Nejad, A. (1987). Comprehension processes and eye movement patterns in the reading of surprise-ending stories. *Discourse Processes, 10,* 127 – 138. DOI:10.1080/01638538709544663

Bothwell, R. K., Brigham, J. C., & Malpass, R. S. (1989). Cross-racial identification. *Personality and Social Psychology Bulletin, 15*, 19 25. doi: 10.1177/0146167289151002

Bruce, V. (1982). Changing faces: Visual and non-visual coding processes in face recognition. *British Journal of Psychology, 73*, 105 -116. DOI: 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. doi: 10.1371/journal.pone.0009708

Chiroro, P. M., Tredoux, C. F., Radaelli, S., & Meissner, C. A. (2008). Recognizing faces across continents: The effect of within-race variations on the own-race bias in face recognition. *Psychonomic Bulletin and Review, 15,* 1089 - 1092. DOI: 10.3758/PBR.15.6.1089

Coin, C., & Tiberghien, G. (1997). Encoding activity and face recognition. *Memory, 5*, 545-568. DOI:10.1080/741941479

Cooper, R. & Kennett, S. (2013). Are all face recognition biases the same? Comparing eye movements in own-race and own-university biases. Paper presented at the EPS Conference, Bangor, July 3rd-5th, 2013.

Coren, S., & Hoenig, P. (1972). The effect of non-target stimuli on length of voluntary saccades. *Perceptual and Motor Skills, 34,* 499 - 508. doi: 10.2466/pms.1972.34.2.499

Cross, J. F., Cross, J., & Daly, J. (1971). Sex, race, age, and beauty as factors in recognition of faces. *Perception Psychophysics, 10,* 393-396. doi: 10.3758/BF03210319

Ellis, H. D. (1981). Theoretical aspects of face recognition. In G. Davies, H. D. Ellis, & J. W. Shepherd (Eds.), *Perceiving and remembering faces* (pp. 143 202). 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. DOI:10.1080/00207597508247332

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. doi:10.1016/S0364-0213(02)00084-8

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. doi: 10.1068/p5705

Girden, E. R. (1992). *ANOVA: Repeated measures.* Sage university paper series on quantitative applications in the social sciences. Newbury Park, CA: Sage.

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, Memoryand Cognition, 35,* 1105-1122. doi: 10.1037/a0016548

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. DOI: 10.3758/PBR.16.3.491

Hahn, A. C., Jantzen, K. J., & Symons, L. A. (2012). Thaterization impacts the processing of own-race faces more so than other-race faces: An ERP study. *Social Neuroscience, 7,* 113-125. doi: 10.1080/17470919.2011.583080

Haig, N. D. (1986). High-resolution facial feature saliency mapping. *Perception, 15*, 373 – 386. doi: 10.1068/p150373

Hanes, D. P. & Schall, J. D. (1996). Neural control of voluntary movement initiation. *Science, 274,* 427 – 430. doi: 10.1126/science.274.5286.427

He, Y., Ebner, N. C., & Johnson, M. K. (2011). What predicts the own-age bias in face recognition memory? *Social Cognition, 29,* 97-109.

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. doi: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. DOI:10.1080/17470210600654750

Hills, P. J. & Lewis, M. B. (2011). Reducing the own-race bias in face recognition attentional shift using fixation crosses preceding the lower half of a face. *Visual Cognition, 19,* 313- 339. Doi: 10.1080/133506285.2010.528250.

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

Hugenberg, K., Miller, J., & Claypool, H. (2007). Categorization and individuation in the CR recognition deficit: toward a solution to an insidious problem. *Journal of Experimental Social Psychology, 43,* 334 - 340. doi:10.1016/j.jesp.2006.02.010

Huynh, H. & Feldt, L. S. (1976). Estimation of the Box correction for degrees of freedom from sample data in randomised block and split-plot designs. *Journal of Educational Statistics, 1,* 69 – 82. doi: 10.3102/10769986001001069

Kuhl, P. K. (1994). Learning and representation in speech and language. *Current Opinion in Neurobiology, 4,* 812 - 822. doi:10.1016/0959-4388(94)90128-7

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. doi: 10.1037/h0031646

Lavrakas, P. J., Buri, J. R., & Mayzner, M. S. (1976). A persepctive on the recognition of other-race faces. *Perception & Psychophysics, 20,* 475-481.

Lebrecht, S., Pierce, L. J., Tarr, M. J., & Tanaka, J. W. (2009). Perceptual other-race training reduces implicit racial bias. *PlosOne, 4(1),* e4215. doi:10.1371/ journal.pone.0004215.

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

Lewis, M. B. (2004). Face-space-r: Towards a unified account of face recognition. *Visual Cognition, 1*1, 29-70. DOI:10.1080/13506280344000194

MacLin, O. H. & Malpass, R. S. (2001). Racial categorization of faces: The ambiguous race face effect. *Psychology, Public Policy, and Law, 7,* 98 – 118. doi: 10.1037/1076-8971.7.1.98

Macmillan, N. A., & Creelman, C. D. (2005). *Detection theory: A user's guide*. Cambridge, UK: Cambridge University Press.

Malpass, R. S., & Kravitz, J. (1969). Recognition for faces of own and other race. *Journal of Personality and Social Psychology, 13,* 330-334. doi: 10.1037/h0028434

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. doi: 10.1037/0033-295X.105.4.734-760

McConahay, J. B. (1986). Modern racism, ambivalence, and the Modern Racism Scale. In S. L. Gaertner & J. F. Dovidio (Eds.), *Prejudice, discrimination, and racism* (pp. 91 126). San Diego, CA: Academic Press.

McGugin, R. W., Tanaka, J. W., Lebrecht, S., Tarr, M. J., & Gauthier, I. (2011). Race-specific perceptual discrimination improvement following short individuation training with faces. *Cognitive Science, 35,* 330-347. DOI: 10.1111/j.1551-6709.2010.01148.x

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. doi: 10.1037/1076-8971.7.1.3

Michel, C., Caldara, R., & Rossion, B. (2006). Same-race faces are perceived more holistically than other-race faces. *Visual Cognition, 14,* 55-73.

Michel, C., Rossion, B., Bülthoff, Hayward, & Vuong (in press). The contribution of shape and surface information in the other-race face effect. *Visual Cognition.*

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. doi: 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. DOI: 10.3758/BF03206543

Nisbett, R. E., Peng, K., Choi, I., & Norenzayan, A. (2001). Culture and systems of thought: Holistic versus analytic cognition. *Psychological Review, 108,* 291-310. doi: 10.1037/0033-295X.108.2.291

Parkhurst, D., Law, K., & Niebur, E. (2002). Modeling the role of salience in the allocation of overt visual attention. *Vision Research, 42*, 107-123. doi:10.1016/S0042-6989(01)00250-4

Sæther, L., Van Belle, W., Laeng, B., Brennen, T., & Øvervoll, M. (2009). Anchoring gaze when categorizing faces' sex: Evidence for eye-tracking data. *Vision Research, 49,* 2870 – 2880. doi:10.1016/j.visres.2009.09.001

Sporer, S. L. (2001). Recognizing faces of other ethnic groups: An integration of theories. *Psychology, Public Policy and Law, 7,* 36-97. doi: 10.1037/1076-8971.7.1.36

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. DOI: 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. DOI:10.1080/09541449108406223

Shriver, E. R., Young, S. G., Hugenberg, K., Bernstein, M. J., & Lanter, J. R. (2008). Class, race, and the face: Social context modulates the cross-race effect in face recognition. *Personality and Social Psychology Bulletin, 34,* 260-274. DOI: 10.1177/0146167207310455

Swets, J. A. (1966). *Signal detection and recognition by human observers*. New York, NY: Wiley.

Tanaka, J. W. & Pierce, L. J. (2009). The neural plasticity of other-race face recognition. *Cognitive, Affective, & Behavioral Neuroscience, 9,* 122-131. doi:10.3758/CABN.9.1.122

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. DOI:10.1080/14640749208401305

Vinette, C., Gosselin, F., & Schyns, P. G. (2004). Spatio-temporal dynamics of face recognition in a flash: It's in the eyes. *Cognitive Science, 28*, 298 - 301. doi:10.1016/j.cogsci.2004.01.002

Wiese, H., Stahl, J., & Schweinberger, S. R. (2009). Configural processing of other-race faces is delayed but not decreased. *Biological Psychology, 81,* 103-109. doi: 10.1016/j.biopsycho.2009.03.002

Williams, C. C., & Henderson, J. M. (2007). The face inversion effect is not a consequence of aberrant eye movements. *Memory & Cognition, 35*(8), 1977–1985. doi:10.3758/BF03192930

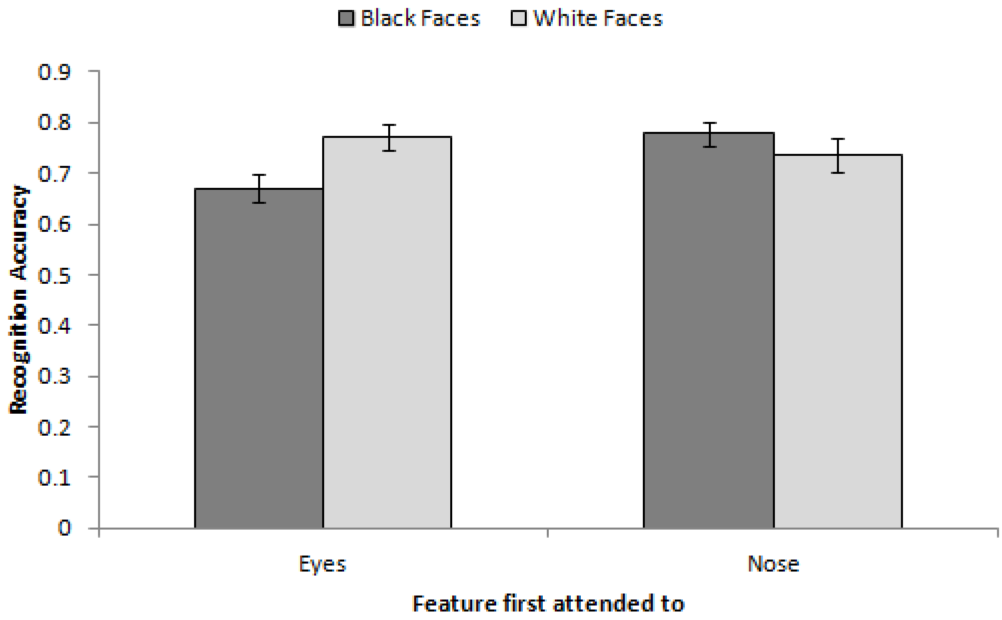
Wu, E. X. W., Laeng, B., & Magnussen, S. (2012). Through the eyes of the own-race bias: Eye-tracking and pupillometry during face recognition. *Social Neuroscience, 7,* 202-216. doi: 10.1080/17470919.2011.596946

Yarbus, A. L. (1969). *Eye movements and vision.* Plenum Press.

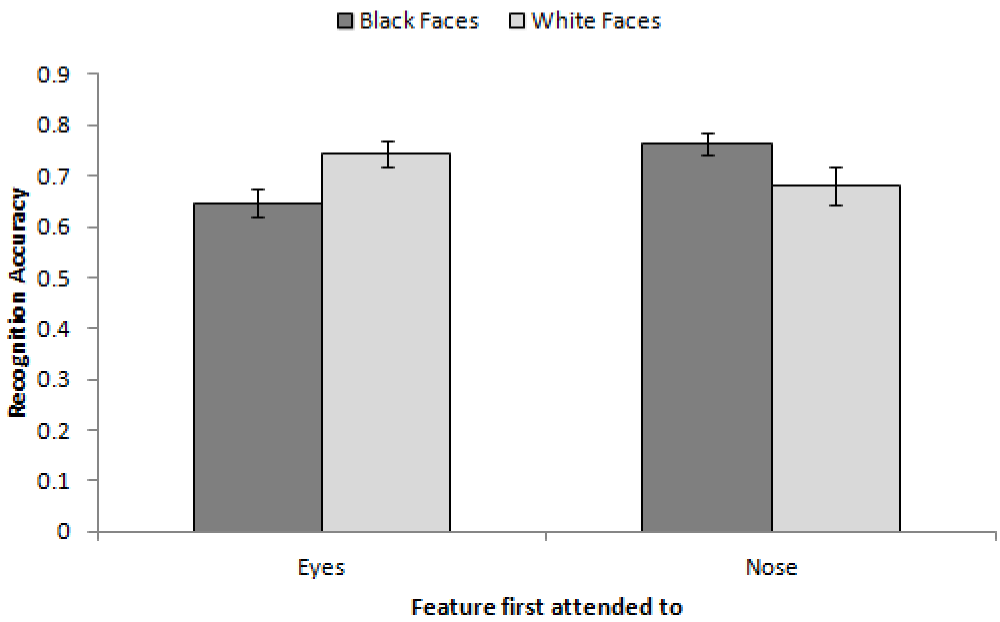
Table 1.

Mean recognition accuracy (*d'* and %) for Black and White faces and ORB split by position of fixation cross for Black and White participants. Standard error in parentheses.

			Position of Fixation Cross		
			No	*High*	*Low*
Recognition Accuracy (d')	***Black Participants***	*Black Faces*	1.88 (0.13)	1.39 (0.14)	1.96 (0.15)
		White Faces	1.34(0.16)	1.82 (0.15)	1.29 (0.15)
		ORB	0.24 (0.06)	-0.17 (0.06)	0.20 (0.04)
	White Participants	*Black Faces*	0.86 (0.13)	0.91 (0.14)	1.29 (0.15)
		White Faces	1.59 (0.16)	1.50 (0.15)	1.31 (0.15)
		ORB	0.29 (0.06)	0.29 (0.06)	0.06 (0.04)
Recognition Accuracy (%)	***Black Participants***	*Black Faces*	80.26% (1.42)	73.38% (2.08)	81.38% (2.02)
		White Faces	71.08% (2.44)	80.13% (1.42)	70.77% (1.18)
		ORB	0.066% (0.015)	-0.047% (0.017)	0.067% (0.012)
	White Participants	*Black Faces*	64.75% (2.47)	65.46% (2.23)	70.63% (2.32)
		White Faces	74.35% (2.73)	73.11% (2.72)	69.97% (2.77)
		ORB	0.068% (0.017)	0.051% (0.019)	0.010% (0.014)



a.



b.

Figure 1. Mean recognition accuracy as a function of the location of the first fixation for Black and White faces for a. Black participants and b. White participants. Error bars show standard error.

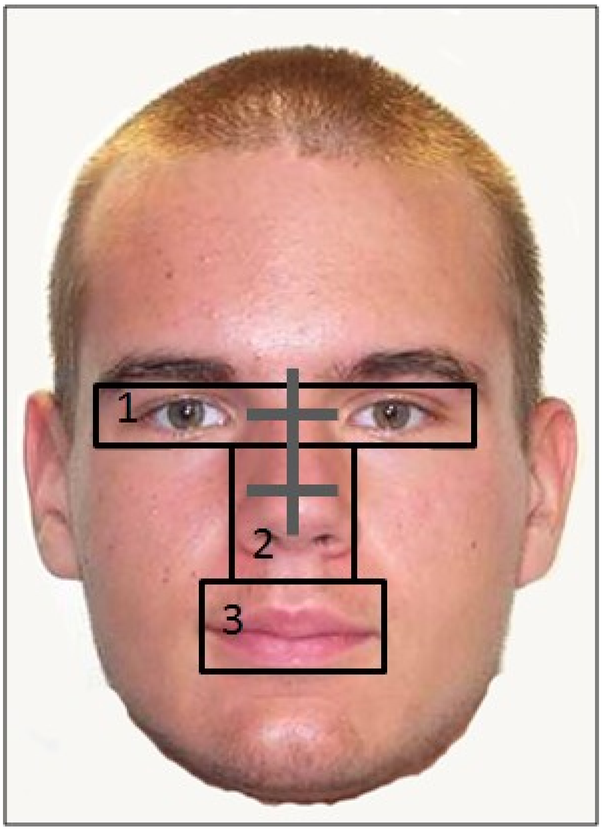


Figure 2. Areas of Interest as mapped out on an example face stimulus: 1 – Eyes; 2 – Nose; and 3 – Mouth. Location of fixation crosses provided (upper fixation cross is between the eyes and lower fixation cross is on the nose).

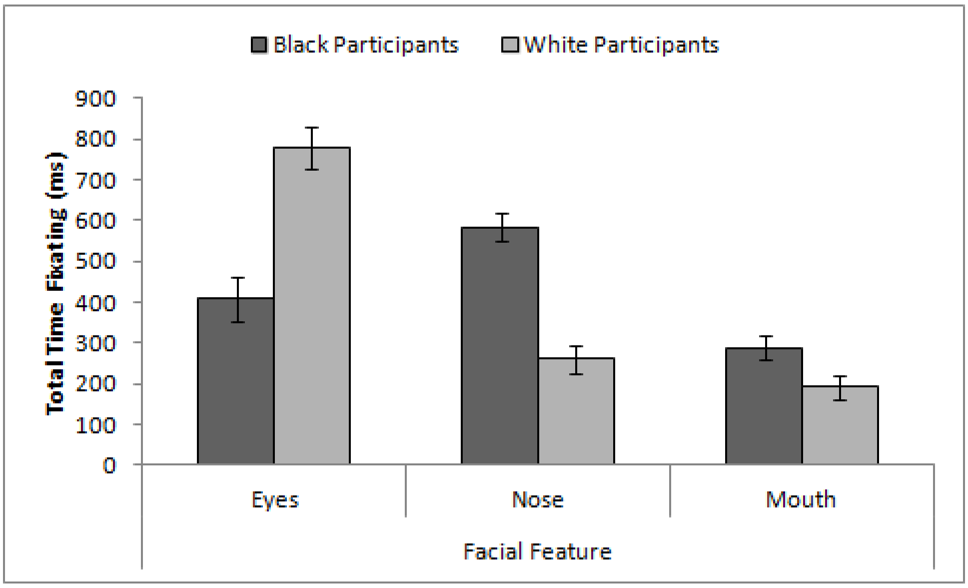


Figure 3. Mean total time fixating in each of the three central AOIs for Black and White participants. Error bars represent standard error.

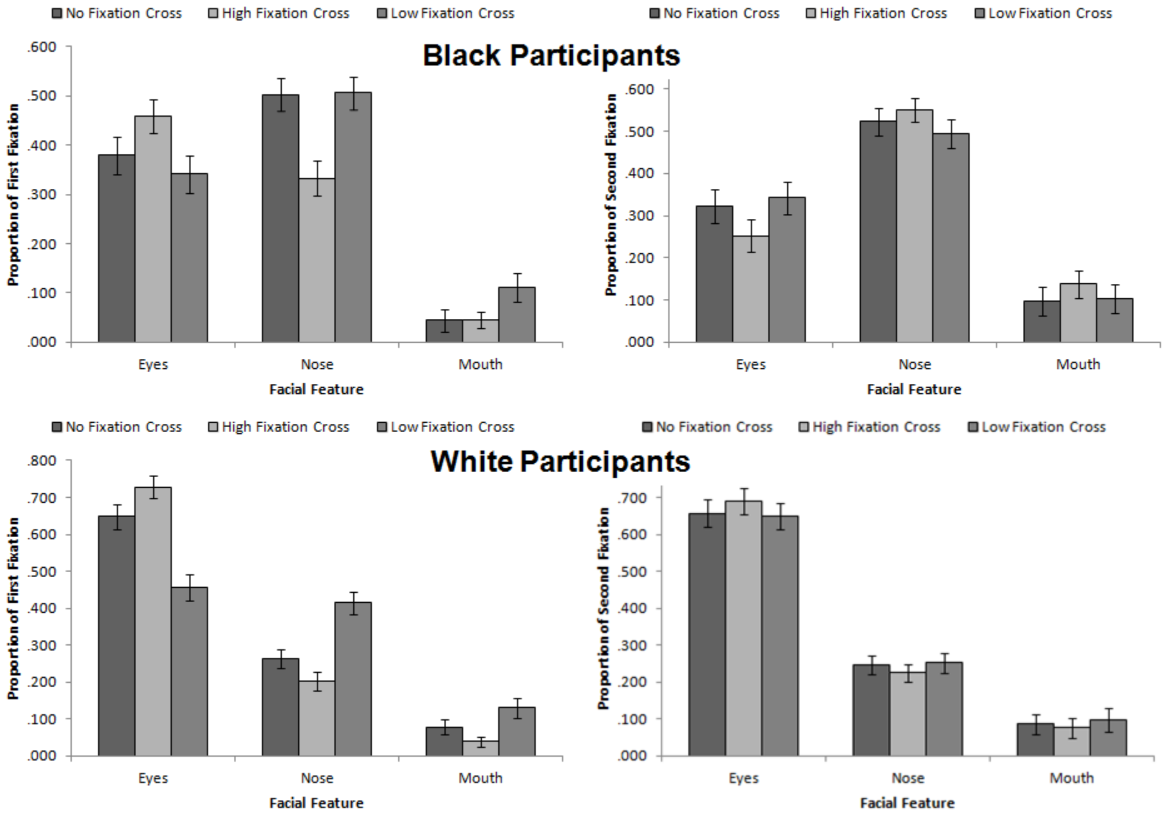


Figure 4. Mean proportion of first fixations (left panels) and second fixation (right panels) to each AOI (facial feature) for Black (top panels) and White (bottom panels) participants. Error bars represent standard error.