Equally attending but still not seeing: An eye-tracking study of change detection in own and other race faces.

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Short Title: Equally attending but still not seeing

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Abstract

The present study aimed to investigate whether the faster change detection in own race faces in a change blindness paradigm, reported by Humphreys, Hodsoll and Campbell (2005, *Visual Cognition, 12*, 249-262) and explained in terms of people's poorer ability to discriminate other race faces, may be explained by people's preferential attention towards own race faces. The study by Humphreys *et al.* was replicated using the same stimuli, while participants' eye movements were recorded. These revealed that there was no attentional bias towards own race faces (analysed in terms of fixation order, number and duration), but people still detected changes in own race faces faster than in other race faces. The current results therefore give further support for the original claim that people are less sensitive to changes made in other race faces, when own and other race faces are equally attended.

Introduction

Numerous studies have shown that people often fail to notice large changes made to objects and scenes across different views. This so-called 'change blindness' occurs when an aspect of a visual scene is altered while at the same time the motion signals that usually accompany the change are disrupted, leading to the loss of attention drawn to the change (e.g. Simons & Levin 1997; Simons & Rensink 2005). The suppression of motion signals in change detection tasks can be achieved in several ways, for example changes could be made across eye movements (e.g. during saccades or eye blinks) and during brief visual occlusions as well as during artificial disruptions in the absence of any eye movements (for an overview see Rensink 2002). One technique that simulates visual events without eye movements is the 'flicker' paradigm, a task which involves repeated alternate presentation of an original and modified scene, separated by a blank interval to simulate visual suppression caused by a saccadic movement, until observers detect the change. Observers can usually find most changes eventually, but often take a long time to do so even when the changes are relatively large (e.g. Hollingworth, Schrock & Henderson 2001; Rensink, O'Regan & Clark 1997). Findings from change blindness studies showing our poor ability to detect large and significant changes have inspired questions about the nature of internal representation of the world, leading some researchers to adopt the view that visual representation of the perceptual world may be relatively sparse, with successful change detection depending on the allocation of visual attention to the changing region (Rensink 2000; Rensink, O'Regan & Clark 1997). Recently, however, an alternative view that the existence of change blindness does not necessarily indicate a lack of detailed visual representation has become more prominent, and successful change detection is thought to be the result of a failure to maintain and/or compare existing representations across alternative scenes (Mitroff, Simons & Levin 2004; Simons, Chabris, Schnur & Levin 2002; Simons & Rensink 2005). However, the precise nature of representation to explain the phenomenon of change blindness still remains to be answered.

One of the important findings established through the change blindness studies is the role of visual attention in change detection. For example, using a flicker paradigm, Rensink, O'Regan and Clark (1997) showed that changes to areas of central interest (semantically) were detected faster than changes made elsewhere, leading to the conclusion that semantically central items were preferentially selected by visual attention. Another important factor that affects the selection of visual information is the overt movement of the eyes, and studies have shown that change detection was more likely if observers fixated on the changing region both before and after the change occurred (Henderson & Hollingworth 1999; Hollingworth, Schrock & Henderson 2001). Findings such as these suggest that both the orienting of eyes and visual attention are important in successful change detection.

Studies on change blindness have also revealed the influence of individual and group differences on successful change detection, and one modulating factor is known to be the prior expertise and group membership of observers. For example, Werner and Thies (2000) showed that American football experts were better able to detect meaningful changes made to football scenes than non-players. A similar finding was found in a study that compared change detection ability in chess configurations amongst expert and novice chess players, showing better change detection in experts when the configuration was meaningful rather than random (Reingold, Charness, Pomplun & Stampe 2001). In addition, Reingold *et al.* (2001) also examined eye movements of expert and novice chess players during a task that required observers to decide whether a King was under attack, and found that experts had larger visual span and required fewer fixations than novices to complete this task. Several factors that affect eye movements in change detection tasks have also been discovered, and manipulations of both the number and the orientation similarity of the changed objects have been shown to increase the number of fixations during change detection (Zelinsky 2001). However, the possible influence of expertise on visual behaviour of eye movements during change detection tasks still remains to be empirically examined.

Recently, change detection ability in the domain of face and person perception was investigated in relation to one specific type of expertise: the racial membership of the observers (Humphreys, Hodsoll & Campbell 2005). It has long been documented that people are generally more accurate in perceiving and recognising differences amongst the faces of their own race than those belonging to other racial groups. This effect, the so-called the own-race bias (also known as the other-race effect or cross-race effect) is robust, and has been shown in numerous experimental studies (for meta-analyses see Bothwell, Brigham & Malpass 1989; Meissner & Brigham 2001). Typically, findings showing the own-race bias come from recognition memory tasks in which people are shown to recognise faces of their own racial group more accurately (e.g. Chiroro & Valentine 1995; Furl, Phillips & O'Toole 2002; Valentine & Endo 1992). However, the own-race bias does not only affect recognition memory, but it has been shown to influence other visual processes such as the recognition of emotional facial expressions (e.g. Elfenbein & Ambady 2002, 2003; Kito & Lee 2004) and the perceptual discrimination of faces in own and other races (e.g. Lindsay, Jack & Christian 1991; Walker & Tanaka 2003).

The study by Humphreys, Hodsoll and Campbell (2005) examined the effect of the own-race bias during the attentional stage of face processing, to determine whether there would be a general bias in attention to faces of own racial group. The own-race bias was examined in a change blindness study using a flicker paradigm. Caucasian and Indian Asian participants viewed original and modified scenes displayed in alternation, separated by a blank interval. Each scene contained Caucasian and Indian Asian people, and the corresponding modified scene contained one change made either to a face (Caucasian or Asian), to body parts (Caucasian or Asian) or to objects in the background. Participants were asked to respond when they detected the change made to the scenes and reaction times were recorded. It was found that changes made to faces were detected faster than changes in body parts, which were detected faster than changes in the background. This was consistent with past findings showing that changes made in the background are more difficult to detect (e.g. Rensink, O'Regan & Clark 1997). More importantly, however, it was found that both Caucasian and Indian Asian people detected changes made to own race faces faster than changes in other race faces, but there was no racial difference in detecting changes made to body parts. The lack of difference for body part changes was taken to imply equal attention to the bodies of own and other races. Humphreys *et al.* (2005) therefore concluded that their participants also attended equally to both race faces and that the observed crossover effect was due to their being less sensitive to changes in other race faces. It was suggested that change detection requires perceptual mechanisms that allow visual information to be differentiated in memory, as well as attention to this visual information, and such perceptual mechanisms are thought to be more suited to process own race than other race faces. A multidimensional ‘face-space’ framework proposed by Valentine (1991) is consistent with this idea. He suggested that individual faces are represented in a space defined by dimensions that serve to discriminate faces we encounter and, because people generally have more experience with own race faces, these dimensions are thought to differentiate own race faces better than faces of other races.

Given that the own-race bias is already present at the encoding stage of face processing (e.g. Lindsay, Jack & Christian 1991; Walker & Tanaka 2003), the Humphreys *et al.* (2005) conclusion is reasonable. However, there is an alternative explanation, namely that people do attend preferentially to their own race faces. Humphreys *et al.* showed that participants were equally sensitive to changes in own and other race body parts and argued that this implied equal attention to both race bodies and by extension to both race faces. However, it has been shown that faces and eye direction capture attention (e.g. Friesen & Kingstone 1998; Theeuwes & Van der Stigchel 2006) and there is also evidence that particular types of faces, for example faces showing negative expression, draw attention (e.g. Eastwood, Smilek & Merikle 2001; Hansen & Hansen 1988). It therefore remains possible that attention might differ between the two face types and that this might explain why observers detect changes more quickly in their own race faces. Put simply, if they look at their own race faces first, they will see changes there sooner.

The current study aimed to examine this possibility directly, by monitoring observers’ eye movements using an eye-tracker during a change detection task to observe their attention to faces. The study by Humphreys *et al.* (2005) was replicated using the same stimuli, with new groups of Indian Asian and European Caucasian participants. In addition to recording reaction times, eye movements during the task were continuously monitored to determine whether or not observers differentially attended to own race faces over other races. Such a difference might be manifested in looking sooner, or more often, or longer at own race faces (or some combination of these).

Method

Participants

Thirteen Indian (Asian) students (8 males; age range 18-28, mean=23.3, s.d.=2.7) and 14 European (Caucasian) students (6 males; age range 18-49, mean=27.2, s.d.=9.8) at University of Stirling (Scotland, U.K.) and University of Glasgow (Scotland, U.K.) participated in this study. All participants had normal or corrected-to-normal vision. All provided informed consent and were paid or received course credits for their participation.

Stimuli and Apparatus

All stimuli used in this study (excluding practice images) were identical to the stimuli used in Humphreys *et al.* (2005). The stimuli consisted of 60 “parent” images in colour (640 x 480 pixels), containing four female actors (two White Caucasian and two Indian Asian). For each “parent” image, five additional images were created (thus creating 300 additional images in total), each containing one change relative to the “parent” image. These five changes were categorised into three types, the first change type made to one of the faces (one to a White

Caucasian face and one to an Indian Asian face), the second change type made to one body part (one to a White Caucasian body part and one to an Indian Asian body part), and the third change type made to a neutral background object. The face changes involved a substitution of a face with another face of the same racial group in the image. The body part changes involved the duplication, deletion, or colour change of one part of either Caucasian or Asian actors. The background objects changes involved the duplication, deletion, or colour change of one of the background objects in the scene. One practice "parent" image and two additional changed images were created for practice trials. The "practice parent" image contained four Caucasian people, and two additional images consisted of one image containing a face substitution and the other image containing a change made to one body part. For more details regarding the stimuli images see Humphreys *et al.* (2005). See Figure 1 for example stimuli.

(a) (b) (c)

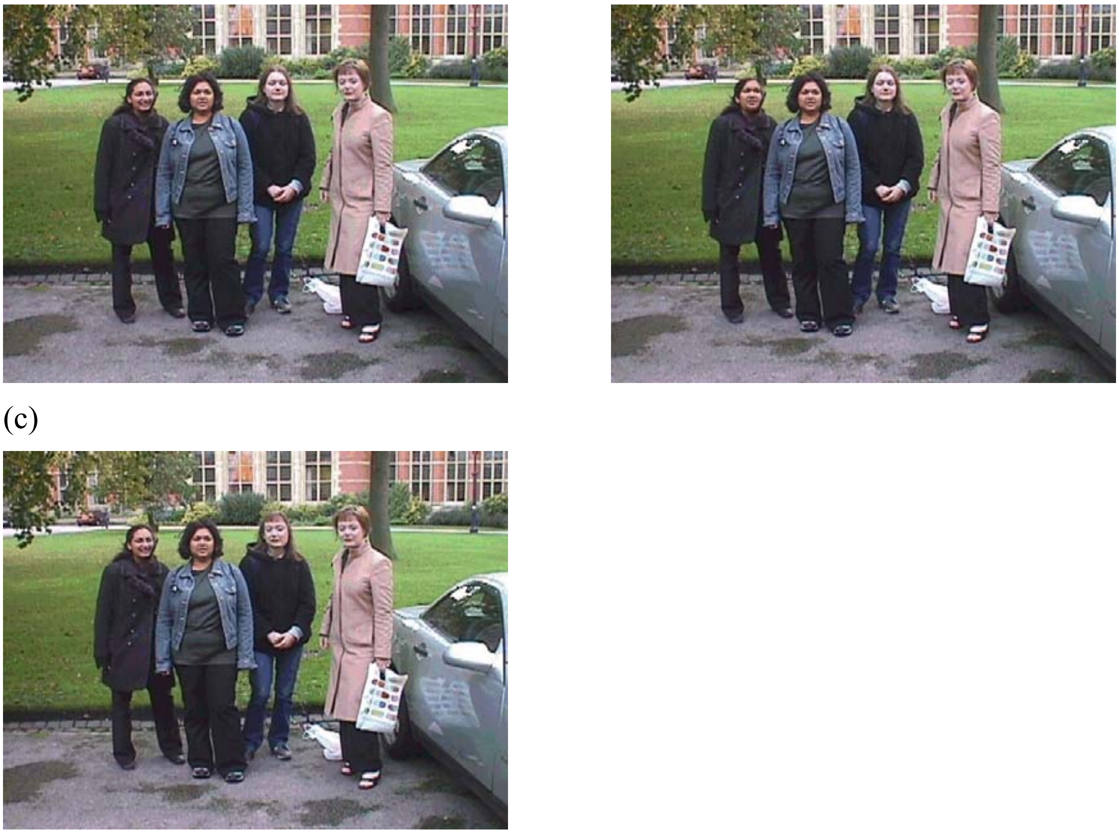

Figure 1 Example stimuli used in the study. (a) A "parent" photograph; (b) change to an Indian Asian face; (c) change to a Caucasian face (adapted from Humphreys *et al.* (2005) with permission).

The stimulus exposures and response recording were controlled by E-Prime®, and in addition eye-movements were recorded using a Tobii® 1750 eye-tracker, which has no interference with the user environment of the experimental participants and gives freedom of head movement. Participants were calibrated prior to the experiment using ClearView eye-gaze analysis software (supplied with the eye-tracker), with its standard 9-point calibration procedure.

The location of each of the four faces was identified by defining a rectangle (usually almost square) around the head. This rectangle, not visible to participants, varied between 2cm and

3.2cm in width, depending on how large the figures were in the scene. At a typical viewing distance of about 55 cm (head restraint was not used, since the Tobii® system does not require it) this corresponds to an angle of view of between 2 and 3.3 degrees. This compares with a rated accuracy of 0.5 degrees for the Tobii® system, so a fixation on the face should be securely recorded as such. The four defined face regions together covered between 2.7% and 6.7% of the total image area, which was 27 x 21.8cm, so by far the majority of image fixations would not be recorded as a hit on a face.

The eye-tracker works at 50Hz, so returning a location every 20ms. We defined a fixation within one of the face regions as being three or more consecutive hits, i.e. 60ms minimum. If the eyes left the region, but returned within 60ms, it was considered to be the same fixation. Thus if the eyes moved away for three or more tracking samples, it was regarded as a new fixation elsewhere, but one or two missed samples were regarded as noise.

Design

This study used a mixed within-subjects design. The race of participants (Asian and European) was used as a classification variable. The independent variable examined was face race (Asian and European). Reaction times for correct responses and eye-movements during trials that included face changes were recorded as dependent variables.

Procedure

All participants were tested individually. Participants were informed that they would be shown several images containing people and objects, and their task was to detect changes made to these scenes as quickly and as accurately as possible, while having their eye-movements recorded at the same time. Following the counter-balancing procedure used in Humphreys *et al.* (2005), the 60 scenes (360 images in total; 60 “parent” images and 60 x 5 changed images) were divided into five sub-groups, each containing 12 instances of each of the five change type (two face changes, two body part changes and one background object change) and the corresponding “parent” images, totalling 60 trials per sub-group. All images were presented in a random order. After the initial 9-point calibration procedure, participants were first presented with two practice trials using images not used in the main trials. The trial began with a fixation cross, which disappeared after the participants fixated for 200 ms, as determined by the eye tracker software. This was followed by two alternating images (either the “parent” or the changed image) shown for 200 ms each, with a blank screen in between (shown for 100 ms). This cycle of scene-blank-scene continued until the participant pressed the space bar to indicate they detected the change between the two scenes, when the participants reported the change they detected verbally to the experimenter. The time from the onset of the first scene until the response was recorded as reaction times. When participants failed to detect the correct change or when failing to respond within 60 seconds, the trial ended and an error was recorded. Eye-movements were continuously recorded while participants performed the tasks.

Results

Trials where participants failed to detect the correct change or when failing to respond within 60 seconds were recorded as errors and not used in the analysis. Only the data from trials containing face changes are reported. The mean error rates for the two participant groups per change type are shown in Figure 2.

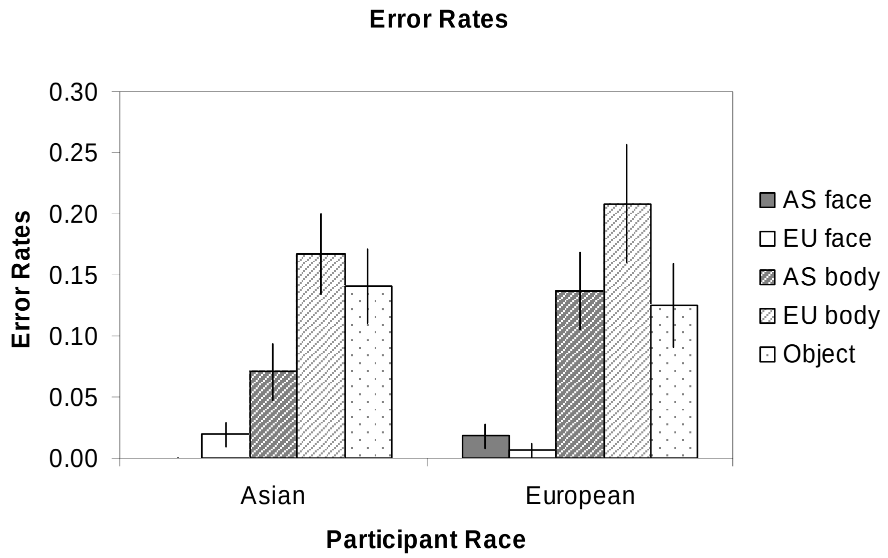

Figure 2 Mean error rates (with error bars ± 1 s.e.) for five change types. Left=Asian participants; Right=European participants.

Mean reaction times and eye-movement data for correct responses for face changes were analysed by means of mixed-design ANOVAs. When failing the Mauchly's test of sphericity, the Greenhouse-Geisser correction (Greenhouse & Geisser 1959) was used. All post-hoc tests of simple main effects using *t*-tests were Bonferroni corrected. Results from the main analyses using ANOVAs and post-hoc analyses are reported with uncorrected degrees of freedom and the corrected *p*-value.

Behavioural data

Reaction times

Mean reaction times, shown in Figure 3, were analysed using a 2 x 2 mixed-design ANOVA with participant race (Asian and European) as the between-participants factor and face race (Asian face and European face) as the within-participants factor. On average changes in European faces were detected faster than in Asian faces ($F_{(1,25)}=4.41$, $p=.05$, r=.39). In addition, a significant interaction between face race and participant race ($F_{(1,25)}=5.41$, $p=.03$, r=.42) was due to faster reaction times for European faces in European participants ($t_{(13)}=3.19$, $p=.007$, r=.66) but not in Asian participants ($t_{(12)}=.16$, $p>.5$, r=.05).

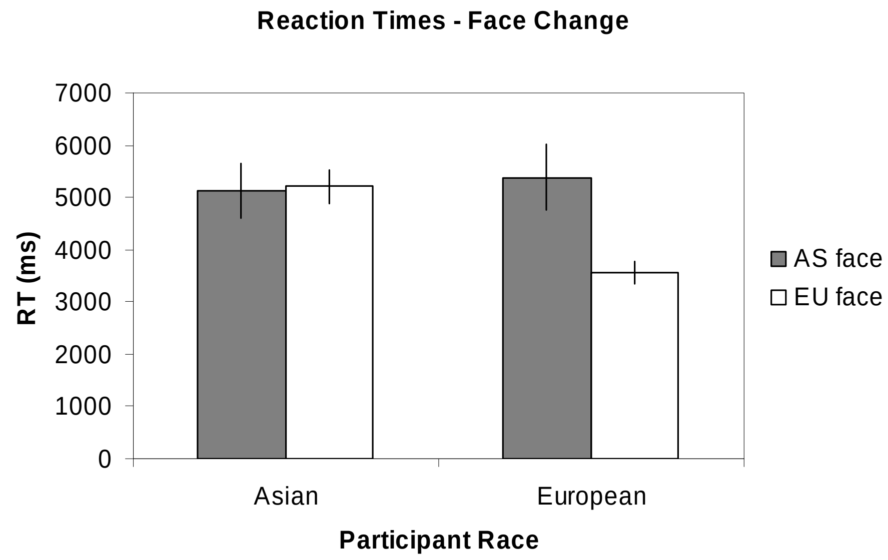

Figure 3 Mean reaction times (with error bars ± 1 s.e.) for face changes. Left=Asian participants; Right=European participants.

Eye movement data

Fixation order

The order in which participants looked at each face was computed. They sometimes looked back at a face, e.g. they might look at one European face, then at the second one and go back to the first before looking at the two Asian faces. Since we were interested in evidence for selective attention, we took account of this and in this example the two Asian faces would be recorded as fourth and fifth, thereby emphasising any order effect and explaining why the mean results shown in Figure 4 do not sum to 4. The figure indicates a general tendency to look at the European faces first. This was confirmed using a 2 x 2 mixed-design ANOVA with participant race (Asian and European) as the between-participants factor and face race (Asian face and European face) as the within-participants factor. Only the main effect of face race was significant ($F_{(1,25)}$=21.2, p<.001, r=.68).

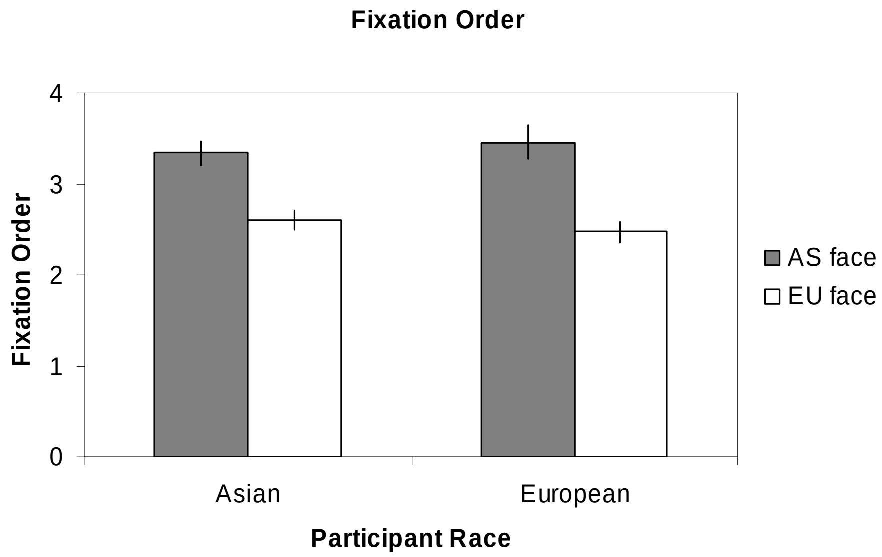

Figure 4 Mean fixation order (with error bars ± 1 s.e.) for face changes. Left=Asian participants; Right=European participants.

Fixation number

A similar analysis was conducted on mean fixation number, for which mean values are shown in Figure 5. Again only the main effect of face race was significant ($F_{(1,25)}$=5.86, *p*=.02, r=.44), reflecting the pattern that overall participants tended to fixate more often on European than Asian faces.

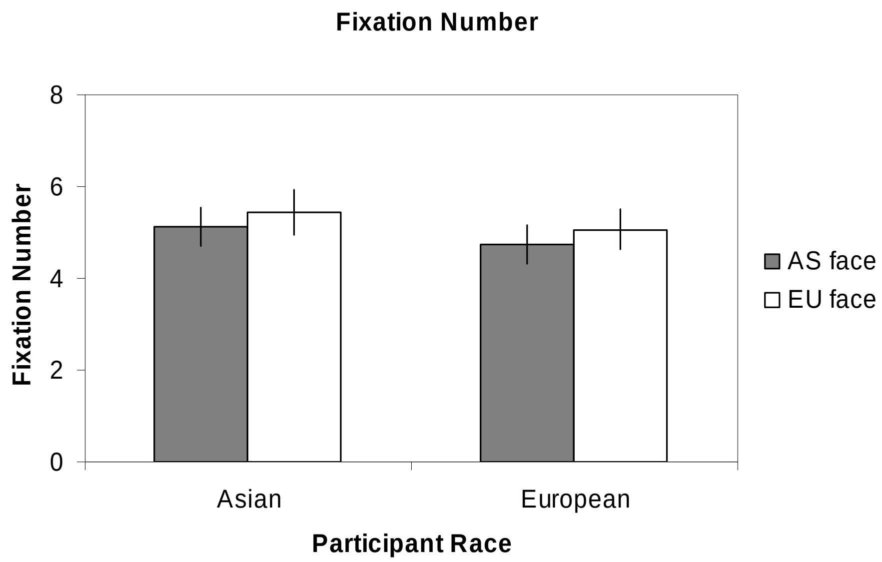

Figure 5 Mean fixation number (with error bars ± 1 s.e.) for face changes. Left=Asian participants; Right=European participants.

Fixation duration

No significant main effects or interaction were found in the analysis of mean fixation duration (all *ps*>.1), illustrated in Figure 6.

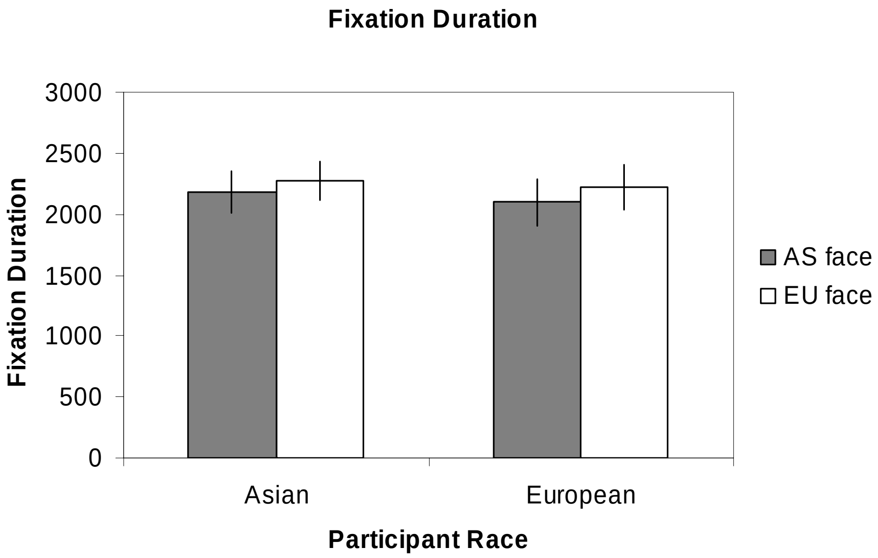

Figure 6 Mean fixation duration (with error bars ± 1 s.e.) for face changes. Left=Asian participants; Right=European participants.

Time after correct fixation (detection delay)

Finally, we considered the time taken from when a participant first fixated on the correct face (if it was a face change condition) to the time they pressed the space bar, which we term the detection delay. The mean values are shown in Figure 7. There were no main effects, but a significant interaction between face race and participant race ($F_{(1,25)}=8.43$, $p=.008$, r=.50). European participants detected changes in European faces faster than in Asian faces ($t_{(13)}=2.26$, $p=.04$, r=.53) and similarly there was a trend for faster change detection for Asian faces in Asian participants ($t_{(12)}=1.85$, $p=.09$, r=.47).

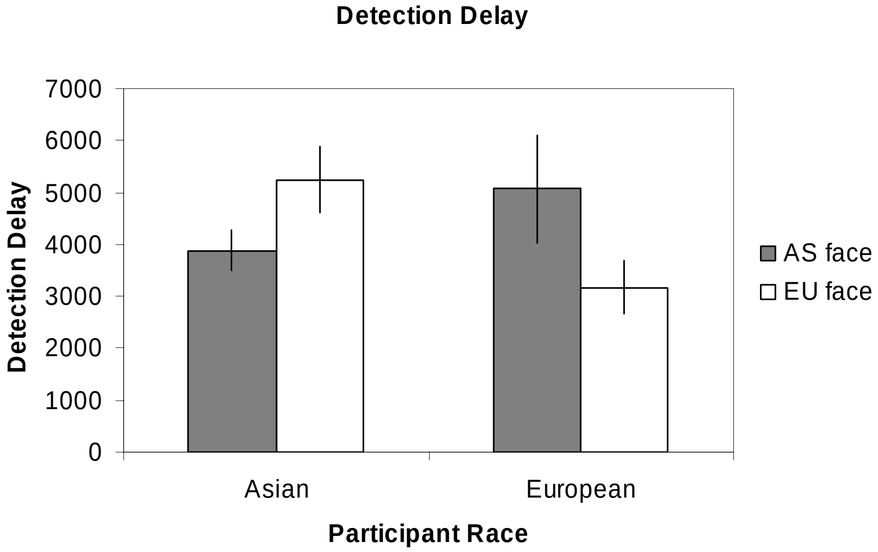

Figure 7 Mean detection delay (with error bars ± 1 s.e.) for face changes. Left=Asian participants; Right=European participants.

Discussion

The current study extended the study by Humphreys *et al.* (2005) and examined the eye movements of observers during change detection tasks involving own and other race faces, to see whether or not people differentially attended to own race over other race faces. The results clearly showed that there was no attentional bias towards the processing of own race faces (which was analysed in terms of fixation order, number and duration), but people still detected changes in own race faces faster than in other race faces, confirming the original conclusion of Humphreys *et al.* that people are less sensitive to changes made in other race faces.

The results from the original study by Humphreys *et al.*, showed a complete crossover interaction in facial change detection in reaction time data (showing faster change detection in own race faces). The present study only showed this pattern in European participants, and Asian participants did not show any racial difference in terms of reaction times during change detection involving own and other race faces. This difference in the pattern of data may seem problematic. However, although the own-race bias has been shown in numerous experimental studies (Bothwell, Brigham & Malpass 1989; Meissner & Brigham 2001), a complete crossover interaction between race of stimulus face and participant group is not universal and has only been shown in some studies. Sporer (2001) maintains that differences in response criterion between two participant groups or differential item difficulty in the facial stimuli used could lead to an asymmetric interaction and potentially mask the crossover interaction. Thus a complete crossover interaction is not regarded as a necessarily prerequisite for demonstrating the own-race bias (Bothwell, Brigham & Malpass 1989). The asymmetric interaction found in the present study is likely to reflect differences between our Asian participant group and that of Humprheys *et al*. The analysis of the eye movement data in the current study showed that both Asian and European participants were in fact faster at detecting changes made to own race faces once they fixated on the correct face that the change was made to. That Asian participants were not faster overall on Asian faces is presumably because they, like the European participants, actually attended preferentially to the European faces, as measured by fixation order and number. This preference might be for a number of reasons, from social to low level image differences, as the slightly paler skin might yield a higher average contrast for the European faces. Overall therefore, the general pattern of the data in the present study and in Humphreys *et al.* is the same, confirming the original conclusion that faster change detection in own race faces was due to differences in processing ability for own and other race faces.

With present knowledge, it is still unclear what factors contribute to the differential processing of own and other race faces. Future studies will be needed to clarify this, in particular the relationship between the differential holistic and local encoding of faces and the own-race bias, as implicated in recent studies (e.g. Michel, Caldara & Rossion 2006; Michel, Rossion, Han, Chung & Caldara 2006; Tanaka, Kiefer & Bukach 2004; Schuchinsky and Murray, 2005). The findings from the present study examining eye movements, however, clarified that the own-race bias is unlikely to be due to attentional bias towards own race faces, at least in a change detection paradigm. This does not necessarily suggest that attentional bias towards own race faces does not exist in other face processing tasks such as face identity recognition or face matching tasks, and therefore future studies should investigate this possibility. The analysis of the eye movement data in the current study also allowed more precise examination of the effect of the own-race bias in face processing that was not reflected in behavioural data. Therefore, analysing eye movements could be an informative way to examine patterns of visual processing that may be masked by unrelated factors.

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