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Inverting faces does not abolish cultural diversity in eye movements

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Abstract

Face processing is widely understood to be a basic, universal visual function effortlessly achieved by people from all cultures and races. The remarkable recognition performance for faces is markedly and specifically affected by picture-plane inversion: the so-called Face Inversion Effect (FIE), a finding often used as evidence for face-specific mechanisms. However, it has recently been shown that culture shapes the way people deploy eye movements to extract information from faces. Interestingly, the comparable lack of experience with inverted faces across cultures offers a unique opportunity to establish the extent to which such perceptual cultural biases in eye movements are robust, but also to assess whether face-specific mechanisms are universally tuned. Here we monitored the eye movements of Western Caucasian (WC) and East Asian (EA) observers while they learned and recognized WC and EA inverted faces. Both groups of observers showed a comparable impairment in recognizing inverted faces of both races. WC deployed a scatter inverted triangular scanpath with a bias towards the mouth, whereas EA uniformly extended the focus of their fixations from the centre towards the eyes. Overall, our data show that cultural perceptual differences in eye movements persist during the FIE, questioning the universality of face processing mechanisms.

The accurate perception of faces is a critical cognitive function and is fundamental to the interpretation of the complex social interactions we experience. The ability to process and recognize faces is a basic visual skill exercised by healthy humans from the early stages of development, which increases in accuracy as the visual system matures and experience in social perception widens (Pascalis & Kelly, 2009). As face processing represents a basic biological skill that is routinely performed by people from all cultures and races, it has typically been assumed that the visual system achieves this perceptual function invariantly. Perceptual strategies elicited during face scanning demonstrate which visual information is critical for performing common face processing tasks. For example, early seminal studies of eye movements during face recognition revealed that visual information is extracted from faces by a series of saccadic eye movements with predominant foveal fixations to the eye and mouth features (Yarbus, 1967). Subsequent eye movement studies have consistently replicated this triangular sequence of fixations to the eyes and mouth during face encoding and recognition (e.g. Walker-Smith, Gale, & Findlay, 1977; Groner, Walder, & Groner, 1984; Henderson, Williams, & Falk, 2005). However, despite the social significance of face perception, this commonly reported face-scanning strategy was observed in studies conducted solely with adults from Western cultures. Consequently, investigation of cultural variance in eye movements was overlooked.

To address this gap, a recent eye movement study by Blais, Jack, Scheepers, Fiset, and Caldara (2008) was conducted with both Western Caucasian (WC) and East Asian (EA) adults to establish (i) whether adults from different cultures use the same perceptual strategies to process faces, and (ii) whether the extraction of visual information changes according to the race of the face observed during face learning, recognition, and categorization by race tasks. As expected, WC adults reproduced the established triangular fixation pattern during learning, recognition, and categorization. Surprisingly, EA adults directed fixations to the central area of the face, around the nose (Figure 1). These culturally divergent scan patterns were consistent across all tasks (learning, recognition and categorization), regardless of the race (Caucasian or Asian) of the face observed. Blais et al. (2008) posited that culture significantly influences the way observers look at faces during face recognition and expression categorization (Jack et al., 2009), but further studies are necessary to identify the origins of such cultural diversity in visual processing.

Robust cross-cultural differences in face processing have been demonstrated by the other-race effect[1] (ORE; Malpass & Kravitz, 1969; see review by Meissner & Brigham, 2001), a phenomenon in which memory for own-race faces is greater than for faces from another, less familiar race (Caldara & Abdi, 2006). The ORE has been shown to interact with a similarly robust face recognition performance constraint, the face inversion effect (FIE; Yin, 1969; for a review, see Rossion & Gauthier, 2002), in which recognition of inverted faces is disproportionately impaired compared to recognition of other mono-oriented homogeneous object categories. The FIE is thus considered by many as strong evidence for specialized face processing, as the impairment suggests there is a qualitative difference in how faces are processed compared to other non-face visual objects: holistic processing (of the spatial relationships between features) is engaged during the processing of upright faces, whereas inexperience with inverted faces engages a qualitatively distinct strategy, featural encoding, or at least, impaired holistic processing (e.g. Rossion & Gauthier, 2002). Furthermore, own-race faces are thought to be processed more holistically than other-race faces (Tanaka, Kiefer, & Bukach, 2004; Michel, Caldara, & Rossion, 2006; Michel, Rossion, Han, Chung, & Caldara, 2006), therefore according to the FIE qualitative encoding switch hypothesis, holistic processing of own-race faces should produce a greater inversion effect than other-race faces that enlist featural encoding. Several studies of the ORE-FIE interaction have

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[1] The other-race effect is also referred to as the cross-race effect, own-race effect, or own-race bias.

revealed a stronger inversion effect for own-race compared to other-race faces (McKone, Brewer, MacPherson, Rhodes, & Hayward, 2007; Rhodes, Tan, Brake, & Taylor, 1989; Vizioli, Foreman, Rousselet & Caldara, 2010). This interaction is assumed to be related to experience, as familiarity with own-race faces produces a stronger inversion effect than less familiar other-race faces (Sangrigoli & de Schonen, 2004). Although the culturally divergent scan patterns observed by Blais et al. (2008) during processing of upright faces did not vary as a function of the race of the face observed as the previous studies describe, normal proficiency in processing is disrupted when faces are inverted, so this may impact regular scan patterns observed with upright faces and may therefore abolish cultural diversity in fixation patterns.

Only a few empirical studies have examined the relationship between eye movements and the face inversion effect. Williams and Henderson (2007) examined scan patterns during encoding and recognition of inverted faces to identify whether eye movements have a role in producing the face inversion effect. They hypothesized face inversion could impede scanning of critical facial features as inversion disorients the regular topography of these features. Measuring the dispersion of eye movement fixations over 7 facial regions that were uniquely defined for each stimulus, Williams and Henderson (2007) found fixation patterns were similar for both upright and inverted faces across face regions, concluding that eye movement patterns are not causally related to the inversion effect. The only significant effect of orientation was for the mean proportion of trials, in which the mouth region was viewed on a greater proportion of trials for inverted faces. Barton, Radcliffe, Cherkasova, Edelman, and Intriligator (2006) similarly found that both the number of fixations and duration spent viewing the mouth increased for inverted faces. In contrast to Williams and Henderson (2007), Barton et al. (2006) found orientation had an effect on fixation patterns as the scanning sequence for inverted faces became more random and fixations were redistributed to the mouth and lower face.

This discrepancy in the effect of orientation on scan paths could result from differences in both the definition of facial regions and the analysis of fixations used in each study. Williams and Henderson (2007) analysed 7 rectangular facial regions that were uniquely defined for each stimulus. By contrast, Barton et al. (2006) analysed 8 facial regions, previously defined by Groner et al. (1984), which were also calculated for each stimulus used. Delineating face regions of interest in this way imposes a dichotomic analysis of eye fixations, as a fixation one pixel outside the border of the region of interest will be excluded from analysis for that region despite the fact that a foveal fixation, around 2° visual angle, processes more information than is contained in a single pixel for faces and scenes (Miellet, Zhou, He, Rodger & Caldara, in press). The definition of facial regions of interest can therefore bias fixation analyses and compromise the generalization of findings across studies. Instead of defining facial regions, Blais et al. (2008) smoothed fixations by applying a spatial filter (Gaussian kernel $\alpha = 10$ pixels) to represent the foveated area (2° visual angle), enabling densely fixated areas to be computed and rendered in fixation distribution maps (further details are described in the methods section).

Here we took advantage of this unbiased method of eye movement analysis in the framework of the face inversion effect. In addition to the limited number of eye movement studies of the FIE, no studies have conducted cross-cultural comparisons of scan patterns for inverted faces. The comparable lack of experience across cultures with inverted faces offers a unique opportunity to establish the extent to which cultural perceptual strategies are robust. This study aims to extend the paradigm used by Blais et al. (2008) to establish whether cultural variance in information extraction strategies persists during processing of inverted faces by monitoring the eye movements of WC and EA observers.

Method

Participants

Fourteen Western Caucasian (8 female) and fourteen East Asian (8 female) adults participated (mean ages 23 and 24 years respectively). WC participants were recruited from the Psychology Department undergraduate participant pool at the University of Glasgow, and were all born in the UK. EA participants were recruited through advertisements placed in the university library and had been in the UK for an average of 5 weeks. All participants had normal or corrected vision and were paid £6 per hour for their participation. All participants gave written informed consent and the Faculty Ethical Committee approved the experimental protocol.

Stimulus and apparatus

The stimuli consisted of 56 grayscale images. 28 Caucasian faces (14 female) were obtained from The Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998), and 28 Asian faces (14 female) from the Asian Face Image Database (Bang, Kim, & Choi, 2001). The faces conveyed either a neutral, happy or disgust expression. The images were cropped so that only the head was visible, and did not include clothing or distinctive features (e.g. facial hair, jewellery). Images were spatially normalised by aligning the eye and mouth positions, and image lumanince was also normalised. The images were 390 x 382 pixels in size, subtending 15.6° of visual angle horizontally and 15.3° of visual angle vertically. Participants viewed the faces at a distance of 70cm so the experimental set-up was as representative as possible of interacting with an adult human face at a natural distance (Hall, 1966). A chin and forehead-rest were used to maintain an equidistant viewing position and to help minimize head movements. The images were displayed on a 800 x 600 pixel grey background using a Dell P1130 19” CRT monitor with a refresh rate of 170 Hz. The images were displayed in random locations on the screen to prevent anticipatory eye movements. Stimuli presentation was controlled by software written in MATLAB 2006a using the Psychophysics (PTB-3) and EyeLink Toolbox extensions.

Eye movements

Eye movements were recorded at a sampling rate of 1000 Hz using an SR Research Desktop-Mount EyeLink 2K binocular eye-tracking system. The EyeLink 2K has an average gaze position error of $<0.5^{o}$ horizontally, $<1.5^{o}$ vertically, a resolution of 1 arc min, and a linear output over the range of the monitor used. Although viewing was binocular, only the participant’s dominant eye was recorded. Eye fixations were calibrated manually prior to each recording session using a nine–point fixation calibration and validation procedure (as implemented in the EyeLink API software, see the EyeLink Manual for details) to ensure that the eye tracker could discriminate the pupil/corneal reflection accurately in all gaze directions. Participants were instructed to fixate a dot in the centre of the screen at the beginning of each trial that served as a drift correction of the gaze estimate. If the drift correction was greater than 1^{o} then the calibration and validation procedure was repeated until an optimal gaze estimate was achieved.

Design

Participants completed two blocks of learning and recognition per race condition. The race condition was counterbalanced across observers. The emotional expressions (neutral, happy, or disgust) of the faces were similarly counterbalanced across the race conditions. Each block comprised 14 inverted faces (7 female) in the learning phase, followed by a recognition phase of 28 inverted faces (14 old, 14 new).

Procedure

Participants were informed that the experiment comprised of two blocks of face learning and recognition, each containing different face stimuli. For the learning session, participants were instructed to study the faces carefully, as they would subsequently be tested on their memory for the faces in the recognition phase. Participants were informed that the emotional expression of a face in the learning phase would be different in the recognition phase. The expression of faces was changed between learning and recognition to prevent trivial image matching strategies in memorizing face identities. Participants were seated and asked to make minimal head movements during the task. Eye fixations were calibrated manually at the beginning of each block, and the experimenter initiated a trial when the participant fixated a dot in the centre of the screen that served as a drift correction. Participants began with a training session of 4 novel images (1 male and 1 female of each race) to become familiar with examples of the stimuli. Each image was presented for 5 seconds in the learning phase, and until the participant made a keyboard press in the recognition phase. At the beginning of the recognition phase, participants were requested to gauge as quickly and accurately as possible if the face appeared in the learning phase by pressing the ‘a’ or ‘l’ key to indicate a yes/no response. The experimenter initiated the recognition phase when the participant’s fingers were placed on the correct keys.

Data Analyses

Only correct trials were analyzed. Fixation distribution maps were computed individually for EA and WC observers for each race condition, and face learning and recognition phases separately, using MATLAB. More than one pixel is processed during a fixation, so each fixation was smoothed with a Gaussian kernel ($\alpha = 10$ pixels) to represent the foveated area (2° visual angle). Fixation distribution maps were computed by summing all fixation locations (x, y coordinates) across time for all correct trials. Blinks and fixations outside of the stimulus area were excluded from the fixation maps. Fixation maps were then calculated for each cultural group by summing the individual maps of observers belonging to each culture.

Group fixation maps were z-scored with the assumption that WC and EA eye movement distributions are identical for both races of faces, forming the null hypothesis. The fixation distributions of each culture were collated, and the mean and standard deviation were obtained for each race condition (WC and EA faces) and used to normalize the data. To establish any difference in fixation patterns across cultural groups, the EA group fixation map was subtracted from the WC group fixation map, and the resulting distribution was z-scored. Significance was established by correcting for multiple comparisons in the fixation map space using a one-tailed Pixel test (Chauvin, Worsley, Schyns, Arguin, & Gosselin, 2005; $Z_{crit} > |4.64|$; $p<.05$) for the group fixation maps, and a two-tailed Pixel test ($Z_{crit} > |4.25|$; $p<.05$) for the differential fixation maps.

Results

Behavioral

Face Recognition Accuracy: Figure 2 illustrates the *d'* accuracy scores by culture for recognition. A 2 (race of face) X 2 (culture of the observer) mixed model ANOVA revealed no significant main effects for the race of face F (1, 26) = .13, p = .71, or culture of the observer F (1, 26) = 2.4, p = .12 on recognition performance. The interaction between the race of face and culture of the observer also failed to reach statistical significance F (1, 26) = .34, p = .56. Recognition performance was comparable across cultures and races of faces observed.

Reaction Times: Figure 3 illustrates the mean response times (ms) for each cultural group. A 2 X 2 mixed model ANOVA revealed no significant main effects for the race of face F (1, 26) = .56, p = .45, or culture of the observer F (1, 26) = .01, p = .9 on mean reaction time. The interaction between race of face and culture of the observer was significant

F (1, 26) = 10.61, p = .001. Post hoc. Two-tailed paired t-tests revealed Western Caucasian observers responded significantly faster to own-race faces, t (13) = -3.35, p = .005.

Eye movements

Number of Fixations: Table 1 shows that, on average, observers made 14 fixations per trial during face learning and 6 fixations during recognition. A two-way mixed model ANOVA revealed no main effects for race of face F (1, 26) = .04, p = .84, or culture of the observer F (1, 26) = .04, p = .84, on number of fixations during face learning. There was no significant interaction between race of face and culture of the observer, F (1, 26) = 2.10, p = .84. During face recognition there was no main effect of culture on number of fixations, F (1, 26) = 3.04, p = .09. There was a main effect of race of face on number of fixations, F (1, 26) = 4.19, p = .05 and a significant interaction between the race of face and culture of the observer F (1, 38) = 14.91, p = .001. Post hoc. Two-tailed paired t-tests revealed Western Caucasian observers made significantly fewer fixations to own-race faces, t (13) = -5.13, p = .001.

Fixation Distribution Maps: Figure 4 shows significant differences ($Z_{crit} > |4.25|$; $p<.05$) in fixation locations between cultures during face learning and recognition. For Western Caucasian observers during face learning of both EA and WC inverted faces, the triangular pattern of fixations to both eyes and the mouth found in previous studies of upright faces with Western participants is also visible here for inverted faces. Similarly during recognition, WC observers show a significant fixation bias for the eye and mouth regions, with a novel bias toward the tip of the nose also visible in this condition. By contrast, EA observers extracted different facial information from inverted faces during learning and recognition, as the fixation bias was not directed toward both eyes and the mouth. Instead, an area surrounding the inner right-eye and cheek was the single most densely fixated region across conditions. Table 2 shows the Cohen's d effect size values for significantly fixated facial features.

Discussion

Consistent with the cultural variance in information extraction strategies reported for upright faces (Blais et al., 2008), the group fixation maps show a cultural contrast in relative fixation biases for inverted faces, but reach comparable face recognition performance. Both cultural groups maintain differential fixation patterns for upright and inverted faces, regardless of the race of the face observed. During processing of inverted faces, Western Caucasians continue to consistently deploy preferential fixations to the eye and the mouth regions in comparison to East Asians, as previously reported for upright faces (Blais et al., 2008). In line with previous findings, the WC fixation bias towards the mouth relative to the eyes is greater for inverted than for upright faces (Barton et al., 2006), suggesting a visual tuning towards the upper visual field for face processing in Westerners (Caldara, Seghier, Rossion, Lazeyras, Michel & Hauert, 2006; Caldara & Seghier, 2009). By contrast, the EA fixation strategy is more disrupted by inversion in comparison to WC observers. The EA central fixation bias observed for upright faces is not perfectly maintained, but instead shifts towards the right eye. In direct comparison of the two groups' strategies, the EA group's shift in fixation bias from the nose region to the right eye for inverted faces affects the relative WC group fixation bias towards both eyes, as this is now predominantly located over the left eye.

Previous studies have revealed an interaction between the face inversion effect and the other-race effect, demonstrating a stronger inversion effect for own-race compared to other-race faces (e.g., Rhodes, Tan, Brake, & Taylor, 1989; McKone et al., 2007). Although recognition accuracy for both cultural groups of observers followed this trend, the effect was not statistically reliable. Potentially, the strength of this effect could have been impeded by the change of images used between face learning and recognition, which showed different facial expressions for the same facial identity. To the best of our knowledge, previous studies of face inversion and the other-race effect have used the same image during both face learning and recognition, so further studies are necessary to directly address the question of whether the use of strong constraints in facial identity encoding affect face recognition performance during inversion.

Consistent with previous studies, both groups of observers showed increased variability in the information sampled from inverted faces (Barton et al., 2006), compared to natural upright viewing conditions (Blais et al., 2008). Despite increased variability, the overall scanning strategy (Williams & Henderson, 2007) and feature use (Sekuler, Gaspar, Gold, & Bennett, 2004) in Western Caucasian adults are not disrupted by inversion, tbut the greater focus of fixations shifts towards the mouth. By contrast, East Asian adults' scanning strategies for inverted faces are disrupted, with a spatial shift in the relative group fixation bias from centre of the face to right eye. The EA shift in the eye movement strategy employed to process faces under an unfamiliar orientation has been demonstrated under other viewing constraints. A recent study examined information use during face processing with a gaze contingent paradigm (Caldara, Zhou, & Miellet, 2010). Facial information available to viewers was restricted to 2^o, 5^o, and 8^o 'Spotlight' apertures that light up the blackened stimulus display as a function of the current gaze position. Critically, in the 2^o and 5^o conditions the Spotlight covered one eye, but both eyes and the mouth were not visible simultaneously when the nose was fixated. By contrast in the 8^o condition, information from both eyes and the nose was simultaneously available when fixating the nose. The results revealed that when constrained by the smaller apertures, the EA and WC fixation strategies were comparable as both cultural groups fixated the eyes and partially the mouth. However, when both eye and mouth information was available from the 8^o Spotlight, cultural strategies diverged. WC observers maintained their existing strategy by fixating the eyes and mouth whereas EA observers solely fixated the nose, their preferred strategy as established by the original free-viewing condition (Blais et al., 2008). Determining that information from the eyes remains necessary for EA recognition strategies, despite the central fixation bias, is consistent with classification image techniques (e.g. Bubbles; Gosselin & Schyns, 2001; Caldara, Schyns, Mayer, Smith, Gosselin & Rossion, 2005) that reveal the eye region is critical for accurate face identification.

Taken together, when extrafoveal information use is limited or accessible in a non-canonical orientation, EA observers modify their regular perceptual strategy while WC observers do not. Blais et al. (2008) suggested that the systematic differences in perceptual processing across cultures, identified by recent studies (e.g. perceptual categorization, Norenzayan, Smith, Kim, & Nisbett, 2002; perceptual judgment, Kitayama, Duffy, Kawamura, & Larsen, 2003; and scene perception, Miyamoto, Nisbett & Masuda, 2006;), might expand and generalize to face processing. Blais et al. (2008) therefore align cultural diversity in face scanning with a recent cultural paradigm that proposes culture influences perception by producing qualitative differences in the way people process information from the visual environment (Nisbett & Miyatomo, 2005). The holistic[2] versus analytic theory of culture and perception describes East Asian perceptual strategies as holistic as visual attention is largely directed toward the context and relationships of environmental stimuli in their entirety. By contrast, Western Caucasians tend to use more analytical perceptual strategies, attending to focal information within their field of vision. In this way Blais et al. (2008) suggest that by allocating attention to isolated facial features (e.g. the eyes and mouth) WC adults demonstrate an analytical perceptual strategy during upright face processing. Conversely, by substantially fixating the centre of upright faces, the perceptual strategy of

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[2] The term holistic used here is defined by the holistic vs.analytic theory of culture and perception. This term is not related to the term holistic used in face literature.

EA adults maximizes the amount of information that can be integrated from this location, and is therefore suggestive of holistic (global) processing. It is worth noting that fixation biases to the central location of faces cannot straightforwardly be related to the holistic processes suggested to be recruited during face processing. Observers from both cultures might construct identical representations to process faces, by using distinct fixation scanpaths (for a detailed discussion on this theoretical point see, Kelly, Miellet and Caldara, 2010). The present eye movement data only suggest that the holistic central fixation bias of the EA upright strategy is not effective under the constraint of an unfamiliar inverted orientation, so must be modified. By contrast, the WC upright strategy is maintained for inverted faces, which indicates that the information sampled from the eyes and mouth during scanning is sufficient for identification regardless of orientation. Further studies are required to establish whether the WC perceptual strategy remains robust under most viewing constraints, or if further constraints motivate a shift in the EA perceptual strategy.

Critically, the present data show that cultural differences in the eye movement strategies deployed by human observers are present even in a marker of face specificity such as the FIE. Those perpetual cultural biases are robust and point towards the existence of cultural specific mechanisms to extract and process information from faces.

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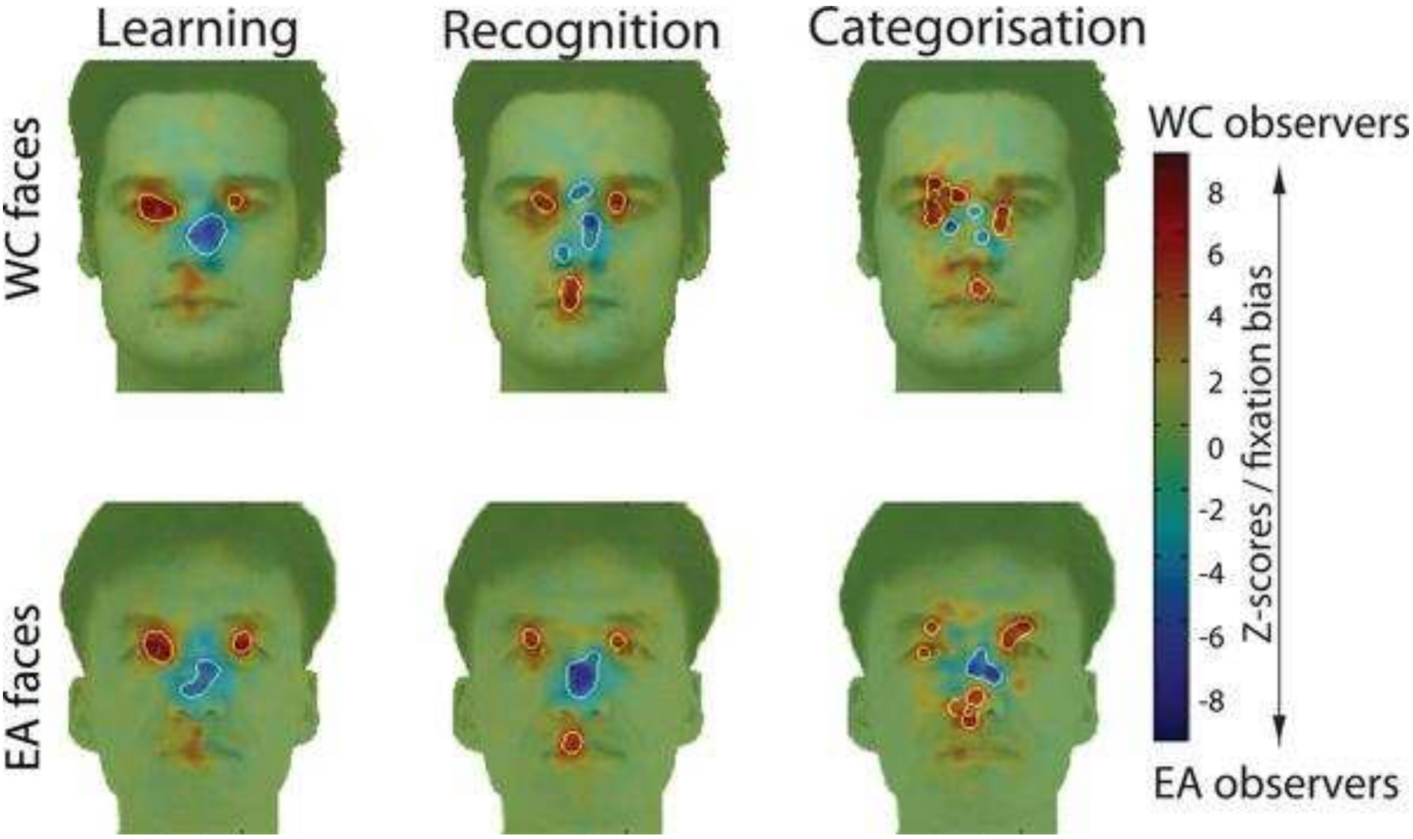
Figure 1. Blais et al. (2008) Fixation biases for Western Caucasian (WC - red) and East Asian (EA - blue) observers are highlighted by subtracting WC and the EA Z-scored fixation distribution maps during WC and EA face learning, recognition and categorization by race.



Areas showing a significant fixation bias are delimited by white borders ($Z_{crit}>|4.25|$; $p<.05$); values near 0 indicate similar magnitude in fixation between observers from different cultures.

Figure 2. ***d'*** **accuracy scores of the old/new face recognition paradigm, for Western Caucasian and East Asian observers.** Error bars report the standard error of the mean.

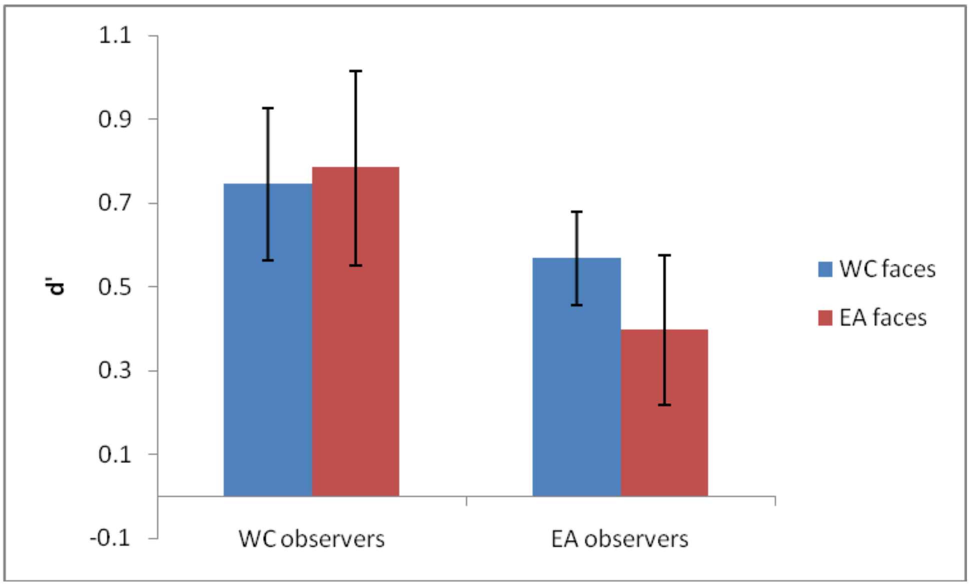
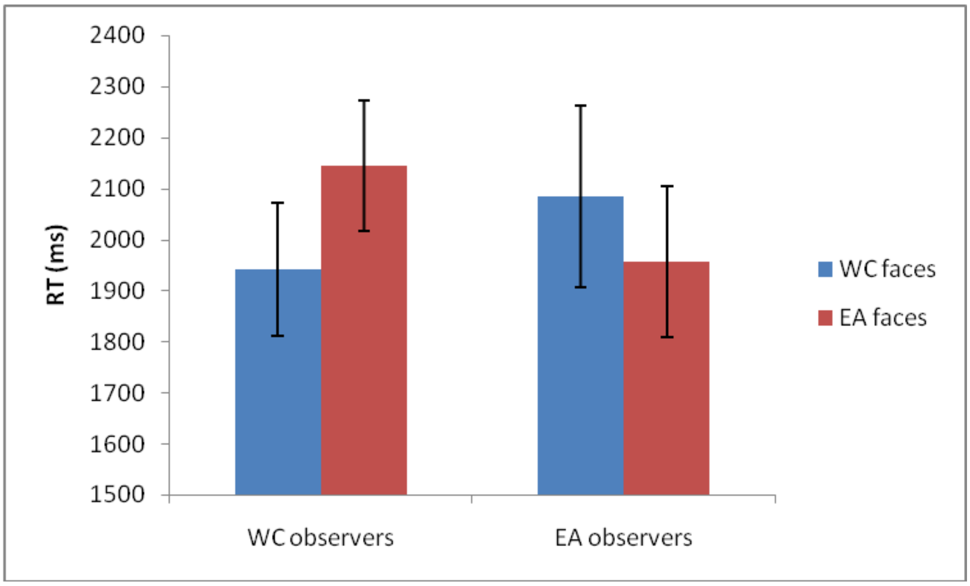


Figure 3. Mean Response Times (ms) to the old/new face recognition paradigm, for Western Caucasian and East Asian observers. Error bars report the standard error of the mean.

Figure 4. Fixation biases for Western Caucasian (WC - red) and East Asian (EA - blue) observers are highlighted by subtracting WC and the EA Z-scored fixation distribution maps during WC and EA face learning and recognition.



Areas showing a significant fixation bias are delimited by white borders ($Z_{crit} > |4.25|$; $p < .05$); values near 0 indicate similar magnitude in fixation between observers from different cultures.

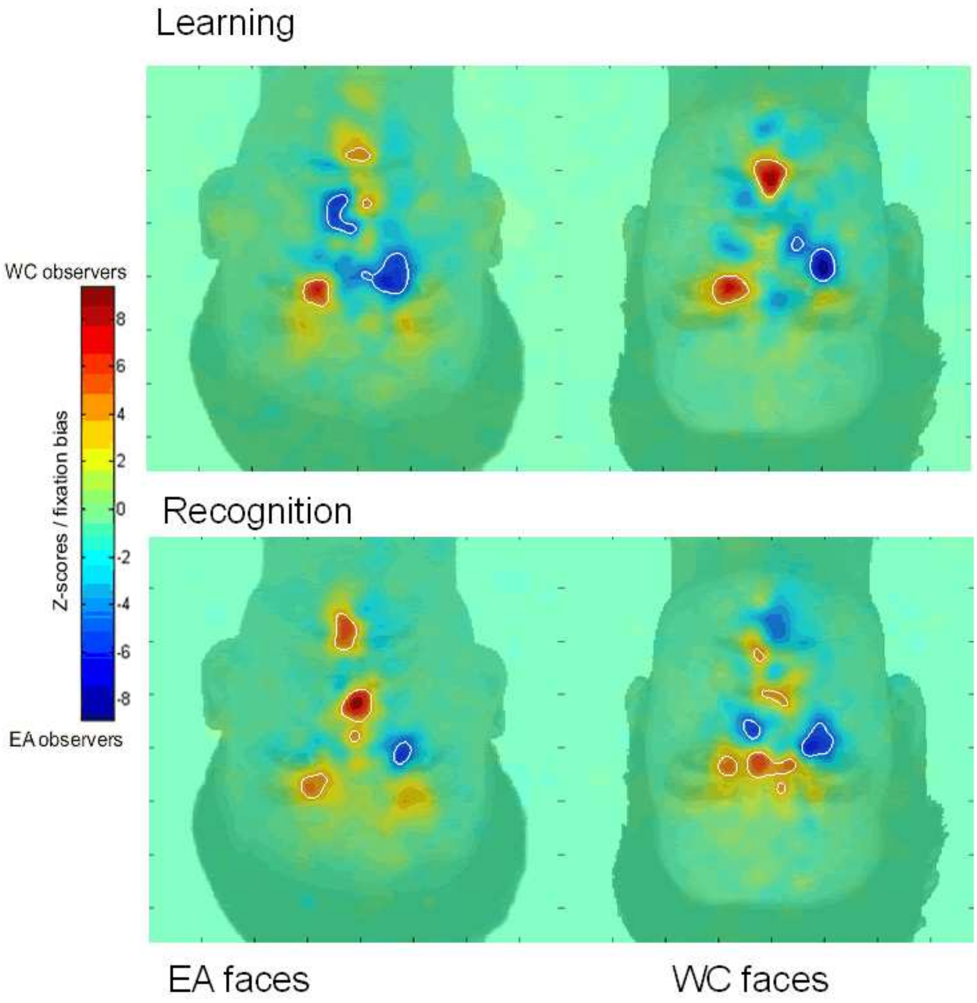


Table 1. Mean number of fixations for Western Caucasian (WC) and East Asian (EA) observers during WC and EA face learning and recognition by race.

	Learning		**Recognition**	
	EA faces	WC faces	EA faces	WC faces
WC observers	13.7 (0.5)	14.0 (0.4)	6.7 (0.4)	6.0 (0.4)
EA observers	13.7 (0.5)	13.5 (0.5)	5.4 (0.5)	6.8 (0.5)

Numbers in parenthesis report the standard error of the mean. The presentation time was fixed during learning (5 seconds).

Table 2. Cohen's d effect sizes by culture for significantly fixated facial features.

Facial feature	**Eyes**	**Nose**	**Mouth**	**Rest**	Race of Face	
Learning	0.31	0.11	0.54	0.04	WC	**WC observers**
	0.35	0.23	0.39	0.03	EA	
	0.29	0.20	0.47	0.04	WC	**EA observers**
	0.37	0.30	0.30	0.04	EA	
Recognition	0.26	0.31	0.40	0.03	WC	**WC observers**
	0.20	0.46	0.29	0.05	EA	
	0.37	0.31	0.29	0.03	WC	**EA observers**
	0.30	0.38	0.22	0.11	EA	