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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 cultural perceptual 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 recognised WC and EA inverted faces. Both groups of observers showed a comparable impairment in recognising inverted faces of both races. WC observers deployed a scattered inverted triangular scanpath with a bias towards the mouth, whereas EA observers 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.

1 Introduction

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 recognise 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 and 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 (eg Groner et al 1984; Henderson et al 2005; Walker-Smith et al 1977). 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 et al (2008) was conducted with both Western Caucasian (WC) and East Asian (EA) adults to establish (i) whether people 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

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the face observed during face-learning, recognition, and categorisation-by-race tasks. As expected, WC adults reproduced the established triangular fixation pattern during learning, recognition, and categorisation. Surprisingly, EA adults directed fixations to the central area of the face, around the nose, and less to the eyes area (figure 1). These culturally divergent scan patterns were consistent across all tasks (learning, recognition, and categorisation), 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 categorisation (Jack et al 2009), but further studies are necessary to identify the origins of such cultural diversity in visual processing.

Robust cross-cultural empirical differences in face processing have been reported in the framework of the other-race effect (ORE—Malpass and Kravitz 1969; see review by Meissner and Brigham 2001), a phenomenon in which memory for own-race faces is greater than for faces from another, less familiar race (Caldara and Abdi 2006; Vizioli et al 2010a). To date, studies have established that the ORE and the popular belief that other-race faces all look alike are not accounted for by anthropometric variations in other-race faces (Caldara and Abdi 2006; Caldara et al 2010; Goldstein 1979a, 1979b), but by a genuine lack of expertise with them. 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 and 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 face-specific 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 (eg Rossion and Gauthier 2002). Furthermore, own-race faces are thought to be processed more holistically than other-race faces (Michel et al 2006a, 2006b; Tanaka et al 2004); therefore, according to the FIE qualitative encoding switch hypothesis, holistic processing of own-race faces should produce a greater inversion effect than of other-race faces that enlist featural encoding. Several studies of the ORE – FIE interaction have revealed a stronger inversion effect for own-race compared to other-race faces (McKone et al 2007; Rhodes et al 1989; Vizioli et al 2010b). This interaction is assumed to be related to experience, as familiarity with own-race faces produces a stronger inversion effect than of less familiar other-race faces (Sangrigoli and de Schonen 2004).

Only in a few empirical studies has the relationship between eye movements and the FIE been examined. 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 FIE. They hypothesised that 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 that 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 et al (2006) similarly found that both the number of fixations and duration spent viewing the mouth increased for inverted faces in comparison to upright 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.

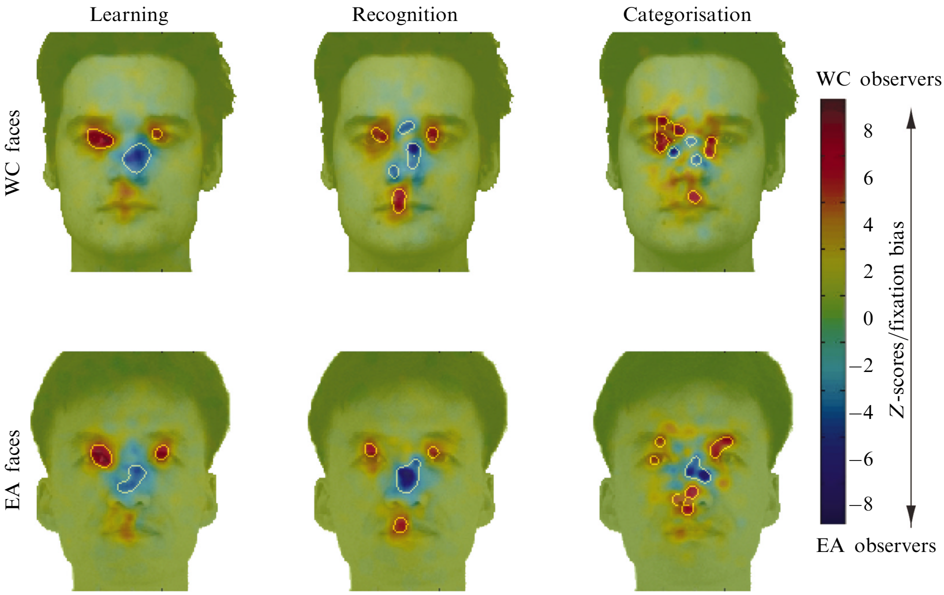

Figure 1. Blais et al (2008): Fixation biases for Western Caucasian (WC, red) and East Asian (EA, blue) observers are highlighted by subtracting WC and the EA Z-scored fixation distribution maps during WC and EA face learning, recognition, and categorisation by race. Areas showing a significant fixation bias are delimited by white borders ($Z_{\text{crit}} > |4.25|$; $p < 0.05$); values near 0 indicate similar magnitude in fixation between observers from different cultures.

This discrepancy in the effect of orientation on scanpaths 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 1 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 deg visual angle, processes more information than is contained in a single pixel for faces and scenes (Miellet et al 2010). The definition of facial regions of interest can therefore bias fixation analyses and compromise the generalisation 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 deg visual angle), enabling densely fixated areas to be computed and rendered in fixation distribution maps (further details are described in section 2).

Here we took advantage of this unbiased method of eye-movement data analysis (*i*Map—Caldara and Miellet, submitted) to isolate the fixation patterns deployed during the FIE across cultures. Apart from the limited number of eye-movement studies of the FIE, no cross-cultural comparisons of scan patterns for inverted faces have been reported. 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. In this study we aim 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. Finally, to investigate whether the FIE modulates eye-movement strategies compared to natural upright viewing conditions, we compared the present data with those collected for upright face recognition (Blais et al 2008).

2 Method

2.1 *Participants*

Fourteen Western Caucasian (eight female) and fourteen East Asian (eight 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. All EA participants were born in China, had not previously resided in a Western country, 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.

2.2 *Stimulus and apparatus*

The stimuli consisted of 56 grey-scale images. 28 Caucasian faces (14 female) were obtained from *The Karolinska Directed Emotional Faces* database (Lundqvist et al 1998), and 28 Asian faces (14 female) from the *Asian Face Image Database* (Bang et al 2001). The faces conveyed either a neutral, happy, or disgusted expression. The images were cropped so that only the head was visible, and did not include clothing or distinctive features (eg facial hair, jewelry). Images were spatially normalised by aligning the eye and mouth positions, and image luminance was also normalised. The images were 390×382 pixels in size, subtending 15.6 deg horizontally and 15.3 deg vertically. Participants viewed the faces at a distance of 70 cm so the experimental setup was as representative as possible of interacting with an adult human face at a natural distance (Hall 1966). Chin-and-forehead rests were used to maintain an equidistant viewing position and to help minimise head movements. The images were displayed on an 800×600 pixel grey background with a Dell P1130 19 inch CRT monitor with a refresh rate of 170 Hz. The images were displayed in random locations on the screen to prevent anticipatory eye movements. Stimulus presentation was controlled by software written in MATLAB with the Psychophysics (PTB-3) and EyeLink Toolbox extensions (Brainard 1997; Cornelissen et al 2002).

2.3 *Eye movements*

Eye movements were recorded at a sampling rate of 1000 Hz with an SR Research Desktop-Mount EyeLink 2K binocular eye-tracking system. The EyeLink 2K has an average gaze position error of < 0.5 deg horizontally, < 1.5 deg vertically, a resolution of 1 min of arc, 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 by 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 deg then the calibration and validation procedure was repeated until an optimal gaze estimate was achieved.

2.4 *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).

2.5 *Procedure*

Participants were informed that the experiment comprised two blocks of face learning and recognition, each containing different face stimuli. In 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 memorising 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 s 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.

2.6 *Data analyses*

Only correct trials were analysed. Fixation distribution maps were computed individually for EA and WC observers for each race condition, and face learning and recognition phases separately, with the use of MATLAB. More than 1 pixel is processed during a fixation, so each fixation was smoothed with a Gaussian kernel ($\alpha = 10$ pixels) to represent the foveated area (2 deg 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 eye-movement distributions of WC and EA observers 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 normalise 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 with a one-tailed Pixel test (Chauvin et al 2005; $Z_{\mathrm{crit}} > |4.64|$; $p < 0.05$) for the group fixation maps, and a two-tailed Pixel test ($Z_{\mathrm{crit}} > |4.25|$; $p < 0.05$) for the differential fixation maps. Finally, for each condition we extracted the average Z-score value for each observer individually, for each area showing significance in the differential fixation maps. Cohen's d effect sizes (Cohen 1988) were calculated from two-way mixed design ANOVAs on the average Z-scores with the region of the face and the culture of the observer as factors carried out for the learning and recognition conditions separately.

In order to clarify the results of the fixation strategies during inverted-face viewing, we compared these findings with previously collected data on upright-face recognition (Blais et al 2008) that used the same methodological framework (with the exemption of stimulus orientation). Since both studies used identical stimulus material and a fully comparable experimental design, this comparison is valid and appropriate.

For a detailed discussion of the novel approach used to analyse eye-movement data (iMap) and the MATLAB code, please refer to Caldara and Miellet (submitted).

3 Results

3.1 *Behavioural*

3.1.1 *Face recognition accuracy.* Figure 2 illustrates the d' accuracy scores by culture for recognition. WC observers showed a d' accuracy of 0.74 (SE $= \pm 0.18$) for Western Caucasian faces and 0.78 (SE $= \pm 0.11$) for East Asian faces. EA observers had d' accuracy scores of 0.57 (SE $= \pm 0.23$) and 0.39 (SE $= \pm 0.17$) for Western Caucasian and East Asian faces, respectively. A 2 (race of face) $\times$ 2 (culture of the observer) mixed-model ANOVA revealed no significant main effects for the race of face ($F_{1,26} = 0.13$, $p = 0.71$) or culture of the observer ($F_{1,26} = 2.4$, $p = 0.12$) on recognition performance. The interaction between the race of face and culture of the observer also failed to reach statistical significance ($F_{1,26} = 0.34$, $p = 0.56$). Recognition performance was comparable across cultures and races of faces observed.

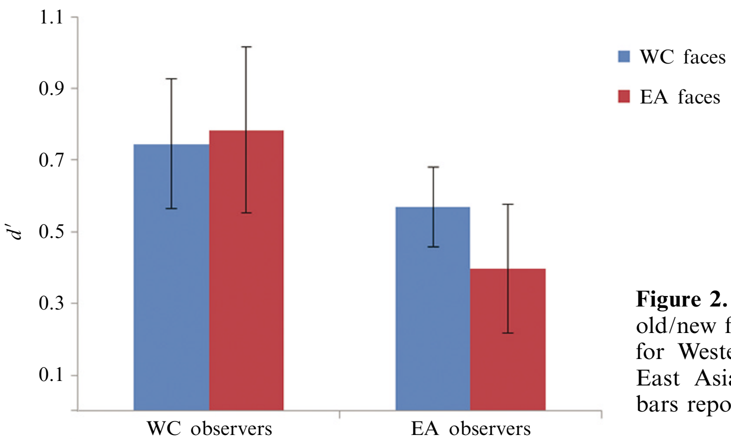

Figure 2. d' Accuracy scores of the old/new face-recognition paradigm, for Western Caucasian (WC) and East Asian (EA) observers. Error bars report ± 1 SEM.

3.1.2 *Reaction times.* Figure 3 illustrates the mean response times for each cultural group. WC observers had a mean recognition response time of 1941 (SE $= \pm 129$) ms and 2145 (SE $= \pm 128$) ms to WC and EA faces, respectively. EA observers had a mean recognition response time of 2083 (SE $= \pm 178$) ms and 1956 (SE $= \pm 146$) ms to WC and EA faces, respectively. A 2×2 mixed-model ANOVA revealed no significant main effects for the race of face ($F_{1,26} = 0.56$, $p = 0.45$) or culture of the observer ($F_{1,26} = 0.01$, $p = 0.9$) on mean reaction time. The interaction between race of face and culture of the observer was significant ($F_{1,26} = 10.61$, $p = 0.001$). A posteriori two-tailed paired t-tests revealed that Western Caucasian observers responded significantly

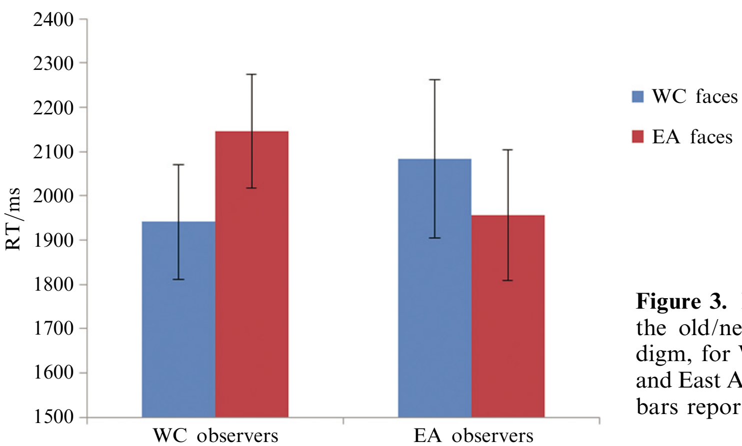

Figure 3. Mean response times to the old/new face-recognition paradigm, for Western Caucasian (WC) and East Asian (EA) observers. Error bars report ± 1 SEM.

faster to own-race faces than EA faces ($t_{13} = -3.35$, $p = 0.005$), but there was no significant difference in recognition response time to the race of face for East Asian observers ($t_{13} = -1.56$, $p = 0.142$).

3.2 *Eye movements*

3.2.1 *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 ($F_{1,26} = 0.04$, $p = 0.84$), or culture of the observer ($F_{1,26} = 0.04$, $p = 0.84$), on number of fixations during face learning. There was no significant interaction between race of face and culture of the observer ($F_{1,26} = 2.10$, $p = 0.84$). During face recognition there was no main effect of culture on number of fixations ($F_{1,26} = 3.04$, $p = 0.09$). There was a main effect of race of face

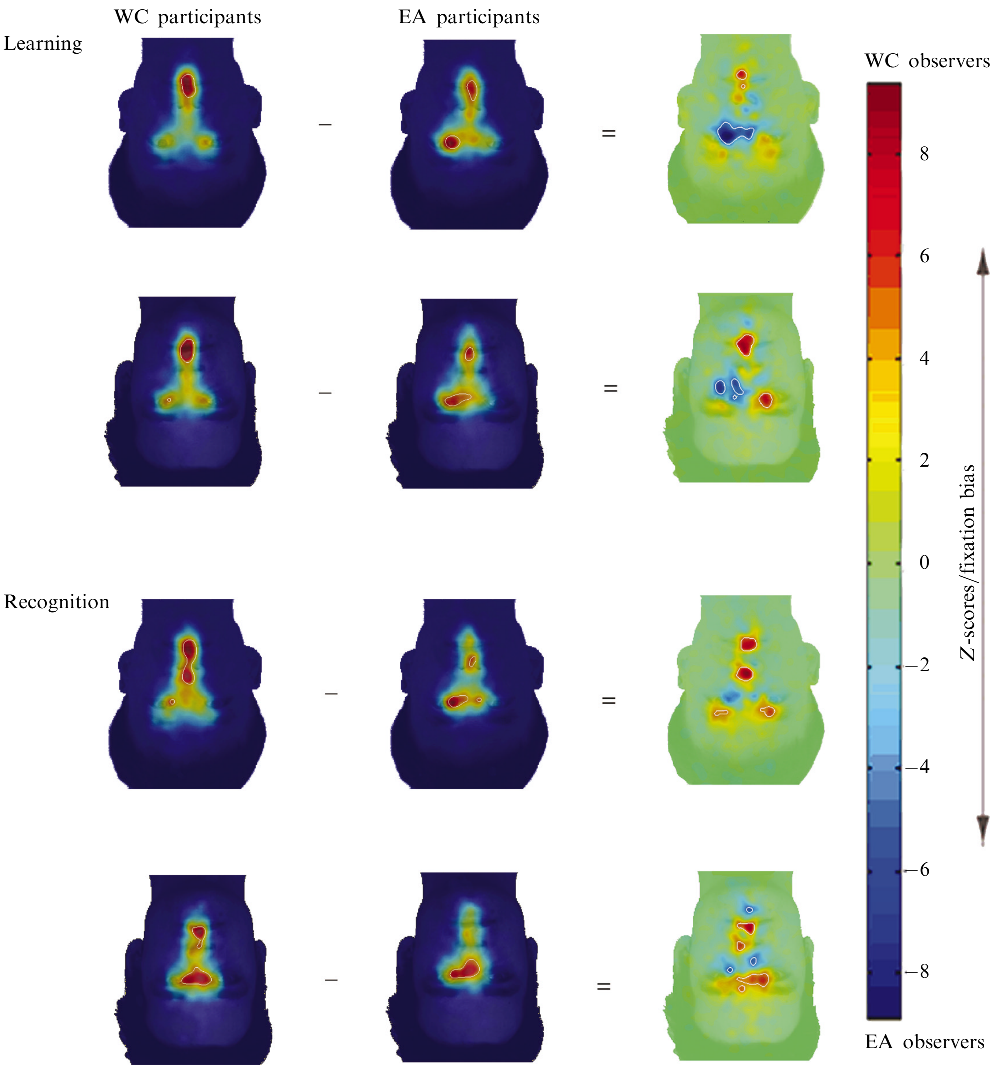

Figure 4. Fixation maps of Western Caucasian (WC) and East Asian (EA) observers for inverted-face learning and recognition (dark blue images). Differential fixation maps (green images) were computed by subtracting WC (red) Z-scored group fixation maps from EA (blue) maps for each condition. Areas showing a significant fixation bias are delimited by white borders ($Z_{\text{crit}} > |4.25|$; $p < 0.05$); values near 0 indicate similar magnitude in fixation between observers from different cultures.

on number of fixations ($F_{1,26} = 4.19$, $p = 0.05$) and a significant interaction between the race of face and culture of the observer ($F_{1,38} = 14.91$, $p = 0.001$). A posteriori two-tailed paired t-tests revealed that WC observers made significantly fewer fixations to own-race faces than EA faces ($t_{13} = -5.13$, $p = 0.001$), whereas EA observers did not ($t_{13} = 1.10$, $p = 0.287$).

3.2.2 *Fixation frequency.* Table 2 shows the mean number of fixations during face learning and recognition for each group of observers. The average fixation frequency during face learning was similar across cultures. The main effect of culture did not reach statistical significance ($F_{1,26} = 0.074$, $p = 0.787$). The main effect of race of face was non-significant ($F_{1,26} = 0.074$, $p = 0.787$). The interaction term also failed to reach significance ($F_{1,26} = 0.251$, $p = 0.618$). On average, WC observers made slightly more fixations during face recognition than EA observers to both WC faces (3.14 versus 2.77), and EA faces (3.17 versus 2.77). The main effect of culture was significant ($F_{1,26} = 9.66$, $p = 0.003$) and a posteriori two-tailed paired t-tests demonstrated that WC observers made significantly more fixations during recognition ($t_{13} = 3.166$, $p = 0.002$). However, neither cultural group differed significantly in frequency of fixations to same-race or other-race faces ($F_{1,26} = 0.025$, $p = 0.874$). The interaction effect was non-significant ($F_{1,26} = 0.013$, $p = 0.909$).

3.2.3 *Fixation distribution maps.* Figure 4 shows significant differences ($Z_{\mathrm{crit}} > |4.64|$; $p < 0.05$) in fixation locations for both cultures during inverted-face learning and recognition, and significant differences ($Z_{\mathrm{crit}} > |4.25|$; $p < 0.05$) in fixation strategies across both groups of observers. WC observers deployed a triangular pattern of fixations to both eyes and the mouth. They also showed a greater tendency to fixate the mouth. By contrast, EA observers fixated different facial regions from inverted faces than WC observers, by most densely fixating the inner right eye and top of the nose across conditions. During recognition, EA observers also made significant fixations to the mouth.

In the differential group fixation maps, WC observers made significantly more fixations to the left eye and mouth than the EA observers in all conditions except learning of EA faces, where only the mouth was significantly fixated. Alternatively, EA observers made significantly more fixations to the inner-right eye and part of the

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. Numbers in parentheses report 1 SEM. The presentation time was fixed during learning (5 s).

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

Table 2. Mean fixation frequencies during face learning and recognition for Western Caucasian (WC) and East Asian (EA) observers. Numbers in parentheses report 1 SEM. The presentation time was fixed during learning (5 s).

Observers	Learning		Recognition	
	EA faces	WC faces	EA faces	WC faces
WC	2.743 (0.11)	2.8 (0.10)	3.17 (0.11)	3.14 (0.11)
EA	2.77 (0.11)	2.72 (0.11)	2.77 (0.14)	2.77 (0.14)

Table 3. Cohen's *d* effect sizes by culture for significantly fixated facial features.

Effect	Observers	Facial feature				Race of face
		eyes	nose	mouth	rest	
Learning	WC	0.31	0.11	0.54	0.04	WC
		0.35	0.23	0.39	0.03	EA
	EA	0.29	0.20	0.47	0.04	WC
		0.37	0.30	0.30	0.04	EA
Recognition	WC	0.26	0.31	0.40	0.03	WC
		0.20	0.46	0.29	0.05	EA
	EA	0.37	0.31	0.29	0.03	WC
		0.30	0.38	0.22	0.11	EA

nose than WC observers across all conditions except recognition of EA observers where this strategy is again present but fails to reach significance. Table 3 shows the Cohen's *d* effect size values for significantly fixated facial features.

Finally, figure 5 shows the differences between inverted and upright (Blais et al's 2008 data) face learning and recognition strategies for both groups of cultures. This analysis did not reveal significant differences in the scanning strategies for upright and inverted faces for either culture, since no facial region elicited significant fixation biases for either of the conditions ($Z_{\mathrm{crit}} > |4.25|$; $p < 0.05$).

4 Discussion

We report a cultural contrast in relative fixation biases for inverted faces, which is consistent with the cultural variance in information extraction strategies for upright faces (Blais et al 2008). Importantly, inverted-face recognition performance was comparable across cultures. In addition, both cultural groups maintained differential fixation patterns for upright and inverted faces, regardless of the race of the face observed. During processing of inverted faces WC observers, in comparison to EA observers, continued to consistently deploy preferential fixations to the eye and the mouth regions, as previously reported for upright faces (Blais et al 2008). In line with previous findings on WC observers with inverted unfamiliar faces (Williams and Henderson 2007), there were no significant differences between the fixation strategies used for inverted and upright faces. It is worth noting that the novel analysis of eye movements applied in this study revealed a trend in both cultural groups of greater fixations to the mouth for unfamiliar inverted faces, a fixation bias previously reported in the literature during the recognition of famous inverted faces (Barton et al 2006). However, this fixation bias towards the mouth region was not robust when directly compared to upright eye-movement strategies for either cultural group (Blais et al 2008). This finding is also in line with recent neuroimaging studies showing the existence of a tuning towards the upper visual field in the face-sensitive areas (Caldara et al 2006; Caldara and Seghier 2009). Although the fixation strategy of EA observers appears to be disrupted by inversion with the established central fixation bias observed for upright faces (Blais et al 2008; Caldara et al 2010; Kelly et al 2010) expanding towards the inner right eye, this apparent disruption failed to reach statistical significance when compared directly to the upright strategy of EA observers. Therefore, similarly to the WC group, the fixation strategy of EA observers for upright faces is maintained for inverted faces.

Previous studies have revealed an interaction between the FIE and the ORE, demonstrating a stronger inversion effect for own-race compared to other-race faces (eg McKone et al 2007; Rhodes et al 1989). Although recognition accuracy for both cultural groups of observers followed this trend in our study, the effect was not statistically reliable.

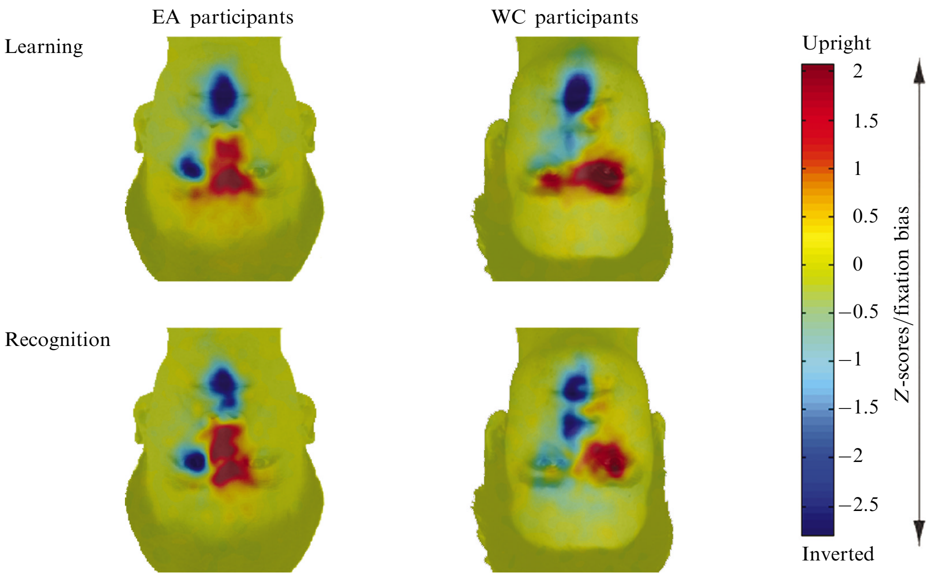

Figure 5. Differential fixation maps between upright [data from the Blais et al (2008) study] and inverted (present study) face learning and recognition, computed by subtracting Z-scored Western Caucasian (WC) group fixation maps from East Asian (EA) maps for each condition.

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 FIE and ORE have used the same image during both face learning and recognition, so further studies are necessary to directly address the question whether the use of strong constraints in facial identity encoding affects face recognition performance during inversion.

It would be tempting to account for the different eye-movement strategies deployed by observers from different cultures by the anthropometric variations inherent to faces from different races (for instance, more information in the nose region in EA faces). However, we have previously demonstrated that the stimulus set of EA and WC faces used here does not contain any significant differences in the pixel space across faces from different races (Caldara et al 2010). This observation is consistent with previous studies of a similar issue (Caldara and Abdi 2006; Goldstein 1979a, 1979b). Therefore, there is no obvious diagnostic information inherent in faces from a particular race that could explain the observed fixation strategies. In addition, a recent study examined information use during face processing with a gaze-contingent paradigm (Caldara et al 2010). Facial information available to viewers was restricted to 2, 5, and 8 deg 'Spotlight' apertures that light up the blackened stimulus display as a function of the current gaze position. Critically, in the 2 and 5 deg conditions the Spotlight was large enough to reveal individual facial features, but both eyes and the mouth were not visible simultaneously when the nose was fixated. By contrast in the 8 deg 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 deg 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 (eg 'Bubbles'—Gosselin and Schyns 2001; Caldara et al 2005) that reveal the eye region is critical for accurate face identification. Since both cultures require the same diagnostic information to achieve face recognition, it becomes natural to ask why observers from different cultures employ diverse eye-movement strategies to adapt to the very same face-recognition constraints.

Blais et al (2008) suggested that the systematic differences in perceptual processing across cultures, identified by recent studies (eg perceptual categorisation—Norenzayan et al 2002; perceptual judgment—Kitayama et al 2003; and scene perception—Miyamoto et al 2006), might expand and generalise to face processing. Blais et al (2008) therefore aligned cultural diversity in face scanning with a recent cultural paradigm that proposes that culture influences perception by producing qualitative differences in the way people process information from the visual environment (Nisbett and Miyatomo 2005). The holistic[(1)] versus analytic theory of culture describes EA perceptual strategies as holistic as visual attention is largely directed toward the context and relationships of environmental stimuli in their entirety. By contrast, WC observers 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 (eg 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 EA adults maximises 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 et al 2010). The present eye-movement data suggest that the holistic central fixation bias of the EA upright strategy is still the most effective strategy under the constraint of an unfamiliar inverted orientation. Similarly, the WC upright strategy is also maintained for inverted faces (eg Sekuler et al 2004), which indicates that the information sampled from the eyes and mouth during scanning is sufficient for identification regardless of orientation.

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. These cultural perpetual biases are robust and point towards the existence of cultural-specific mechanisms to extract and process information from faces.

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[(1)] The term 'holistic' used here is defined by the holistic versus analytic theory of culture and perception. This term is not related to the term 'holistic' used in face literature.

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