Vision Research 100 (2014) 105–112

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Looking at faces from different angles: Europeans fixate different features in Asian and Caucasian faces

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ARTICLE INFO

Article history:
Received 18 November 2013
Received in revised form 16 April 2014
Available online 4 May 2014

Keywords:
Face
Race
Categorization
Eye movements
Face orientation

ABSTRACT

Race categorization of faces is a fast and automatic process and is known to affect further face processing profoundly and at earliest stages. Whether processing of own- and other-race faces might rely on different facial cues, as indicated by diverging viewing behavior, is much under debate. We therefore aimed to investigate two open questions in our study: (1) Do observers consider information from distinct facial features informative for race categorization or do they prefer to gain global face information by fixating the geometrical center of the face? (2) Does the fixation pattern, or, if facial features are considered relevant, do these features differ between own- and other-race faces? We used eye tracking to test where European observers look when viewing Asian and Caucasian faces in a race categorization task. Importantly, in order to disentangle centrally located fixations from those towards individual facial features, we presented faces in frontal, half-profile and profile views. We found that observers showed no general bias towards looking at the geometrical center of faces, but rather directed their first fixations towards distinct facial features, regardless of face race. However, participants looked at the eyes more often in Caucasian faces than in Asian faces, and there were significantly more fixations to the nose for Asian compared to Caucasian faces. Thus, observers rely on information from distinct facial features rather than facial information gained by centrally fixating the face. To what extent specific features are looked at is determined by the face's race.

1. Introduction

There is considerable evidence that race categorization occurs early and mostly automatically for faces (e.g. Levin, 1996; Taylor et al., 1978), despite the fact that there are no human races in the biological sense (Cosmides, Tooby, & Kurzban, 2003; Tishkoff & Kidd, 2004). Nonetheless, perceived race affects subsequent face encoding profoundly: The "other-race effect" (ORE) for example is a robust psychological phenomenon (for a meta-analysis see Meissner & Brigham, 2001), describing the fact that other-race faces are more difficult to recognize compared to own-race faces.

Behavioral and electrophysiological findings suggest that differences in own- vs. other-race face perception appear at early stages of visual processing (Caharel et al., 2011; Ito & Urland, 2003). Assessing where observers initially direct their gaze during face categorization could therefore help investigating whether differences in visual input could be at the basis of such differences in face processing. Precise visual input is only available within the visual field of the fovea. Thus, specific parts of a visual scene are fixated foveally one after another to bring crucial visual information into focus (Loftus & Mackworth, 1978; Yarbus, 1967), and eye tracking techniques serve as a useful tool for assessing which parts of a face a viewer considers most informative for the task at hand.

In contrast to many recent studies on eye movements in face perception tasks, here, we are not investigating the ideal strategy to optimize performance (as e.g., Peterson & Eckstein, 2012), or the ability of the visual system to efficiently use the information provided by natural or manipulated face stimuli (e.g., Schyns, Bonnar, & Gosselin, 2002). What we are studying here is what information human observers *consider* diagnostic by recording where they look in a face while judging its race. We concentrated on the first fixation in our analyses, because it probably provides the visual input most crucial for face race categorization for three reasons: First, many face categorization tasks can be completed, if necessary, after one or two fixations only (Hsiao & Cottrell, 2009).

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http://dx.doi.org/10.1016/j.visres.2014.04.011
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Second, face race categorization is considered to be an especially fast and automatic process (e.g. Levin, 1996; Taylor et al., 1978) generally occurring before and faster than other judgments, e.g. sex categorization (Ito & Urland, 2003). Third, differences in brain activity for own- and other-race faces strongly suggest that face race affects the earliest stages of face perception (Caharel et al., 2011; Ito & Urland, 2003).

Eye tracking has recently been used in a range of studies investigating race- and culture-specific fixation strategies: Generally, it has been reported that Western Caucasian observers use rather analytical viewing strategies, fixating the most prominent features of a scene or object, whereas East Asian observers look at stimuli more holistically, i.e. they pay more attention to the background and/or central regions than Westerners (Chua, Boland, & Nisbett, 2005; Kelly, Miellet, & Caldara, 2010). The same differences between observers of European and Asian backgrounds have also been found for face perception (Blais et al., 2008; Kelly, Miellet, & Caldara, 2010; Kelly et al., 2011; Miellet et al., 2013). Some of these studies report that observers employ the same culture-specific fixation strategies regardless of whether they look at own- or other-race faces (Kelly, Miellet, & Caldara, 2010; Kelly et al., 2011). Contrary to that, however, there are also studies reporting diverging fixation patterns for own- and other-race faces in Asian (Fu et al., 2012) as well as European (Goldinger, He, & Papesh, 2009) observers. The authors of these latter studies propose that such differences might arise due to the enculturation of particular visual strategies (Fu et al., 2012; Liu et al., 2011; Wheeler et al., 2011): As these culturally shaped strategies develop predominantly in interaction with own-race faces, they might not be used for other-race faces, resulting in differing viewing patterns for both face categories. Yet another line of evidence for differing scanning strategies argues that observers directly access the individuation level, i.e. they process information about idiosyncratic features, only when viewing own-race faces (Levin, 1996, 2000; MacLin & Malpass, 2001). According to this theory, the presence of a "racial marker" in other-race faces directs the observer's attention away from the identity of the face and towards the feature that serves as this marker.

Overall, thus, the literature so far is quite inconsistent concerning differences in fixation patterns between own- and other-race faces, with recent studies reporting contradictory results. We aimed to address these inconsistencies in the task that usually precedes other face-related judgments, i.e. during race categorization. There is an advantage of studying race categorization itself, rather than identification or other face judgments in different races: In the latter tasks, the features that are most informative, e.g. for judging a face's sex, age or other not race-related properties, might differ between races, making it thus necessary to look at each race differently for optimal performance. As for face race categorization, however, the features diverging most in appearance between face races can be considered the most diagnostic ones. Hence, it would be an efficient strategy for race categorization to look at these same features preferentially across all face races. Differences in fixation distributions for own- and other-race faces are thus least likely to emerge in a face race categorization task. If such differences emerge nonetheless, these findings would strongly suggest that observers' fixation behavior changes according to face race *per se* and not only because they chose fixation strategies most efficient for the task at hand.

So far no study yet concentrated on differences in fixations across face races during race categorization. Even though Blais et al. (2008) employed such a task, alongside learning and recognition trials, they did not report whether there were differences in viewing strategies for own- compared to other-race faces during race categorization. In the current study, we thus investigated where observers look in own- and other-race faces when classifying them by race. As it has been suggested that centrally located fixations – as opposed to fixations distributed over specific facial features – are characteristic for face processing in a variety of tasks (Armann & Bülthoff, 2009; Schwarzer, Huber, & Dümmler, 2005) or at least for the first fixation on a face (Bindemann, Scheepers, & Burton, 2009), we disentangled the position of inner facial features from the center of the face stimulus by presenting the faces in different orientations. Most features are visible in all orientations, but their position changes, with for example the nose moving from center-most feature in a frontal face to the outer border on either side in profile view.

In view of the findings reviewed above, several possible outcomes could be predicted for our experiment: First, if our observers consider detailed information about specific facial features to be crucial for race categorization of own- and other-race faces, they should always direct their gaze to those features, independent of face orientation. If, in contrast, face processing and thus race categorization, too, relies mostly on fixations to the center of the visible face, a preference to look at the center of the face in all face orientations would be expected. Second, if one or a few features serve as "racial markers" for other-race faces only, these features should be more often fixated in other- compared to own-race faces. If however culture-specific fixation strategies are applied to all faces, locations of initial fixations should be similar for own- compared to other-race faces.

Thus, we aimed to answer two major questions in our study: (1) Does race categorization generally rely on sampling information from distinct facial features or rather on gaining global face information by fixating the geometrical center of the face (Blais et al., 2008)? (2) Do fixation distributions differ for own- and other-race faces when categorizing faces by race?

We tested European participants on Asian and Caucasian faces in a time-controlled race categorization task while recording their gaze position. We have not included the factor cultural background of the observer in this study; rather, we focused on first assessing the effect of different face orientations in combination with face race in one culturally homogenous sample of observers. These insights may then serve to guide further research on intercultural differences. Our results clearly indicate that information from distinct facial features is sampled for race categorization and that those features vary depending on *face race*. Specifically, our European participants clearly fixated the eyes more in Caucasian (own-race) than in Asian (other-race) faces, in which, in comparison to Caucasian faces, they looked at the nose more often.

2. Methods

2.1. Observers

Observers were 24 individuals (12 females, mean age = 27.5 yrs, $SD = 8.5$) with European cultural and ethnical background, normal or corrected-to-normal visual acuity and no known impairments of face recognition. None of the participants has reported to have lived in Asia for more than 6 months and none of the participants stated to have intense contact with Asian individuals. All participants received a remuneration of €8 per hour and participated only once. All participants gave written informed consent according to the Declaration of Helsinki.

2.2. Stimuli and setup

Static face images were derived from three-dimensional laser scans collected in the face database of the Max Planck Institute for Biological Cybernetics (http://faces.kyb.tuebingen.mpg.de). From these heads, 2D face images were derived in a full-frontal, 45° and 80° clockwise rotated view. Faces were between 555 and 749 pixels in height and between 440 and 701 pixels in width, which on the monitor screen corresponds roughly to the natural size of a face from chin to hair line (about 20 by 14 cm). At a viewing distance of 65 cm, a distance at which adults typically interact (Baxter, 1970), a face covered a visual area of about $11° \times 13°$–$17° \times 17°$ of visual angle. The size of the stimuli, as measured by the percentage of area covered by the face, did not differ between Asian and Caucasian faces in any view, all $p \geqslant .13$. All faces were shown in color (24-bit color depth).

To achieve most natural looking face images, scanning artifacts were corrected and the cut-out borders of each face were slightly blurred. To generate face stimuli looking to the left as well as to the right, 45° and 80° rotated faces were flipped along the vertical axis. Flipped face stimuli will subsequently be referred to as "mirror images". Thus, five face images were created from each head.

We created images of Asian and Caucasian female faces as well as Asian and Caucasian male faces. Ten face identities were used for each category, resulting in a total of 40 face identities and 200 different face images (40 identities $\times$ 5 views). All stimuli were presented on the same uniform grey background on the screen of a Tobii T 60 XL eye tracker (24 in., resolution 1920×1200 pixels, refresh rate 60 Hz) which was also used for eye movement recording. Stimulus presentation and data collection was managed by Tobii Studio 3.1.2 software. Participants were free to move their head while maintaining a viewing distance of approximately 65–70 cm.

2.3. Procedure and design

The experiment consisted of two blocks of 15–20 min each. Trial sequence remained the same throughout the whole experiment (Fig. 1). Each trial started with the presentation of a red fixation cross in the middle of a randomly chosen quadrant of the screen for 1.5 s, as it has been demonstrated that the initial fixation position before stimulus presentation critically influences the landing position of the first fixation (Arizpe et al., 2012). Then a randomly selected face image was shown for 3 s at the center of the screen, followed by the question "Did the face look European or Asian to you?" as well as the response options "Asian" and "European" and their corresponding keys (left and right arrow key, respectively). There was no time limit for answering. Thus, participants were able to judge face race under most natural viewing conditions. Assignment of keys to race was counterbalanced

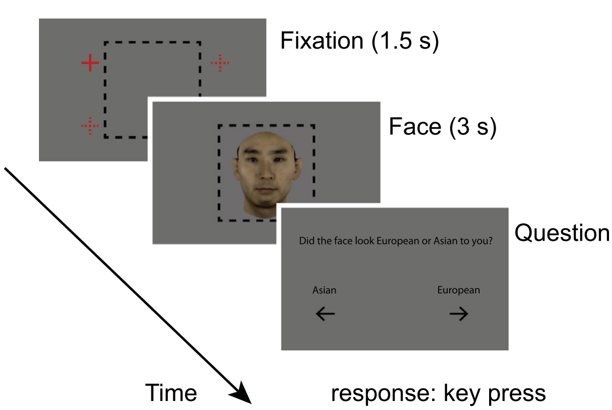

Fig. 1. Trial timeline. Trials in all experiments started with a fixation cross, followed by the face image at the center of the screen. The question (European or Asian?) followed immediately and was displayed until participants responded via the keyboard. Dashed red crosses indicate other potential locations of the fixation cross. Dashed black squares indicate the region outside which fixations were excluded from analysis. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

between blocks. All 200 face images were shown once in each block.

Participants were given oral as well as written instructions before the experiment. Additionally, each block started with an instruction screen explaining the task and key assignments. Between blocks participants had a short self-timed break. The standard Tobii Studio calibration procedure was carried out before each block. After completing the experiment participants were asked to complete a questionnaire about the stimuli and their amount of contact with Asian people and media.

2.4. Data processing

We used the Tobii Studio software to record responses and collect stimulus information. Fixations were defined as a set of gaze points during which eye velocity did not exceeded a threshold of 20°/s during a minimum duration of 100 ms. Fixations with more than 60% missing eye position data or for which the distance between gaze points exceeded 0.5° were discarded. The output used for further analysis were gaze positions sampled every 17 ms and averaged across both eyes by the Tobii Studio software, thus resulting in multiple gaze points per fixation detected. Subsequent analysis of eye movement data was done with MatLab (© 1984–2012 The MathWorks, Inc., Version R2012a). The average position of one entire fixation was calculated as the average across all 17 ms interval gaze points that were classified as belonging to the same fixation.

First, we excluded fixations landing on the grey background outside an 800×800 pixels area surrounding the face (see dashed squares Fig. 1) from further analysis. If a trial's first fixation landed inside this region it was classified as missing value. To analyze fixations in terms of their positions on the face we divided each face into areas of interest (AOIs) corresponding to the main facial features (Fig. 2). AOIs were defined on each face individually using key feature points (e.g., corners of the eyes, tip of the nose, etc.). There were five AOIs in total (eye region, cheeks, nose, mouth and outline).

Moreover we determined the coordinates of each face image's center as the middle of the face's maximal width and height for *x*- and *y*-coordinates, originating at the top left of the screen. Fixations were classified as landing on the left side of the face if their location was left from the center-x-coordinate. A circular "central region" was defined around the central coordinate (see shaded area Fig. 2), its diameter defined as 40% of the mean of the face's height and width. This diameter was calculated separately only for face categories for which diameters significantly diverged, i.e. for face orientations and for Asian and Caucasian faces, but not for male and female faces.

2.5. Statistical analysis

As data loss never exceeded a threshold of 15%, the complete data from all 24 participants was included in the analysis. Total looking time did not differ for Asian and Caucasian faces in either face orientation, $F(1.44, 33.32) = 0.24$, $F(1,23) = 0.88$, and $F(1.45, 33.32) = 1.15$, for the main effect of face orientation, face race and their interaction respectively, all $p > .31$. Thus, the proportional distribution of the amount of fixations per AOI was used as dependent variable, with proportions of fixations calculated relative to the total number of fixations. Note that, as our predefined AOIs did not cover the entire face area, the proportion of fixations does not necessarily sum up to 1. Data was pooled across blocks as well as across mirror images (−45° and +45°. head rotation and −80° and +80° head rotation respectively) as distribution of fixations on the predefined AOIs did not differ between those conditions.

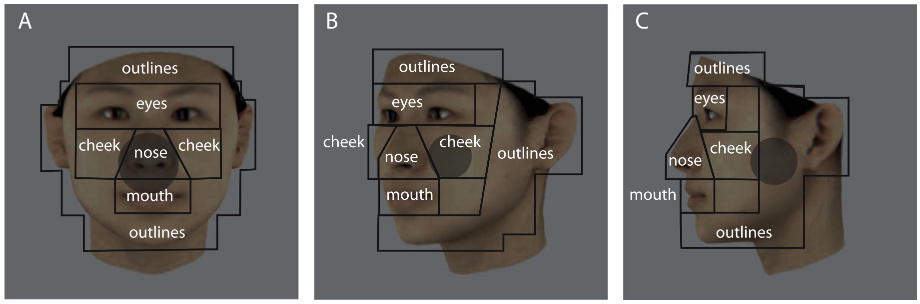

Fig. 2. Areas of interest (AOIs) for (A) full-frontal, (B) half-profile and (C) profile view. Solid black lines represent outlines of the AOIs defined for facial features. The shaded disk in each face indicates the central region. Note that AOIs for mirrored face images were determined by mirroring coordinates and not by separate measurements.

Multi-way repeated measures analyses of variance (rmANOVAs) were used to test the hypotheses of interest. Greenhouse–Geisser corrections were used if the assumption of sphericity was violated. For all post hoc pairwise comparisons, Bonferroni adjustments were used. In order to increase intelligibility, the exact statistical procedures performed are introduced at the beginning of each paragraph in Section 3.

3. Results

3.1. Behavioral data

Participants were clearly able to distinguish Asian from Caucasian faces, as can be seen from the mean accuracy over all blocks and participants: 96.90%, $SD = 3.50\%$. We therefore considered differences in eye movement data to accurately reflect differences in response to faces of different races that were correctly categorized as own- or other-race face. In view of the very small error rate, eye movement data of all trials, regardless of the correctness of the response, was used for analysis.

3.2. Distribution of first fixations

3.2.1. No fixation bias towards central region

To compare the proportion of fixations located at the central region across views, we entered the data into a 3×2 (*face orientation* $\times$ *face race*) rmANOVA. The main effect of *face orientation* was highly significant, $F(1.02, 23.42) = 24.67$, $p < .001$, $\eta^2 = .52$, indicating that there was no general bias towards fixating the geometrical center of the face. Post hoc pairwise comparisons confirmed that fixations of the central region were more frequent for the frontal than the half-profile and profile views, both $p < .001$, for differences between frontal vs. half-profile and frontal vs. profile views, respectively. Note that in the frontal face orientation the center of the visible facial features and the geometrical center of the face overlap. As illustrated in Fig. 3, participants' fixations were systematically directed towards facial features rather than the geometrical center of the face, indicating that distinct facial features are considered informative for face categorization and require foveation. We did not find any effects of *face race* regarding this central region, $F(1, 23) = 0.10$, $p = .76$, nor an interaction of *face race* with *face orientation*, $F(1.14, 26.22) = 1.17$, $p = .30$ (compare Fig. 3A–C to D–E).

We also replicated these findings using data of all fixations, yielding the same results. Only face orientation had a strong effect on the proportion of central fixations, $F(1.02, 23.42) = 48.51$, $p < .001$, $\eta^2 = .68$, with more fixations on the central region in frontal compared to both, half-profile and profile views, both $p < .001$. Again, there was no main effect for face race, $F(1, 230) = 1.61$, $p = .22$, and no interaction, $F(1.14, 26.22) = 1.84$, $p = .19$.

3.2.2. Differences between faces of different races

The second major goal of our study was to assess how *face race* and *face orientation* influence the distribution of first fixations across AOIs. Thus a 3×2 (*face orientation* $\times$ *face race*) mixed model rmANOVA was conducted for each AOI separately. Main effects of *face race* are illustrated in Fig. 4A, main effects of *face orientation* in Fig. 4B. Fig. 5 illustrates differences in fixation distribution according to *face race* for each *face orientation* separately.

Regarding the eye region we found that observers looked at the eyes more frequently in Caucasian compared to Asian faces, $F(1, 23) = 7.48$, $p = .01$, $d = 0.26$. Moreover, the proportion of first fixations dedicated to the eyes depended on face orientation, $F(1.35, 31.05) = 12.11$, $p < .01$, $\eta^2 = .35$: The eyes were less often looked at in profile compared to frontal, $p = .02$, $d = 0.31$, and half-profile views, $p < .001$, $d = 0.37$. There was no interaction of face race and face orientation, $F(1.49, 34.16) = 3.12$, $p = .07$.

For the nose region, face race, and face orientation had a main effect on the proportion of first fixations, too, $F(1, 23) = 12.63$, $p < .01$, $\eta^2 = .35$, and $F(1.14, 26.23) = 6.10$, $p = .02$, $\eta^2 = .21$, without interacting, $F(1.57, 36.12) = 0.51$, $p = .56$. The nose was more often looked at in Asian faces compared to Caucasian faces, $p < .01$, $d = 0.21$ and less often looked at in the frontal compared to the half-profile view, $p = .02$, $d = -0.46$.

For the cheeks region we found no main effects, $F(1.23, 28.26) = 2.61$, and $F(1, 23) = 2.39$, for face orientation and face race respectively, both $p > .11$. There was an interaction of face orientation and face race, $F(1.26, 29.01) = 4.03$, $p < .05$, with an effect size of $\eta^2 = .15$, indicating that this effect is negligible, which was further supported by post hoc tests not revealing any differences, all $p > .05$.

For the mouth region we found clearly no effect of either face race, $F(1, 23) = 0.59$, or face orientation, $F(1.52, 34.86) = 1.14$, or their interaction, $F(1.45, 33.44) = 0.68$, all $p > .32$. First fixations to the outline region were influenced by face orientation, $F(1.45, 33.41) = 40.18$, $p < .001$, $\eta^2 = .64$. The outline region was looked at increasingly from frontal to half-profile to profile views, all $p < .01$, $d = -0.46$ and $d = 0.88$, respectively. Neither face race, $F(1, 23) = 1.00$, $p = .33$, nor the interaction, $F(1.78, 40.74) = 0.25$, had an effect.

In summary, the proportion of fixations dedicated to specific features changed according to *face race* (see Figs. 4A and 5) as well as *face orientation* (see Fig. 4B). Changes in proportions of fixations for the most looked at features (eyes and nose) according to *face orientation* largely followed the size changes of those features from frontal to profile views. However, the size changes of those areas do not explain the changes of fixations for all areas across face orientations, as AOI sizes also considerably changed for other features

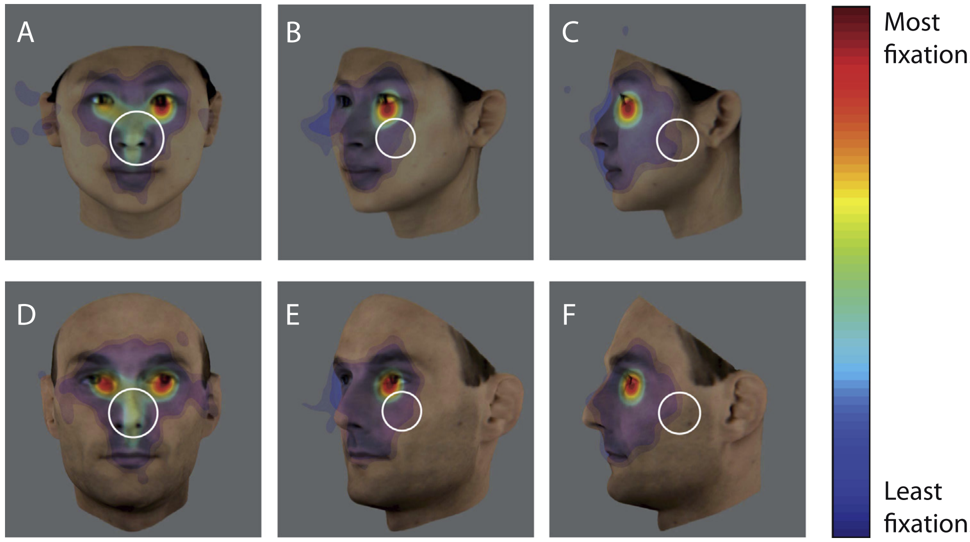

Fig. 3. Heat maps of first fixation data for Asian (A–C) and Caucasian (D–E) faces. White circles mark the "central region". Data matrices underlying the heat maps were smoothed using a Gaussian low pass filter (size = 50 × 50 px, σ = 20). Areas not overlaid by any color did not receive any fixations. Note that each heat map displays relative fixation distribution per condition. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

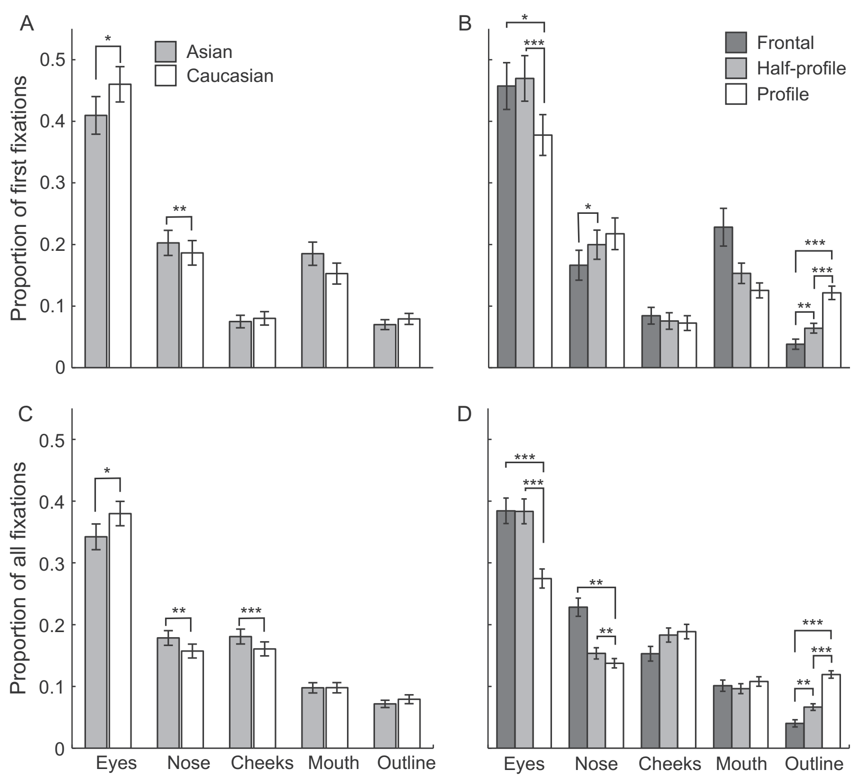

Fig. 4. Distribution of first fixations on AOIs according to face race (A and C) and face orientation (B and D). The top row (A and B) shows values for the first fixations only, the bottom row (C and D) for all fixations. Asterisks mark significant differences between Asian and Caucasian faces (A and C) and between the three face orientations (B and D) according to Bonferroni corrected pairwise comparisons; ***$p < .001$; **$p < .01$, *$p < .05$. Error bars represent SEM.

such as the cheeks. Moreover, changes in proportional fixations on distinct features according to *face orientation* were not specific to race.

3.3. Generalization of effects across entire viewing time

We were interested in whether differences in fixation behavior between Asian and Caucasian faces persisted over the entire viewing time of 3 s, i.e., when observers took their time to explore the stimuli more thoroughly, probably after already making a decision. Therefore, we conducted a replication of the 3 × 2 (*AOI* × *face orientation* × *face race*) mixed model rmANOVAs using data of all fixations. The bottom row of Fig. 4 illustrates the distribution of all fixations across AOIs.

The analyses including all fixations yielded essentially the same results as the analyses of the first fixations only: For the eye region again main effects of face orientation, $F(1.53,35.29) = 39.96$, $p < .001$, $\eta^2 = .64$, as well as face race, $F(1,23) = 5.11$, $p = .03$, $\eta^2 = .18$, sustained and pointed into the same direction as for first fixations: Eyes were more often looked at in frontal compared to

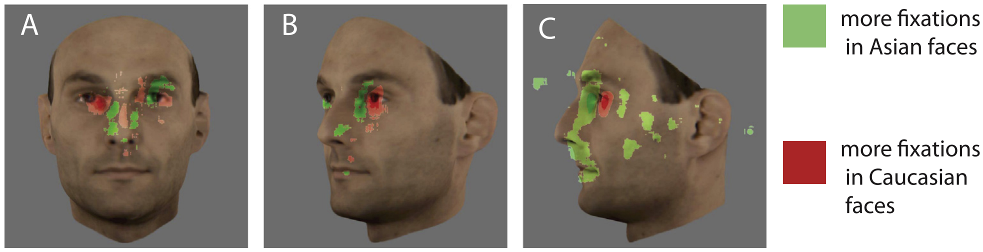

Fig. 5. Heat maps of differences in first fixations between Asian and Caucasian faces. Data matrices underlying the heat maps were smoothed using a Gaussian low pass filter (size = 50 × 50 px, σ = 20). Areas shaded in red were more often looked at in Caucasian faces, areas shaded in green in Asian faces. Areas not overlaid by any color were fixated equally often in faces of both races. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

half-profile and profile views, both $p < .001$, $d = .0.62$ and $d = 0.63$ respectively, and eyes were more often looked at in Caucasian compared to Asian faces, $d = .19$. However, when looking at all fixations, an interaction of face race and face orientation, $F(1.34, 30.84) = 5.30$, $p = .02$, $\eta^2 = .19$, post hoc tests showed that in profile views the effect of face race vanished, $p = .58$.

For the nose region we found identical results compared to our analyses of first fixations. The nose was more often looked at in Asian compared to Caucasian faces, $F(1,23) = 14.85$, $p < .01$, $\eta^2 = .39$, $d = 0.19$. The proportion of overall fixations to the nose was also influenced by face orientation, $F(1.16, 26.64) = 11.53$, $p < .01$, $\eta^2 = .33$, but not by the interaction of face orientation and face race, $F(1.95, 44.73) = 0.14$. The nose was more often looked at in frontal and half-profile views compared to profile views, both $p < .01$, $d = 0.77$ and $d = 0.19$, respectively.

Regarding the cheek region, face orientation still had no effect when considering all fixations, $F(1.12, 25.75) = 2.69$, $p = .11$. However, the interaction of face race and face orientation reached significance, $F(1.58, 36.41) = 15.24$, $p < .001$, $\eta^2 = .40$, as well as the main effect of the factor face race, $F(1,23) = 8.52$, $p < .01$, $\eta^2 = .27$. Post hoc tests showed that the cheeks were more often looked at in Asian compared to Caucasian faces in frontal and half-profile views, both $p < .01$, $d = 0.44$ and $d = 0.21$, respectively, but less often in profile views, $p = .03$, $d = -0.12$. However, the negligible effect size of this reversion of a face race effect implies that the interaction has rather to be interpreted as reflecting a decline of a face race effect from frontal to half-profile to profile views.

Regarding the mouth region again no significant effects were found, $F(1.29, 29.64) = 1.04$, $F(1,23) = 0.00$, $F(1.70, 39.16) = 0.51$, for main effects of face orientation, face race and the interaction of both respectively, all $p > .34$. For the outline region we found again that only face orientation had an effect, $F(1.25, 28.77) = 53.82$, $p < .001$, η^2 8 .70, but neither face race nor the interaction, $F(1,23) = 0.97$, and $F(1.47, 33.70) = 0.31$, respectively, both $p > .34$. The outlines of a face were progressively looked at more often from frontal to half-profile to profile views, all $p \leqslant .001$, all $d \geqslant 0.51$. Thus, analyses of first and all fixations yielded the same results for nose, mouth, and outline region. Regarding the eye region, the same main effects were present in analyses of first and all fixations. However, for the cheeks and the eye region meaningful interactions of *face race* and *face orientation* emerged only when considering all fixations. Both interactions revealed a decline in face race effects from frontal to profile views.

4. Discussion

In this study, European participants of Caucasian origin viewed Asian and Caucasian face images. To investigate where participants looked at first during race categorization and whether fixation distribution differed for Asian vs. Caucasian faces, we used an eye-tracker to record their fixations on each face separately while they were performing a race categorization task. Our first major finding is that for race categorization, Caucasian observers allocated visual attention mostly to discrete facial features and not to the geometrical center of the face regardless of the face's race. Our second major finding is that these features were fixated to different extents for own- and other-race faces. A race effect was present from the first fixation onwards and its presence was largely independent of *face orientation*, even though fixation behavior generally depended on *face orientation*.

4.1. Features always matter

By presenting faces in different orientations we disentangled the potential propensity to first look at the center of a face (Bindemann, Scheepers, & Burton, 2009; Hsiao & Cottrell, 2009) from fixations to discrete features. Thereby we were able to show that in a race categorization task, participants showed no bias towards looking at the geometrical center of face stimuli.

Our results question the interpretation made by Hsiao and Cottrell (2009) about their findings: In their study, these authors exclusively used faces shown in frontal views and found the nose to be the most frequently initially fixated AOI during a face recognition task. They interpret the location of the nose as the "center of information" in the face which, when fixated upon, provides sufficient information about the whole face for successful recognition. Our results demonstrate that information is acquired from fixations to specific features. We would thus suggest that the nose was fixated in the study of Hsiao and Cottrell (2009), not the center of the face. Our findings reinforce the hypothesis that observers rely on information from internal features in various face recognition tasks, as has been shown to be the case in identification and familiarity rating (Stacey, Walker, & Underwood, 2005). Thus, if a "center of information" as proposed by Hsiao and colleagues exists, this center is clearly different from the geometrical center of a face. Our findings also stand in contrast to the results of Bindemann, Scheepers, and Burton (2009) who found the first fixation to be most often directed toward the geometrical center of faces, even when faces were shown in mid-profile or profile. One major difference between their and our study was the task at hand: While Bindemann and colleagues asked observers to categorize faces by their sex or employed a free-viewing paradigm we asked participants to judge face race. Peterson and Eckstein (2012), when investigating human eye movement behavior and ideal observer strategies in face identification, sex and emotion categorization, found that fixation patterns change depending on the task. Thus, the fact that in our study observers showed no tendency to first look at the center of the face might be a task-specific finding. Note however that Peterson and Eckstein (2012) also found no evidence for a fixation bias toward the face center: In all tasks (including sex categorization), they never observed participants fixating preferentially either the geometrical center of the face or the global center of the (invisible) head or the center of the screen. Another difference between our and Bindemann and colleagues' study which might contribute to differing findings is that faces in our study were presented at the center of the screen (and fixation crosses in the four quadrants, randomly), whereas Bindemann and colleagues showed faces randomly in one of the four screen quadrants (following a central fixation cross). One might thus argue that our participants, unlike the observers in Bindemann's study, were able to anticipate the location of, for example, the eyes before a face stimulus appeared. We do however think that this is an advantage of our design: Since participants knew approximately where to expect the main face features, they were able to already aim for a more or less specific location, instead of just aiming for the center of the stimulus. We think, therefore, that presenting faces in a random screen quadrant might have triggered fixations to the faces' center in the Bindemann study, as participants with their first fixation needed to make sure to look at the face rather than already exploring the face's content.

By showing that absolute spatial fixation positions (relative to the geometric center of the face) varied highly between face orientations, we go beyond the findings from Hsiao and Cottrell (2009) as well as from Peterson and Eckstein (2012). Using three different viewpoints in this study allows us to conclude that observers first look at facial features, which simply happen to largely overlap with the geometrical center of the face in frontal views. Also note that in our study, a separate analysis of all fixations during the entire viewing time of 3 s was congruent with the analysis of first fixations. This finding stands again in contrast to what has been observed by Bindemann, Scheepers, and Burton (2009): They found that fixations were directed to specific facial features only *after* the initial (central) fixation. As described above, differences between task and stimulus presentation might be the main reason for the diverging results. There are however also some methodological differences: Bindemann and colleagues' definition of first fixation was restricted to a time window from 0 to 250 ms. Moreover, our face stimuli were close to their natural size and they were shown at a normal distance for a conversational setting. One could imagine that using faces covering a smaller visual angle might first trigger a more global fixation-to-the-center strategy, rather than the inspection of specific features. Despite these differences, it is worth noting that our and Bindemann and colleagues' study show similar distributions of subsequent fixations, more specifically, most fixations were located next to the innermost eye in all face orientations.

Our findings regarding Caucasian observers' fixation patterns agree with previous studies that focused on general differences between fixation patterns of Asian and Caucasian observers (Blais et al., 2008 for triangular patterns in Caucasians; Chua, Boland, & Nisbett, 2005; Kelly, Miellet, & Caldara, 2010 for fixation of prominent features in artificial stimuli & scenes). One limitation of this study is that it is restricted to Caucasian observers. It remains for future studies to investigate whether Asian observers show the same or different fixations patterns depending on face orientation. As a side effect of presenting faces in different orientations, we also found that fixation distribution across features changed according to *face orientation*. These changes largely follow the changes in sizes of AOIs: For example, observers fixated the eye region less in profile views, in which only one eye is visible in contrast to frontal and half-profile views in which both eyes are visible. Nonetheless, changes in AOI size cannot fully explain our findings, as the overall distribution of fixations clearly reflects features' relevance rather than their size. Even though the eyes were less often looked at in profile views, they still remained the relatively most often looked at feature. We will therefore not discuss these findings in detail but focus on our second major research question, i.e. how fixations change according to face race.

4.2. Face race matters: different fixation patterns on own- and other-race faces

Until now, the evidence for differences in fixation behavior for own- and other-race faces has been mixed. Several previous studies have brought to light differences in fixation distributions for own- and other-race faces during face learning as well as subsequent face recognition tasks (Fu et al., 2012; Goldinger, He, & Papesh, 2009). Our data obtained with European observers clearly confirms these findings and extends them into the realm of face race categorization. In accordance with the report by Goldinger, He, and Papesh (2009), we found that, when comparing own- and other-race faces, observers fixated the eyes more often in own-race than other-race faces, whereas they fixated the nose more frequently in other-race compared to own-race faces, and that there was no effect of *face race* on fixations to the face outline.

Developmental studies have shown that *face race* effects already emerge in early infancy. Wheeler et al. (2011) have found that 6–10 month old infants fixated the eyes of own-race faces more than the eyes of other-race faces and that this difference in fixation behavior increased with age. This finding fits well with our results showing that adults also fixated the eyes of own-race faces more frequently than the eyes of other-race faces. Wheeler et al. (2011) also found *face race* effects for the mouth (similar to Goldinger, He, & Papesh, 2009), with infants fixating the mouth more in own-race faces than in other-race faces. Our results suggest that a *face race* effect only emerges when the overall amount of fixations dedicated to a distinct feature is sufficient. Probably, the relevance for the task (face learning and recognition) and thus the percentage of fixations to the mouth in the Goldinger study was higher than in ours. Similarly, the usage of video clips in a free viewing paradigm rather than still pictures in Wheeler and colleagues study may account for a higher percentage of mouth fixations.

In contrast to our results and to those of the studies mentioned above, there is another line of research that has not reported any differences between fixation patterns on own- and other-race faces (Blais et al., 2008; Kelly et al., 2011). Note however that these studies have mainly focused on differences in fixation behavior between Asian and Caucasian observers, i.e. on feature-directed fixation patterns in Caucasians and center-directed fixation patterns in Asians. They did not intend to profoundly investigate differences between own- and other-race face stimuli within one ethnic and cultural group of participants. What is more, in the two studies of Blais et al. (2008) and Kelly et al. (2011) faces were standardized with regard to hair, eye and mouth position, as well as luminance and size. Unlike these authors, we kept natural individual variations of size and luminance (lighting conditions were standardized) and individual second-order organization of facial features to maintain most natural cues observers might use for race categorization. Hair however was cropped in our stimuli as is usual in most studies on face perception. Interestingly and importantly, in the face categorization task in the study of Blais and colleagues (where the authors focused on the comparison between groups of observers), a difference between fixation patterns in Asian compared to Caucasian faces for Western observers is in fact visible but not reported (see Blais et al., 2008; Fig. 3): Consistent with our *face race* effects described above, their figure reveals that when comparing fixation patterns for own- and other-race faces, Caucasian observers looked at the eyes more often in own-race faces and more at the nose in other-race faces.

In line with other results suggesting that discrete feature information, as opposed to more global information, is used for race categorization (Zhao & Bentin, 2011), as well as for learning and recognizing faces (Henderson, Williams, & Falk, 2005), effects of *face race* did not result in a general change of *spatial* fixation position, i.e. differences in fixations toward the face center. Rather we observed a change of fixation distribution across features. The nose for example was always fixated more in Asian than in Caucasian faces despite the fact that it was located at the center in frontal views and completely on the left or right side of the face in profile views. Only when looking at the fixation pattern across the entire viewing time (3 s), we found that differences between the proportion of fixations for Asian and Caucasian faces partially depended on face orientation. For all fixations, the face race effects on eye and cheek fixations vanished in profile views. Moreover this change in fixation behavior according to *face race* may not be attributed to the fact that features differed systematically between face races in their task-relevant information content: Looking at the same feature in faces of both races would have been an ideal strategy to categorize them by race. Our results emphasize a general tendency of European observers to look at different features in own- vs. other-race faces, irrespective of whether this diverging fixation distribution is task-appropriate. It will be interesting to investigate the differences between Asian and Caucasian observers' fixation strategies, using our paradigm, in view of the differences in fixation patterns between these two groups reported in numerous earlier studies (Blais et al., 2008; Chua, Boland, & Nisbett, 2005; Kelly, Miellet, & Caldara, 2010; Kelly et al., 2011; Miellet et al., 2013).

4.3. Conclusions

In this study we showed that eye movements made in order to gather visual information for a race categorization task differ for own- and other-race faces in European observers. Further, these *face race* effects are based on fixations to distinct facial features, not on differences in fixations to the center of the face. From a more general perspective, our results add evidence to the notion that information from distinct features is critical for face processing, and regardless of face orientation.

Acknowledgments

Preliminary results were presented at the 36th European Conference on Visual Perception in Bremen, Germany, 2013 (Brielmann, Bülthoff & Armann, 2013). We gratefully acknowledge the support of the Max Planck Society.

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