The neural signature of the own-race bias: Evidence from event-related potentials

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Abstract

Participants are more accurate at remembering faces of their own relative to another ethnic group (own-race bias, ORB). This phenomenon has been explained by reduced perceptual expertise, or alternatively, by the categorization of other-race faces into social out-groups and reduced effort to individuate such faces. We examined event-related potential (ERP) correlates of the ORB, testing recognition memory for Asian and Caucasian faces in Caucasian and Asian participants. Both groups demonstrated a significant ORB in recognition memory. ERPs revealed more negative N170 amplitudes for other-race faces in both groups, probably reflecting more effortful structural encoding. Importantly, the ethnicity effect in left-hemispheric N170 during learning correlated significantly with the behavioral ORB. Similarly, in the subsequent N250, both groups demonstrated more negative amplitudes for other-race faces, and during test phases this effect correlated significantly with the ORB. We suggest that ethnicity effects in the N170 reflect an early categorization of other-race faces into a social out-group, resulting in less efficient encoding and thus decreased memory. Moreover, ethnicity effects in the N250 may represent the “tagging” of other-race faces as perceptually salient, which hampers the recognition of these faces.

KEYWORDS: Faces, N170, N250, Ethnicity, Recognition

Introduction

Although humans are often considered to be experts in recognizing faces, such expertise is not equally prominent for different classes of faces. Thus, it is well known that people are more accurate at remembering faces of their own relative to another ethnic group (Malpass and Kravitz 1969; Meissner and Brigham 2001). This so-called own-race bias (ORB) has been suggested to result from differences in perceptual expertise with own- as compared to other-race faces[1]. In support of this assumption, participants with high amounts of individuating contact towards other-race persons show a reduced ORB (Chiroro and Valentine 1995; Hancock and Rhodes 2008), and children raised in an other-race context (such as Asian adoptees raised in Europe) show either no or even reversed memory biases (Sangrigoli et al. 2005; de Heering et al. 2010). Similarly, training participants to individuate other-race faces increases their ability to recognize these faces (Tanaka and Pierce 2009).

A number of different theoretical accounts have been suggested to explain the ORB (for a review, see Meissner and Brigham 2001). Contact- or expertise-based explanations of the ORB can be broadly divided into two subclasses. First, facial expertise is often assumed to depend on the processing of metric distances between facial features (so-called second-order configural processing) and on merging these individual features into a holistic representation (see e.g., Maurer et al. 2002). It has been suggested that such configural and/or holistic *processing* of other-race faces is reduced (Rhodes et al. 1989; Tanaka et al. 2004; Michel et al. 2006; Bukach et al. 2012), which may in turn result in less accurate recognition memory. Second, it has been suggested that other-race faces are *represented* less accurately in memory. The multidimensional face space (MDFS) model (Valentine 1991) assumes that faces are coded on multiple dimensions, which are optimized to discriminate between individual faces, and which evolve through perceptual learning. Since most people have more contact to own-

[1] Please note that the term “race” is exclusively used to refer to visually distinct ethnic groups.

race faces, the face space's dimensions are optimized to represent own-race but not other-race faces (Valentine and Endo 1992), which are therefore clustered more densely in MDFS (for empirical evidence, see e.g., Byatt and Rhodes 2004). These less distinctive representations are in turn suggested to lead to weaker memory for other-race faces. Although the two expertise-based accounts are not mutually exclusive, they originate from different lines of research and have been presented as independent mechanisms.

Alternatively, socio-cognitive accounts suggest that the ORB is based on perceived social "in-" or "out-group" status of the presented faces rather than perceptual expertise (Sporer 2001; Hugenberg et al. 2010). Accordingly, an early categorization of a presented face as belonging to an ethnic "out-group" on the basis of an out-group-defining feature (such as skin tone or eye shape; see Levin 2000) may result in impaired processing and reduced motivation to individuate other-race faces (Hugenberg et al., 2010; but see Rhodes et al. 2010). Importantly, socio-cognitive accounts assume that an initial "in-group/out-group" categorization precedes in-depth perceptual analysis of the faces.

The analysis of event-related brain potentials (ERPs) represents a viable option to further investigate predictions that can be derived from these models. Several previous ERP studies examined the processing of own- and other-race faces. Many of these studies focused on the N170 (Bentin et al. 1996), a face-sensitive component presumably related to early structural encoding (Eimer 2011) and face detection (Schweinberger and Burton 2003), and reported more negative amplitudes for other- relative to own-race faces (Herrmann et al. 2007; Gajewski et al. 2008; Walker et al. 2008; Caharel et al. 2011; Wiese 2012). Similarly, the positive counterpart of the N170, the Vertex Positive Potential (VPP; Jeffreys 1989; Joyce and Rossion 2005) or P200 as it is sometimes called, has been described to be larger for other- as compared to own-race faces (Ito and Urland 2003, 2005; Kubota and Ito 2007; Ito and Bartholow 2009). As a limitation, it has to be noted that most of these studies examined only one group of Caucasian participants, and other studies did not find corresponding effects in

N170 (Caldara et al. 2004; Wiese et al. 2009; Herzmann et al. 2011). Accordingly, it has been argued that differences in low-level stimulus characteristics (such as luminance or contrast) rather than ethnicity per se drive such effects (Vizioli, Foreman et al. 2010; Vizioli, Rousselet et al. 2010).

Subsequent to N170, the occipito-temporal P2 has been shown to be more positive for own- as compared to other-race faces (Stahl et al. 2010). Importantly, this P2 ethnicity effect is significantly reduced in participants with substantial expertise with other-race faces (Stahl et al. 2008). P2 has also been shown to be larger for own- versus other-age faces in young participants (Wiese et al. 2008; Wiese 2012; Wiese et al. in press), and for veridical versus spatially caricatured faces (Kaufmann and Schweinberger 2012), and may thus reflect the perceived typicality of a given face. P2 has also been associated with so-called second-order configural processing, i.e., with the analysis of metric distances between facial features (Latinus and Taylor 2006). A subsequent negative-going component, the N250, has been observed to be larger for other- relative to own-race faces (Stahl *et al.* 2010). However, N250 is also known to reflect processes of face learning (Tanaka et al. 2006; Kaufmann et al. 2009). In a training study by Tanaka and Pierce (2009), the N250 was increased by individuation, but not categorization training of other-race faces. This finding suggests a direct relation between the ORB, which is reduced with increasing expertise, and neural activity in the N250 time range.

While previous ERP studies on own- versus other-race face processing mostly focused on relatively early visual components, several more recent studies also examined memory-related effects. Two recent reports observed the Dm effect, reflecting larger amplitudes during learning for those items, which are subsequently remembered as compared to those, which are subsequently forgotten, to differentiate between own- and other-race faces (Herzmann *et al.* 2011; Lucas et al. 2011). Moreover, the centro-parietal ERP old/new effect, reflecting more positive amplitudes for correctly recognized as compared to new items at test, has been shown to be larger for own- as compared to other-race faces (Stahl *et al.* 2010; Herzmann *et al.* 2011; Wiese 2012), which is generally in line with research demonstrating larger old/new effects for stimuli of expertise (Herzmann and Curran 2011).

Although a number of studies examined ERP correlates of own- versus other-race face processing, direct correlates with the behavioral ORB in recognition memory have not yet been reported. Such correlations, however, would be particularly informative for theoretical accounts of the ORB. First, since socio-cognitive accounts suggest an early categorization mechanism during learning to underlie the effect, an ERP component that both reflects early face processing and is sensitive to facial ethnicity (such as the N170) may be predicted to correlate with the memory biases. Second, if differential processing of second-order configurations during learning were important for the ORB, as suggested by configural processing accounts, and if P2 reflected such analyses of metric distances between facial features, one might expect the ethnicity effect in the P2 to correlate with the memory bias at test. Third, since training perceptual expertise with other-race faces has been shown to affect the N250, an expertise-based account would suggest differences in N250 between own- and other-race faces to predict the own-race bias. Moreover, since repetition-related ERP effects in this time range (i.e., the so-called N250r) are known to reflect accessing perceptual representations of familiar faces (Schweinberger et al. 2002), *representational* accounts might suggest that N250 ethnicity effects may be particularly important at test (when incoming stimuli have to be compared with representations from the learning phase) rather than study.

Importantly, however, the establishment of the sensitivity of these various ERP effects to own- versus other-race faces (rather than to low-level visual differences between faces of different races) represents an important prerequisite for an unambiguous interpretation of the predicted correlations. The demonstration of crossover interactions between stimulus and participants' ethnic group (as opposed to main effects of face ethnicity in a given group of participants) represents a viable solution to this problem. The present study thus examined

ERP correlates of own- and other-race face processing in both Asian and Caucasian participants during learning and test phases of a recognition memory experiment.

Methods

Participants

20 Asian (17 Chinese, 2 South Korean, 1 Japanese; 14 female, mean age = 24 y. +/- 2.3 SD) and 20 Caucasian participants (all German; 13 female, mean age = 24 y. +/- 2.9 SD) were tested. Asian participants had been living in Germany for 22 months on average (range 6 to 60 months). None of the Caucasian participants had lived in an Asian country. All participants were right-handed according to a modified version of the Edinburgh Handedness Inventory (Oldfield 1971), reported normal or corrected to normal vision, and received course credit or a monetary reward of 5€/h for partaking. All participants provided written informed consent.

Stimuli

Stimuli consisted of 120 unfamiliar Caucasian and 120 unfamiliar Asian faces (50% female respectively). Although the exact nationality of the depicted persons is not known, the stimuli were categorized as Asian or Caucasian with near-ceiling accuracies, and were rated as being highly typical with respect to ethnic group (see below). All stimuli depicted front-view faces with neutral expression, the majority of which were taken from the CAL/PAL database (Minear and Park 2004). Faces were converted to grey-scale, cut out, pasted in front of a black background, and framed within an area of 170 x 216 pixel, corresponding to a viewing angle of 3.8° x 4.8° at a viewing distance of 90 cm.

Experimental design and procedure

Participants were seated in an electrically shielded, sound-attenuated, and dimly lit cabin (400 A-CT-Special, Industrial Acoustics, Niederkrüchten, Germany) with their heads in a chin rest at 90 cm distance from the computer screen. Each trial started with a fixation cross for 500 ms, followed by a face stimulus for various durations (see below), and a final blank screen for 500 ms. Participants had to respond via button presses within 2000 ms after stimulus onset.

The experiment consisted of six blocks, each divided into a learning and a test phase. During learning, ten Asian and ten Caucasian faces, 50% female respectively, were presented for 5 s each. The task was to decide whether the current face was Asian or Caucasian. Participants were additionally instructed to memorize the faces. Learning and test phases were separated by a fixed break of 30 s. During test the 20 faces from the directly preceding learning phase were presented, randomly intermixed with 20 new faces (again 50% Asian, 50% female). Each face was presented for 2 s, and participants were asked to decide whether or not the current face had been presented in the directly preceding learning phase. Key assignment and allocation of stimuli to learned versus non-learned conditions were counterbalanced across participants.

Responses from the test phases were sorted into four conditions for Asian and Caucasian faces respectively: hits (correctly identified learned faces), misses (learned faces wrongly classified as new), correct rejections (CR, new faces correctly identified as new), and false alarms (new faces wrongly classified as learned). Signal detection measures of sensitivity (d', see e.g., Macmillan and Creelman 1991) were calculated. For correlational analyses, the following memory bias score was calculated: Memory bias = (d’[Asian face] – d’[Caucasian faces]) / (d’[Asian faces] + d’[Caucasian faces]). Note that positive values reflect biases towards Asian faces, whereas negative values represent biases towards Caucasian faces.

After the main experiment, all face stimuli were presented again in random order. Participants were asked to rate the faces with respect to ethnic typicality on a 6-point scale (ranging from 1 = not at all typically Asian/Caucasian, to 6 = highly typically Asian/Caucasian) via key presses. Stimuli remained on the screen until a key was pressed, but participants were asked to respond spontaneously. Finally, all participants completed a questionnaire to estimate quantity (measured in h/week and number of contact persons) and quality of contact towards own- and other-race persons (for a detailed description, see Wiese 2012).

EEG recording and analysis

32-channel EEG was recorded using a BioSemi Active II system (BioSemi, Amsterdam, Netherlands). Recording sites corresponded to Fz, Cz, Pz, Iz, FP1, FP2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, F9, F10, FT9, FT10, TP9, TP10, P9, P10, PO9, PO10, I1, and I2. EEG was recorded continuously with a 512 Hz sample rate from DC to 155 Hz. Note that BioSemi systems work with a "zero-Ref" setup with ground and reference electrodes replaced by a so-called CMS/DRL circuit (for further information, see www.biosemi.com/faq/cms&drl.htm).

Contributions of blink artefacts were corrected using BESA 5.18. EEG was segmented from -200 to 1000 ms relative to stimulus onset, with the first 200 ms as baseline. Trials with non-ocular artefacts and saccades were rejected from further analysis using the BESA 5.18 tool with an amplitude threshold of 100 µV and a gradient threshold of 50 µV. Remaining trials were recalculated to average reference, digitally low-pass filtered at 40 Hz (12 db/oct, zero phase shift), and averaged according to experimental conditions of the learning (Asian faces, Caucasian faces) and test phases (hits – Asian faces, CR – Asian faces, hits – Caucasian faces, CR – Caucasian faces) for Asian and Caucasian participants separately. An inclusion criterion of at least 16 trials per condition for each participant was applied.

In the resulting test phase waveforms, mean amplitudes for P1 (100 – 130 ms relative to stimulus onset at O1 and O2), N170 (150 - 190 ms at P9/PO9/P10/PO10), occipito-temporal P2 (210 - 280 ms at P9/PO9/P10/PO10), and N250 (280 – 400 ms at P9/PO9/P10/PO10) were calculated. Statistical analyses were performed by calculating mixed-model ANOVAs.

Results

Performance

Mean accuracies for the categorization task during learning in Asian participants were .985 (+/- 0.019 *SD*) for Asian faces and .986 (+/- 0.026 *SD*) for Caucasian faces. Mean accuracies in Caucasian participants were .980 (+/- 0.028 *SD*) for Asian faces and .975 (+/- 0.037 *SD*) for Caucasian faces. A mixed-model ANOVA with the within-subjects factor "face ethnicity" (Asian vs. Caucasian faces) and the between-subjects factor "group" (Asian vs. Caucasian participants) yielded no significant effects (all $p > .05$). Mean categorization RT in Asian participants was 888.92 ms (+/- 237.91 *SD*) for Asian faces and 899.72 ms (+/- 251.28 *SD*) for Caucasian faces. In Caucasian participants, corresponding mean RT was 749.52 ms (+/- 184.96 *SD*) for Asian faces and 762.52 ms (+/- 196.72 *SD*) for Caucasian faces. A mixed-model ANOVA revealed a trend for faster RT in Caucasian relative to Asian participants ($F[1,38] = 4.079$, $p = .051$, $\eta^2_p = .097$). No additional effects reached significance (all $p > .05$).

Behavioral results from the test phase (hits, misses, false alarms and correct rejections for Asian and Caucasian faces) are reported in Table 1. A mixed-model ANOVA on d' yielded a significant interaction ($F[1,38] = 42.201$, $p < .001$, $\eta^2_p = .526$; see Figure 1). Post-hoc t-tests revealed significantly more accurate memory for own- as compared to other-race faces in both Caucasian ($t[19] = 6.455$, $p < .001$, $d = 0.935$) and Asian participants ($t[19] =$

2.864, $p = .010$, $d = 0.475$). At the same time, comparison of d' scores between participant groups revealed significantly more accurate memory for Asian faces in Asian relative to Caucasian participants ($t[38] = 3.124$, $p = .003$, $d = 0.988$), but no significant difference between groups with respect to d' for Caucasian faces ($t[38] = 1.429$, $p = .161$, $d = 0.438$). Overall, while a significant own-race bias was detected in both groups, the effect was larger in Caucasian participants.[2]

- Enter Table 1 and Figure 1 about here -

To test for a potential influence of the relatively smaller homogeneity with respect to the nationality of the participants within the Asian relative to the Caucasian group, we calculated d' scores for Chinese participants only (N=17). The resulting measures were compared to those from a subgroup of 17 randomly chosen Caucasian participants in a mixed-model ANOVA. This analysis revealed a significant interaction of "face ethnicity x participant group" ($F[1,32] = 35.027$, $p < .001$, $\eta^2_p = .523$), with more accurate memory for own-race faces in both Asian ($t[16] = 2.848$, $p = .012$, $d = 0.551$) and Caucasian participants ($t[16] = 5.613$, $p < .001$, $d = 0.990$). Moreover, memory for Asian faces was more accurate in Asian relative to Caucasian participants ($t[32] = 3.214$, $p = .003$, $d = 1.102$), while no significant difference between groups was detected for Caucasian faces ($t[32] = 1.318$, $p = .197$, $d = 0.452$). In sum, these results are highly similar to those reported in the previous paragraph.

[2] A mixed-model ANOVA on d' with the additional within-subjects factor "face gender" and the additional between-subjects factor "participant gender" also revealed a significant interaction of "participant ethnicity x face gender" ($F[1,36] = 4.981$, $p = .032$, $\eta^2_p = .122$), with more accurate recognition memory for female as compared to male faces in Asian ($F[1,18] = 9.352$, $p = .007$, $\eta^2_p = .342$), but not in Caucasian participants ($F < 1$). However, this latter effect did not interact with the own-race bias. Please note, that we did not focus on the analysis of gender effects in the present design as this would have required impractically large group sizes, and consequently these results should be regarded as preliminary at best.

Ratings after the main experiment revealed high and consistent mean ethnic typicality measures for both Asian faces (Asian participants: 5.53 +/- 0.40 *SD*; Caucasian participants: 5.19 +/- 0.60 *SD*) and Caucasian faces (Asian participants: 5.31 +/- 0.62 *SD*; Caucasian participants: 4.90 +/- 1.05 *SD*). A mixed-model ANOVA yielded only a trend towards higher ethnic typicality ratings for Asian as compared to Caucasian faces ($F[1,38] = 3.950$, $p = .054$, $\eta^2_p = .094$), as well as a trend towards higher ratings given by Asian relative to Caucasian participants overall ($F[1,38] = 2.975$, $p = .093$, $\eta^2_p = .073$). The interaction was not significant ($F < 1$).

Contact measures

Self-reported amount of contact in h/week was analyzed using a mixed-model ANOVA with the within-subjects factor “contact person’s ethnicity” (Asian vs. Caucasian) and the between-subjects factor “group”, which yielded a significant interaction ($F[1,38] = 38.066$, $p < .001$, $\eta^2_p = .500$). Post-hoc tests revealed significantly more contact towards own-race relative to other-race people in Caucasian ($t[19] = 7.763$, $p < .001$, $d = 2.106$), but not Asian participants ($t[19] = 1.275$, $p = .218$, $d = 0.250$). A corresponding analysis for self-reported contact as measured in numbers of contact persons revealed a significant interaction ($F[1,38] = 5.508$, $p = .024$, $\eta^2_p = .127$), and post-hoc tests yielded significantly higher numbers of own- as compared to other-race contact persons in Caucasian ($t[19] = 5.621$, $p < .001$, $d = 1.591$), but not Asian participants ($t[19] = 1.161$, $p = .260$, $d = 0.375$). Finally, an ANOVA on self-reported quality of contact again revealed a significant interaction ($F[1,38] = 74.697$, $p < .001$, $\eta^2_p = .669$), reflecting more intense contact towards own-race persons in both Asian ($t[19] = 3.596$, $p = .002$, $d = 1.147$) and Caucasian participants ($t[19] = 8.752$, $p < .001$, $d = 3.222$).

Across both participant groups, the memory bias score correlated significantly with both the difference in amount of contact towards Asian versus Caucasian persons (in h/week;

Pearson correlation; $r = .498$) and the difference in quality of contact towards Asian versus Caucasian people ($r = .673$), thus suggesting a stronger memory bias towards Asian faces with increasing amount and quality of contact towards Asian people and a stronger memory bias towards Caucasian faces with increasing amount and quality of contact towards Caucasian people (see figure 2).

- Enter Figure 2 about here -

Event-related potentials

The mean numbers of trials contributing to an individual averaged ERP in the study phase were 57.3 (+/- 2.5 *SD*) and 57.5 (+/- 2.5 *SD*) for Asian and Caucasian faces in Asian participants, and 57.4 (+/- 2.7 *SD*) and 57.4 (+/- 2.3 *SD*) in Caucasian participants, respectively. In the test phase, the respective numbers for Asian and Caucasian faces were 45.5 (+/- 7.1 *SD*) and 39.1 (+/- 8.9 *SD;* Asian participants, hits), 47.6 (+/- 11.0 *SD*) and 49.9 (+/- 7.5 *SD*; Asian participants, correct rejections), 40.7 (+/- 10.3 *SD*) and 44.5 (+/- 7.3 *SD*; Caucasian participants, hits), and 42.9 (+/- 8.2 *SD*) and 49.8 (+/- 7.0 *SD*; Caucasian participants, correct rejections).

In the following paragraphs, main effects of "group", "hemisphere", or "site", as well as interactions containing only these factors are not reported in the interest of economy of presentation. For the same reason, main effects and interactions are not described when all constituting factors were further qualified in higher-order interactions. Full information about all omnibus ANOVAs carried out during ERP analysis are provided in Supplementary Table 1. Learning and test phase ERPs are depicted in figure 3, effects of response type at test are presented in figure 4.

- Enter Figures 3 and 4 about here -

P1. A mixed-model ANOVA on P1 amplitude at O1/O2 during learning, with the within-subjects factors “hemisphere” (left vs. right) and “face ethnicity”, and the between-subjects factor “group” yielded no significant effects of interest. Similarly, a corresponding repeated-measures ANOVA on P1 amplitude at test with the additional within-subjects factor “response type” (hits, correct rejections) revealed no significant effects of interest (all $p > .05$).

N170. A mixed-model ANOVA on N170 amplitude during learning with the additional factor “site” (PO9/PO10 vs. P9/P10) yielded significant interactions of “site x face ethnicity” ($F[1,38] = 5.773$, $p = .021$, $\eta^2_p = .132$), reflecting larger effects of face race at more anterior electrodes. Importantly, a significant interaction of “face ethnicity x group” ($F[1,38] = 10.763$, $p = .002$, $\eta^2_p = .221$) reflected significantly more negative N170 amplitudes for other-race faces in Asian participants ($F[1,19] = 11.651$, $p = .003$, $\eta^2_p = .380$) and a corresponding trend in Caucasian participants ($F[1,19] = 3.905$, $p = .063$, $\eta^2_p = .170$).

An ANOVA on test phase data yielded a significant main effect of “response type” ($F[1,38] = 5.626$, $p = .023$, $\eta^2_p = .129$), with more negative amplitudes for hits as compared to correct rejections, and a significant interaction of “face ethnicity x group” ($F[1,38] = 20.807$, $p < .001$, $\eta^2_p = .354$), reflecting more negative amplitudes for other-race faces in both Asian ($F[1,19] = 9.617$, $p = .006$, $\eta^2_p = .336$) and Caucasian participants ($F[1,19] = 11.672$, $p = .003$, $\eta^2_p = .381$).

P2. Analysis of learning phase P2 mean amplitudes yielded a significant interaction of “face ethnicity x group” ($F[1,38] = 13.154$, $p < .001$, $\eta^2_p = .257$), which reflected significantly more positive amplitudes for own-race relative to other-race faces in Caucasian ($F[1,19] = 17.591$, $p < .001$, $\eta^2_p = .481$) but not in Asian participants ($F<1$).

A mixed-model ANOVA on test phase P2 revealed a significant main effect of "response type" ($F[1,38] = 5.474$, $p = .025$, $\eta^2_p = .126$), with more negative amplitudes for hits as compared to correct rejections, and a significant interaction of "face ethnicity x group" ($F[1,38] = 28.816$, $p < .001$, $\eta^2_p = .431$). While Caucasian participants demonstrated significantly more positive amplitudes to own- as compared to other-race faces ($F[1,19] = 26.578$, $p < .001$, $\eta^2_p = .583$), more positive amplitudes for own-race faces were only reflected in a statistical trend in Asian participants ($F[1,19] = 4.291$, $p = .052$, $\eta^2_p = .184$).

N250. Analysis of the N250 time window during the learning phases yielded a significant interaction of "face ethnicity x group" ($F[1,38] = 60.684$, $p < .001$, $\eta^2_p = .375$), with more negative amplitudes for other-race faces in both Asian ($F[1,19] = 7.145$, $p = .015$, $\eta^2_p = .273$) and Caucasian participants ($F[1,19] = 17.266$, $p < .001$, $\eta^2_p = .476$).

During test, a significant main effect of "response type" ($F[1,38] = 10.738$, $p = .002$, $\eta^2_p = .220$) was due to more negative amplitudes for hits relative to CR. Moreover, a significant interaction of "face ethnicity x group" ($F[1,38] = 37.923$, $p < .001$, $\eta^2_p = .499$) again reflected more negative amplitudes for other-race faces in both Asian ($F[1,19] = 18.756$, $p < .001$, $\eta^2_p = .497$) and Caucasian participants ($F[1,19] = 19.217$, $p < .001$, $\eta^2_p = .503$).

Correlations between ERP ethnicity effects and the own-race bias

Correlations between the memory bias score and ERP ethnicity effects (Asian faces – Caucasian faces) were calculated for those ERP components, which had exhibited significant interactions between face ethnicity and participant group (i.e., N170, P2, N250; Pearson correlations, Bonferroni-corrected for multiple comparisons; see Table 2). During learning, a significant positive correlation between the memory bias score and N170 was detected at the left-hemispheric electrode P9, associating larger memory biases with increasing N170 amplitude differences between Asian and Caucasian faces (see left part of Figure 5). At test, significant positive correlations between the memory bias score and ERP effects of face ethnicity in the N250 time range, predominantly at right-hemispheric electrode positions, were observed (see right part of Figure 5). These effects again reflected larger memory biases to correlate with increasing differences in N250.

- Enter Table 2 and Figure 5 about here -

Discussion

The present study examined the neural basis of the ORB by analyzing ERP correlates of own- and other-race face processing in Asian and Caucasian participants. While both groups demonstrated more accurate memory for own-race faces, the ORB in Asian participants, who had been living in Germany for several months, was significantly reduced, which is consistent with previous results demonstrating an influence of other-race contact on the ORB (Chiroro and Valentine 1995; Hancock and Rhodes 2008; Rhodes et al. 2009). Similarly, members of minority ethnic groups, who have more contact to other-race persons than majority group members, typically demonstrate a decreased ORB (Meissner and Brigham 2001; but see Eberhardt 2005, for a discussion of fMRI results potentially conflicting with this finding). In the present study a significant correlation between the ORB and self-reported amount and quality of contact was observed. In direct support of a contact-based explanation of the ORB, those participants with increased and more intense contact towards other-race people demonstrated smaller memory biases towards their own ethnic group.

The present results in the N170 time range complement previous reports of increased amplitudes for other-race faces (e.g., Stahl *et al.* 2008, 2010). Critically, since most previous studies exclusively examined Caucasian participants, it has been suggested that low-level differences between images of faces from different ethnic groups rather than ethnicity per se drive this effect (Vizioli, Foreman *et al.* 2010). The present results clearly contradict this interpretation, since both Asian and Caucasian participants demonstrated increased N170 amplitudes for the respective other-race faces. As a qualification, N170 ethnicity effects may not be independent of experimental context. In fact, using stimuli from a highly similar set as in the present study, we observed no difference in N170 in an orientation task with upright and inverted faces (Wiese *et al.* 2009). Importantly, in that study own- and other-race faces were presented in the context of images that did not depict human faces (i.e. ape faces and houses), presumably making the distinction between own- and other-race faces perceptually less salient. Thus, while ethnicity effects in N170 clearly do not exclusively reflect low-level differences between images, perceptual salience of facial ethnicity in a given experimental context may influence the effect (see also Caharel *et al.* 2011; Ofan et al. 2011).

The present results further extend our earlier findings on the occipito-temporal P2, which was previously observed to be larger for own- relative to other-race faces (Stahl *et al.* 2008, 2010). Similarly, a larger P2 was observed for young as compared to old faces in young participants (Wiese *et al.* 2008; Wiese 2012; Wiese *et al.* in press) and for veridical relative to spatially caricatured faces (Kaufmann and Schweinberger 2012). P2 has thus been suggested to reflect the typicality of a face relative to a prototype, with those faces which deviate from this prototype (such as other-race, other-age, or caricatured faces) eliciting smaller amplitudes (Schulz et al. 2012). Interestingly, the P2 difference between own- and other-race faces has previously been found to be significantly reduced in Caucasian participants with substantial expertise for Asian faces (Stahl *et al.* 2008). Similarly, in the present study, the P2 ethnicity effect was reduced in Asian participants, who reported similar amounts of contact towards Caucasian and Asian people and have thus likely developed considerable expertise with Caucasian faces.

Furthermore, more negative amplitudes for learned as compared to new faces were observed. This effect started in the N170 time range, but was most pronounced in the N250. The N250 is known to be more negative for repeated as compared to novel famous faces in immediate repetition priming experiments (N250r, see Schweinberger et al. 1995; Schweinberger *et al.* 2002), presumably reflecting the facilitated access of perceptual representations of repeated faces, and for explicitly learned as compared to novel faces (Tanaka *et al.* 2006; Kaufmann *et al.* 2009). Importantly, a recent study also demonstrated a more negative N250 for other-race faces after individuation training but not after categorization training (Tanaka and Pierce 2009). In sum, these findings indicate that processes in the N250 time range are engaged in the individualization of faces. Effects of stimulus repetition in the N250, however, were not observed to be more efficient for own- relative to other-race faces (for discrepant results from the own-age bias, see Wiese *et al.* 2008; Wiese 2012).

Crucially, the present study is the first that demonstrates direct relationships between ERP effects of face ethnicity and the ORB in recognition memory. During learning, the left-hemispheric N170 effect correlated positively with the memory bias, thus associating increasing N170 ethnicity effects with larger own-race biases. Of particular interest, a previous fMRI study demonstrated a significant correlation between the difference in left-hemispheric fusiform gyrus activation for own- versus other-race faces during learning and the later ORB in memory (Golby et al. 2001). There is some evidence suggesting that the left hemisphere is more concerned with the processing of facial features, rather than faces as a whole, or the configurations of its constituting parts (Rossion et al. 2000; Scott and Nelson 2006). If so, the present findings may indicate that those participants who tend to process other-race faces on the basis of piecemeal featural information rather than holistic or configural information during learning later demonstrate a larger own-race memory bias at test, which may be seen as being in accordance with the expertise-based processing account.

Alternatively, a correlation between the left N170 ethnicity effect during learning and the ORB in memory could also be reconciled with socio-cognitive accounts, which suggest an early categorization of other-race faces on the basis of out-group defining features to result in less accurate encoding and consequently to less accurate later recognition memory (Levin 1996, 2000). One might argue that the left-hemispheric N170 ethnicity effect reflects a neural correlate of this categorization process, and that a more pronounced N170 effect will thus result in a larger behavioral ORB. Other predictions of socio-cognitive accounts, however, are less well supported by earlier ERP results, as such theories also suggest that motivation to individualize other-race faces should affect in-group/out-group categorization (Hugenberg *et al.* 2010), and N170 ethnicity effects are not modulated by tasks that either reinforce individualization or categorization of the faces (Stahl *et al.* 2010).

It is remarkable that the occipito-temporal P2 did not correlate with the ORB, neither during learning nor at test. Thus, although the processes underlying the P2 differ for own- and other-race faces, and although this differential processing is less pronounced in our Asian “expert” group, these processes are not directly related to the ORB in recognition memory. Previous research suggested that P2 reflects the analysis of metric distances between facial features (Latinus and Taylor 2006). If so, differences in such second-order configural processing for own- and other-race faces may not contribute substantially to the ORB in memory, and differences in some aspects of perceptual processing may not necessarily result in corresponding memory effects (see also Michel *et al.* 2006). Similarly, if P2 effects reflected differences in perceived typicality, such differences may not be directly related to the ORB.

A further important finding of the present study is the significant correlation between the behavioral memory bias and the ethnicity effect in the N250 time range at test. More specifically, while memory effects in N250 did not interact with face ethnicity (see above), other-race faces generally elicited more negative amplitudes than own-race faces in this time window, and thus memory and ethnicity effects in the N250 time range appear to reflect separate processes. Interestingly, the ethnicity effect is reminiscent of a stronger early posterior negativity for emotional relative to neutral faces, which occurs at similar electrode sites and in a similar time range (Schupp et al. 2004; Schacht and Sommer 2009; Rellecke et al. 2012). This EPN effect has been interpreted as reflecting the “tagging” of particularly salient stimuli for further processing (Schupp et al. 2007). Given that the face processing system established a perceptual deviance of other-race faces from the more commonly observed own-race faces during preceding processing stages (i.e., in the P2 time range), it seems plausible to suggest that other-race faces are similarly “tagged” as perceptually salient and may thus bind processing resources to a larger extent. Crucially, in the present study, those participants who demonstrated a larger N250 ethnicity effect at test also exhibited a larger memory bias for faces of their own ethnic group. Our interpretation of this pattern is that the processes reflected in the larger negativity for other-race faces during the N250 time range *interfere* with accessing memory representations of individual faces and thus *hamper* recognition memory.

As noted above, a significant ethnicity effect, with more negative amplitudes for other-race faces was observed in the P2 time window in Caucasian but not Asian participants, whereas significantly more negative amplitudes for other-race faces were observed in both groups in the N250. This pattern of results has thus far been interpreted as reflecting the influence of facial ethnicity information on two separate ERP components and two respective underlying cognitive operations. Alternatively, ERP ethnicity effects in these two time windows may be seen as a neural correlate of a single process, which occurs later in Asian participants. While the present results cannot definitely decide between these alternative explanations, they nevertheless provide important information about the time course of neural processes directly affecting the ORB in memory, since the test phase ERP effect in the earlier

P2 time range was not correlated with the memory bias, while the ethnicity effect in the subsequent N250 was.

In conclusion, the present ERP findings suggest that the ORB is related to processes occurring during both encoding and memory retrieval. During learning, more efficient processing of own-race faces at early perceptual processing stages is reflected in the N170 ethnicity effect. In addition, the enhanced N250 for other-race faces at test may represent the “tagging” of these faces for further processing, which interferes with within-category differentiation of individual faces, and thus hampers memory retrieval. This interpretation is substantiated by the significant correlations of ethnicity effects in these ERP components with the ORB in memory, pointing to a direct relation between the processes underlying these neural markers and face memory. Our findings are consistent with theoretical accounts emphasizing the importance of perceptual processes during learning and test, as well as individual contact for face recognition memory, and for the first time demonstrate the ERP signature underlying the ORB.

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Figure captions

Figure 1. Mean d' from the test phases of the experiment, error bars denote standard errors of the mean. Please note that both groups demonstrate an ORB, which is significantly reduced for Asian participants.

Figure 2. Significant correlations between the memory bias towards Asian versus Caucasian faces and (left part) the difference in self-reported amount of contact in h/week (Asian – Caucasian faces), as well as (right part) the difference in self-reported quality of contact (Asian – Caucasian faces).

Figure 3. a) Grand mean ERPs from the study phases of the experiment. b) Grand mean ERPs from the test phases of the experiment averaged across the response factor. Vertical dashed lines depict the P2 and N250 time ranges, respectively.

Figure 4. Grand mean ERPs from the test phases of the experiment depicting effects the response factor (hits, correct rejections [CR]). Vertical dashed lines depict the N170, P2 and N250 time ranges, respectively.

Figure 4. Significant correlations between the memory bias towards Asian versus Caucasian faces and (left part) the N170 ethnicity effect (Asian – Caucasian faces) at left-hemispheric electrode P9 during study, as well as (right part) the N250 ethnicity effect (Asian – Caucasian faces) at electrode right-hemispheric electrode PO10 during test phases.

Table 1. Mean hits, miss, false alarm (FA), and correct rejection (CR) rates (and standard errors of the mean, SEM) from the test phase of the experiment. Please note that measures do not add up to 1 in all cases due to time-out trials.

		Asian Faces				Caucasian Faces			
		Hits	Misses	FA	CR	Hits	Misses	FA	CR
Asian Participants									
	M	.78	.22	.19	.80	.67	.32	.15	.84
	SEM	.03	.03	.04	.04	.03	.03	.02	.03
Caucasian Participants									
	M	.69	.30	.24	.73	.75	.24	.16	.84
	SEM	.04	.04	.03	.03	.03	.03	.03	.03

Table 2. Pearson coefficients depicting correlations between the memory bias score and ERP ethnicity effects at electrode P9/PO9/P10/PO10. Asterisks denote significant effects (corrected for multiple comparisons).

	Study Phases				Test Phases			
	P9	PO9	P10	PO10	P9	PO9	P10	PO10
N170 (Asian - Cauc.)	.52*	.25	.09	.21	.28	.40	.25	.36
P2 (Asian - Cauc.)	.42	.20	.11	.11	.27	.27	.36	.38
N250 (Asian - Cauc.)	.44	.26	.18	.32	.43	.48*	.50*	.56*

Figure 1

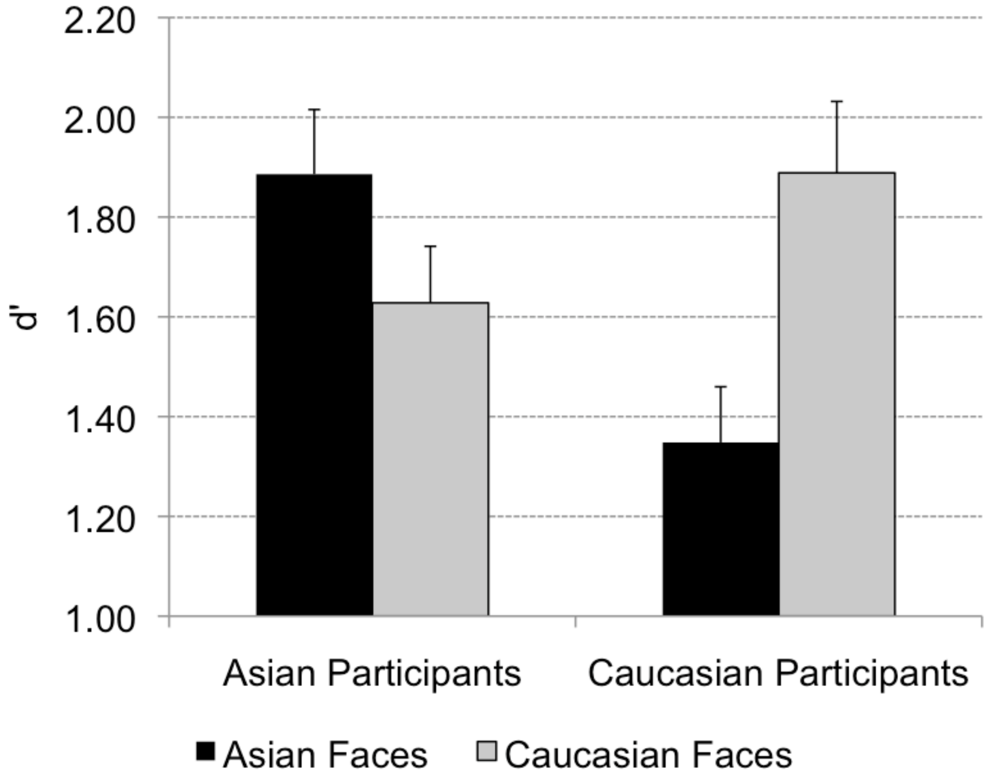

2.20
2.00
1.80
1.60
1.40
1.20
1.00
d'
Asian Participants
Caucasian Participants
Asian Faces
Caucasian Faces

Figure 2

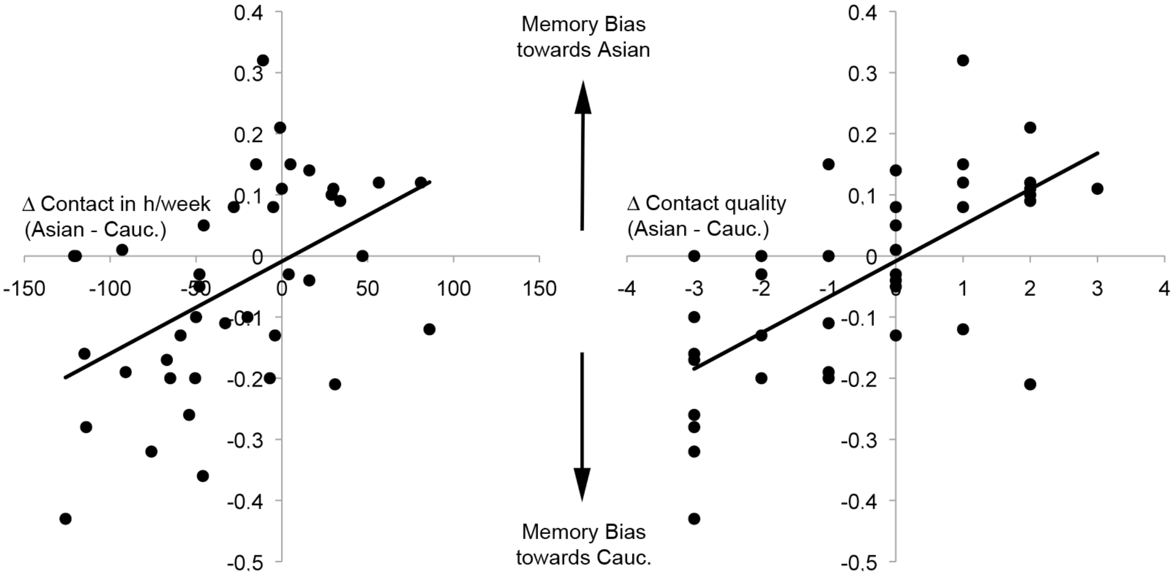

Δ Contact in h/week
(Asian - Cauc.)
Memory Bias
towards Asian
Memory Bias
towards Cauc.
Δ Contact quality
(Asian - Cauc.)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-150
-100
-50
0
50
100
150
-4
-3
-2
-1
0
1
2
3
4

Figure 3

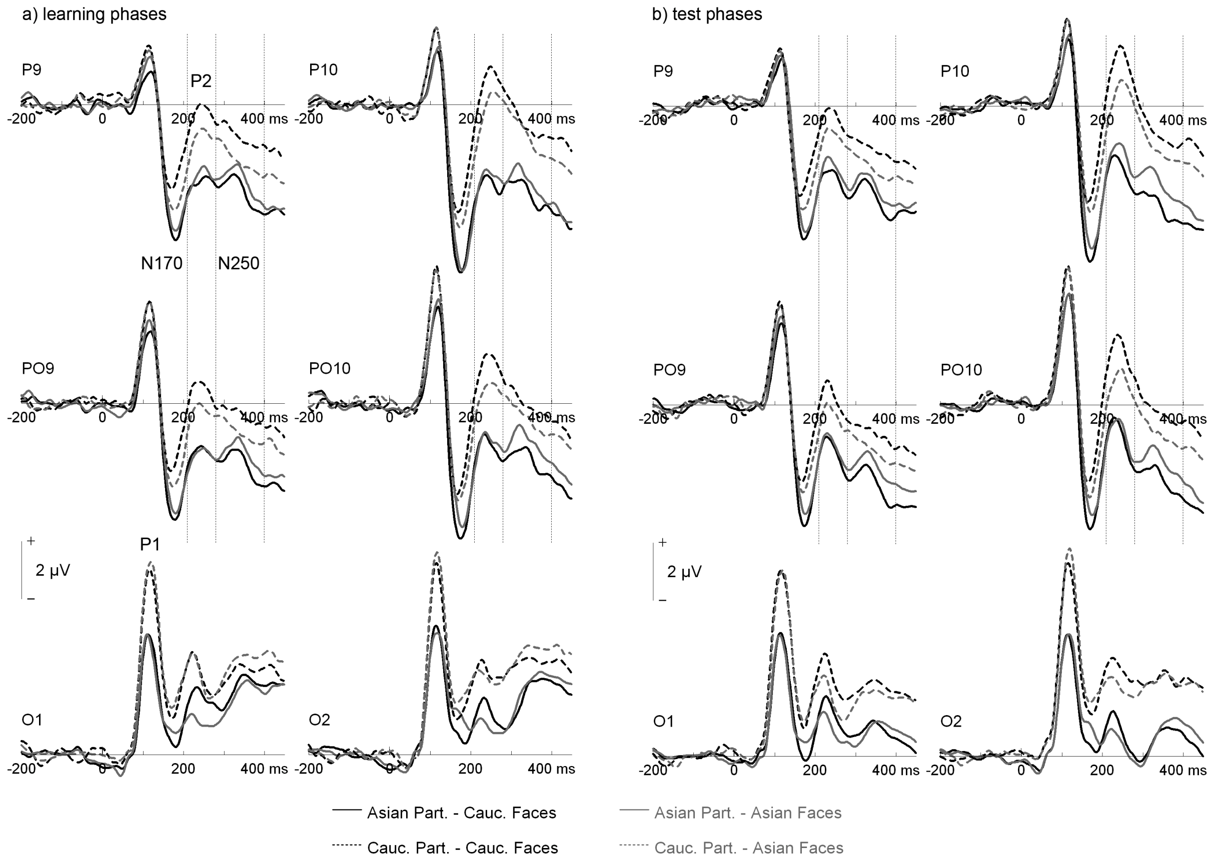

a) learning phases
b) test phases
P9
P10
PO9
PO10
O1
O2
P1
P2
N170
N250
2 µV
-200
0
200
400 ms
Asian Part. - Cauc. Faces
Asian Part. - Asian Faces
Cauc. Part. - Cauc. Faces
Cauc. Part. - Asian Faces

Figure 4

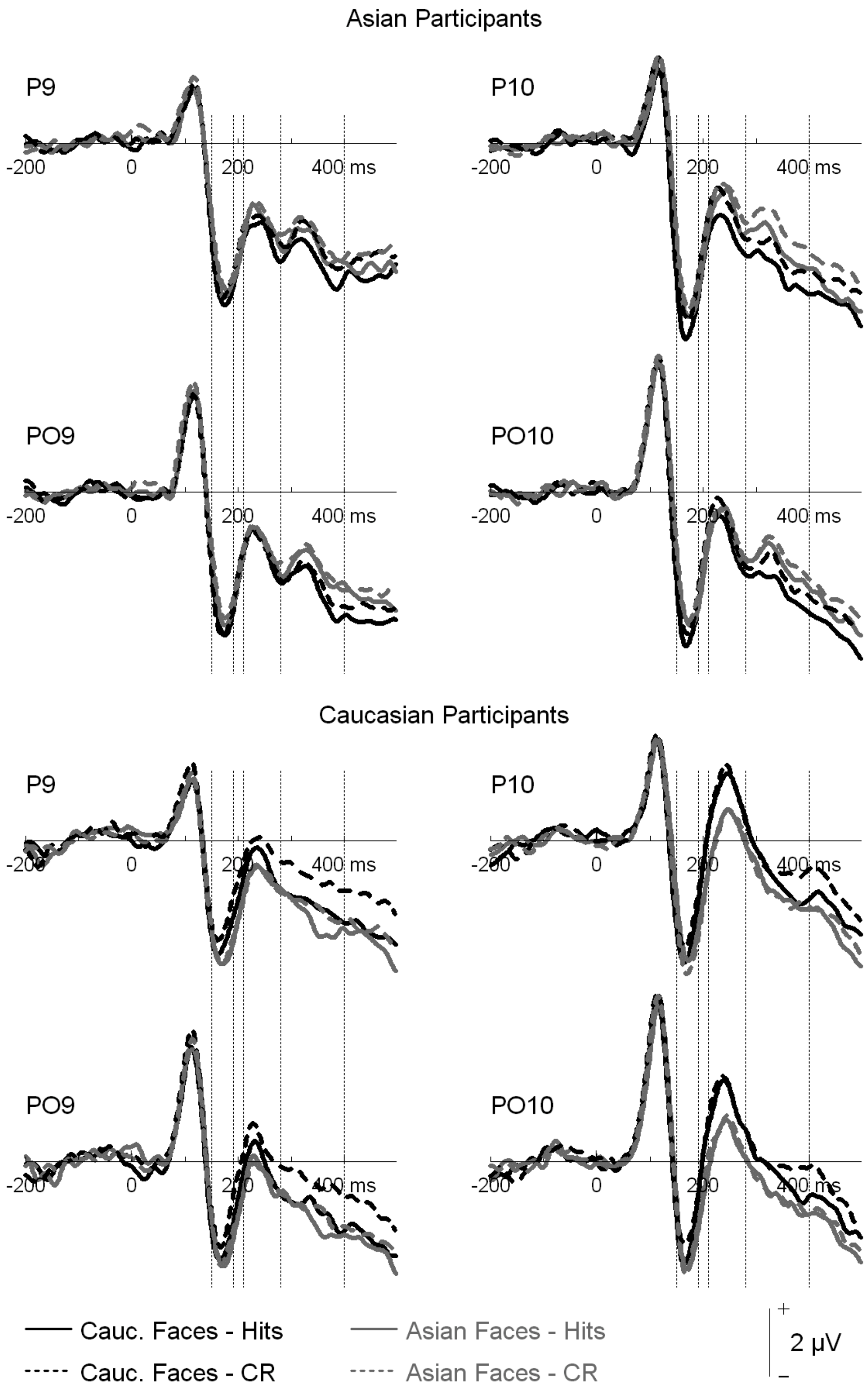
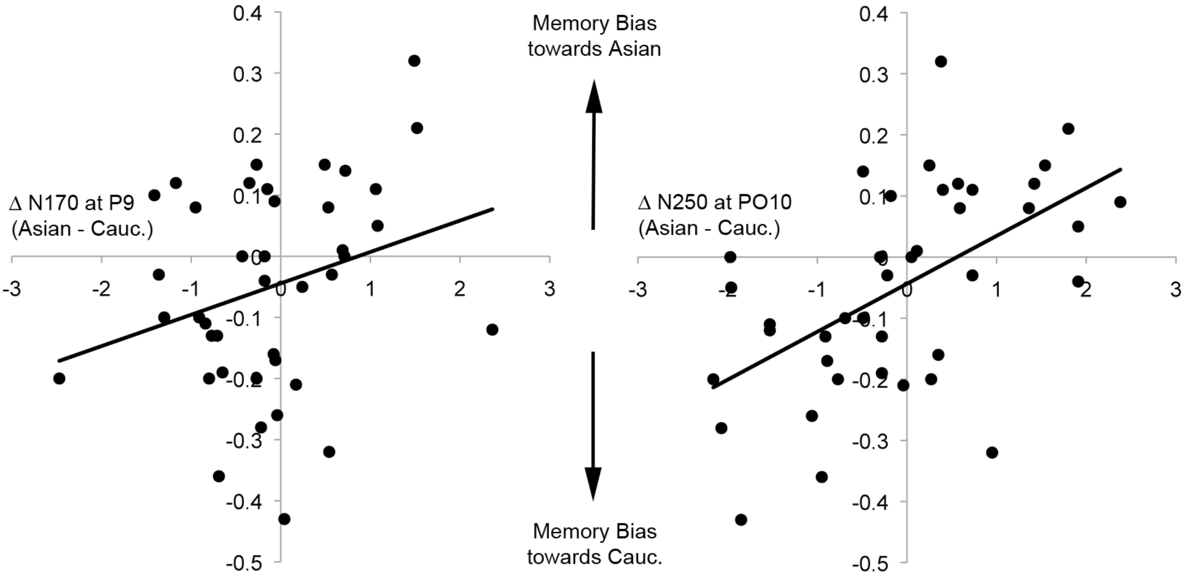

Asian Participants
P9
P10
PO9
PO10
-200
0
200
400 ms
Caucasian Participants
P9
P10
PO9
PO10
Cauc. Faces - Hits
Cauc. Faces - CR
Asian Faces - Hits
Asian Faces - CR
+
2 µV
–

Figure 5



Δ N170 at P9
(Asian - Cauc.)
Memory Bias
towards Asian
Memory Bias
towards Cauc.
Δ N250 at PO10
(Asian - Cauc.)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-3
-2
-1
0
1
2
3