Received: 28 January 2022 | Revised: 9 June 2022 | Accepted: 22 June 2022

DOI: 10.1111/psyp.14147

PSYCHOPHYSIOLOGY SPR WILEY

ORIGINAL ARTICLE

Neural sensitivity to faces is increased by immersion into a novel ethnic environment: Evidence from ERPs

Xiaoli Ma[1] | **Nick Modersitzki**[2] | **Urs Maurer**[3,4] | **Werner Sommer**[1,5]

[1]Institut für Psychologie, Humboldt-Universität zu Berlin, Berlin, Germany

[2]Abteilung Psychologie, Universität Bielefeld, Bielefeld, Germany

[3]Department of Psychology, The Chinese University of Hong Kong, Hong Kong, China

[4]Brain and Mind Institute, The Chinese University of Hong Kong, Hong Kong, China

[5]Department of Psychology, Zhejiang Normal University, Jin Hua, China

Correspondence
Xiaoli Ma and Werner Sommer, Institut für Psychologie, Humboldt-Universität zu Berlin, Rudower Chaussee 18, Berlin 12489, Germany.
Email: maxiaolq@hu-berlin.de and sommerwe@hu-berlin.de

Funding information
China Scholarship Council, Grant/Award Number: 201708330288; Deutscher Akademischer Austauschdienst, Grant/Award Number: 57447990; Germany-Hong Kong Joint Research Scheme of the Research Grants Council, Grant/Award Number: G-CUHK409/18

Abstract

Previous reports suggest that East-Asians may show larger face-elicited N170 components in the ERP as compared to Caucasian participants. Since the N170 can be modulated by perceptual expertise, such group differences may be accounted for by differential experience, for example, with logographic versus alphabetic scripts (script system hypothesis) or by exposure to abundant novel faces during the immersion into a new social and/or ethnic environment (social immersion hypothesis). We conducted experiments in Hong Kong and Berlin, recording ERPs in a series of one-back tasks, using same- and other-ethnicity face stimuli in upright and inverted orientation and doodle stimuli. In Hong Kong we tested local Chinese residents and foreign guest students who could not read the logographic script; in Berlin we tested German residents who could not read the logographic script and foreign Chinese visitors. In both experiments, we found significantly larger N170 amplitudes to faces, regardless of ethnicity, in the foreign than in the local groups. Moreover, this effect did not depend on stimulus orientation, suggesting that the N170 group differences do not reflect differences in configural visual processing. A group of short-term German residents in Berlin did not differ in N170 amplitude from long-term residents. Together, these findings indicate that the extensive confrontation with novel other-ethnicity faces during immersion in a foreign culture may enhance the neural response to faces, reflecting the short-term plasticity of the underlying neural system.

KEYWORDS
configural processing, event-related potentials, face perception, N170, social experience

1 | INTRODUCTION

How we process visual information is influenced by previous experience. Experience with certain stimulus classes improves the ability to detect, discriminate, and identify these stimuli (e.g., Sigman & Gilbert, 2000; Yi et al., 2006) – an effect termed perceptual learning, leading to perceptual expertise for certain visual objects. Arguably the most important domain of objects for which most individuals have acquired visual expertise is human faces. A robust demonstration of expertise in face perception is the disproportionally strong decrement in performance following picture-plane inversion of faces as compared to inverting other objects (Diamond & Carey, 1986; Rossion & Curran, 2010; Yin, 1969). This face inversion effect is usually explained by assuming that inversion specifically disrupts the processing of configural information (spatial relations between facial features) which is especially important for face perception (for a review see Maurer et al., 2002). Perceptual training studies demonstrated that the face inversion effect increased after training with upright faces and decreased after training with inverted faces (Ashworth et al., 2008; Hussain et al., 2009).

Valuable tools for investigating the neural correlates of face processing and perceptual expertise are the electroencephalogram (EEG) and event-related potential (ERP). ERP studies revealed a negative-going component peaking at about 170 ms after face presentation onset, termed N170 and suggested to reflect the structural encoding of faces (for reviews see Eimer, 2011; Rossion & Jacques, 2011). More specifically, the N170 is considered to index configural processing (Eimer et al., 2011; Sagiv & Bentin, 2001; Zion-Golumbic & Bentin, 2007), most prominently evidenced by its sensitivity to face inversion, which increases both N170 amplitude and latency (Caharel et al., 2013; Jacques & Rossion, 2010; Rossion et al., 2000; Sadeh & Yovel, 2010).

ERP studies have reported effects of perceptual expertise on the N170 component. Long-term perceptual expertise about certain objects is associated with larger N170 amplitudes in response to objects of a participant's area of expertise (e.g., dogs, birds, fingerprints, or cars) as compared to objects outside of this area (Busey & Vanderkolk, 2005; Gauthier et al., 2003; Tanaka & Curran, 2001). Other studies showed that short-term perceptual training with laboratory-created stimulus categories (e.g., greebles) increased N170 amplitudes in response to these stimuli (Rossion et al., 2002, 2004). Face-like N170 inversion effects were also found in domains of non-face objects of expertise (e.g., words) (Dering et al., 2013; Wang et al., 2011). Since the N170 response is frequently modulated by perceptual experience, culture-specific perspectives have attracted interest.

It is well-known that faces of different ethnicity are recognized with greater difficulty than faces of one's own ethnicity (e.g., Byatt & Rhodes, 2004; Walker & Tanaka, 2003). This other-race effect is commonly accounted for by the relative lack of perceptual experience with other-race as compared to same-race faces (e.g., Rhodes et al., 2009; Tanaka et al., 2004). Specifically, greater experience with own-race faces may cause them to be processed in a configural way, whereas other-race faces may process in a more feature-based manner because of low levels of expertise (Michel et al., 2006; Rhodes et al., 1989; Tanaka et al., 2004). Some researchers argued the role of social cognitive factors in other-race effects. In particular, the ingroup/outgroup hypothesis holds that when individuals encounter a face, they first assess whether it belongs to an in-group (i.e., same race) or an out-group (i.e., other race) member (see reviews Hugenberg et al., 2010; Young et al., 2012). For instance, Hugenberg and Corneille (2009) found that ingroup faces (Western students from the same university) were processed more configurally than outgroup ones (Western students at a different university), suggesting a role of the ingroup/outgroup status in configural processing and supporting the importance of social cognitive aspects in accounting for the other-race effect. The other ongoing debate concerns whether the N170 is sensitive to face race. A number of studies found other-race effects in the N170 but with inconsistent direction, some showing larger N170 to same-race than to other-races faces (e.g., Herrmann et al., 2007; Ito & Urland, 2005), whereas others show the opposite pattern (Gajewski et al., 2008; Stahl et al., 2008; Wiese et al., 2014). However, other studies failed to report the sensitivity to race on the N170 (e.g., Caldara et al., 2003, 2004; Tanaka & Pierce, 2009). The heterogeneity of the N170 race effects might be due to methodological differences across previous studies such as task demand (Senholzi & Ito, 2013; Wiese, 2013).

Some studies indicate differences between participant groups of different ethnic origins. Face-elicited N170 in adults was significantly larger in East-Asian than in Caucasian participants in the study of Dering et al. (2013); in other studies (Gajewski et al., 2008; Herzmann et al., 2011; Vizioli et al., 2010; Wiese et al., 2014), similar patterns of (statistically non-significant) larger mean face-elicited N170 amplitudes in East-Asians than Caucasians were observed. In children, Ma et al. (2022) found significantly larger face-elicited N170 responses in Chinese as compared to German early readers. The authors suggested that this difference may be due to the differential demands placed on the visual and mnemonic processing in different script systems learned by the Children after one year of formal reading training. This script system hypothesis is based on the neuronal recycling hypothesis proposed by Dehaene and Cohen (2007), that reading "recycles" preexisting cortical networks that evolved for different but similar functions (e.g., face perception) and creates its own brain networks. Numerous empirical studies have demonstrated the effects of reading acquisition on face perception (e.g., Dehaene et al., 2010, 2015; Hervais-Adelman et al., 2019; Szwed et al., 2011; van Paridon et al., 2021). For example, some ERP studies indicated a dependent relationship between the face N170 and word N170, especially concerning their co-dependent trajectory of development during reading acquisition (e.g., Dundas et al., 2014; Li et al., 2013). Furthermore, previous evidence that readers of visually more complex scripts (e.g., logographic Chinese) tend to demonstrate superior visual skills compared to readers of less complex alphabetic scripts (e.g., Demetriou et al., 2005; Huang & Hanley, 1995; McBride-Chang et al., 2011). For example, Demetriou et al. (2005) found that Chinese children outperformed Greek school children on tests of global (holistic) visuospatial processing. Therefore, it may be plausible that differential training of visual perception and memory required for becoming a skilled Chinese reader as compared to an alphabetic script reader might differentially impact non-verbal visual processing, manifesting also in processing other visual stimuli of sufficient complexity, such as faces. Given that the resemblance with respect to visual characteristics is particularly striking between logographic scripts (e.g., Chinese characters) and faces (Liu et al., 2009; Ma et al., 2022), the script system hypothesis assumes that learning Chinese script during reading acquisition is likely to transfer to and influence face processing to a larger extent than learning an alphabetic script.

In the adult studies indicating group differences in N170, the East-Asians were mainly Chinese and Japanese, who are required to master logographic script systems, which are visually more complex than alphabetical scripts used by Western Caucasians (Chang et al., 2016). Therefore, differences in face-elicited N170 between East-Asian adults and Caucasian adults might be contributed to their differences in visual and mnemonic training experience required for becoming a skilled logographic script reader as compared to alphabetic script readers. Specifically, the script system hypothesis assumes that learning a logographic script system may have generalized neurocognitive consequences by strengthening holistic visual processing to visual stimuli of sufficient complexity, such as faces. This notion is supported by the finding of Ma et al. (2022) that Chinese children also showed an enhanced N170 to Mooney faces which have to be processed holistically as there are no separable facial features (Mooney, 1957), as compared to German children, indicating that the N170 differences specifically related to the superiority of Chinese children in holistic face processing. Since the N170 is held to be a neural signature of holistic processing (e.g., Eimer et al., 2011), the enhanced face-N170 in East-Asian adults relative to Caucasian adults might also reflect a relative dominance of holistic processing in East-Asians.

The evidence in favor of more holistic processing in East-Asians has been reported in a large number of cross-cultural studies where Westerners tend to be more independent and more analytic, while East-Asians tend to be more interdependent and holistic (e.g., Markus & Kitayama, 1991; Nisbett et al., 2001; Varnum et al., 2010). In particular, similar cultural differences were found in face perception areas. For instance, Miyamoto et al. (2011) found that Japanese were more likely to use overall resemblance rather than feature-matching for choosing a prototypical face as compared to Americans. Furthermore, a series of eye-tracking studies reported that East-Asians tended to maintain fixation on the nose or central area, (i.e., a holistic pattern) whereas Westerners tended to focus on the eyes and lips of faces (i.e., an analytic pattern) (Blais et al., 2008; Miellet et al., 2013; Rodger et al., 2010), consistent with cultural differences in face processing strategies. Unfortunately, findings of culture-specific eye movement patterns have not been found in other studies on adult participants (Chuk et al., 2017; Or et al., 2015; Rayner et al., 2007) and the holistic face processing measured by inversion effects is not modulated by the fixation patterns on faces (Zhong et al., 2021). Hence, it is unclear, whether an enhanced N170 in the East-Asian adult population would indeed relate to preferentially holistic vision in face processing.

As mentioned above, the N170 can be modulated by short-term training experience. For example, increased exposure to a specific visual stimulus category leads to a significant increase in N170 amplitude to this stimulus category (Scott et al., 2006, 2008), thus the apparently enhanced face N170 in East-Asian participants in the adult studies might be due to increased exposure experience with faces as compared to Caucasians. Notably, the East-Asian participants of the above-mentioned cross-cultural studies had been foreigners and hence immersed for some time into the (Western) society where the study was conducted; in contrast, the Caucasian participants likely had been locals of the host country.

As compared to children, adults typically engage in a larger variety of activities, related to their occupation and social life, bringing with them, a greater variety of social encounters. Thus, Oruc et al. (2019) reported that faces have a prominent presence in the every-day visual experience of adults with an average of 255 faces per day. Therefore, the East-Asians in the cross-cultural adult studies probably had been exposed to a relatively large number of new faces in an unfamiliar and other-ethnic social environment as compared to the Caucasians. According to face space theory (Valentine, 1991), new faces may alter the representational space of the face recognition system where faces are coded on multiple dimensions in reference to a prototype, representing the average of the faces that a person has encountered. For example, visual training on the dimensions of other-race faces led to a reduction of the other-race effect (Hills & Lewis, 2006). Possibly, the substantial increase of unfamiliar face exposure in foreigners, especially in a different predominant ethnicity may stimulate the face processing system, resulting in enhanced N170 amplitudes to faces. We will refer to this alternative explanation for the increased N170 in the East-Asian participants in previous studies as the social immersion hypothesis.

The social immersion hypothesis is supported by evidence that after about 1 to 2 years spent in a new ethnic environment emotion recognition performance improves and the correlated neural activity increases, indicating successful acclimatization and adaptation (Derntl et al., 2009; Elfenbein & Ambady, 2002). More specifically, Gajewski et al. (2008) found that the duration of residence in Europe for East-Asian participants positively correlated with the latency of the N170 to both own and other-race faces, suggesting that the short-term experience in a new ethnic environment may influence the neural correlates of face processing.

For the participants with increased face-N170 amplitudes in the above-mentioned adult studies, the geographical region where the study was conducted constituted not only a new social environment but also a different ethnic environment. Thus, two types of immersion experience may have to be distinguished: immersion into a different ethnic social environment (new-ethnicity immersion hypothesis) and/or immersion into a new social context (global new social immersion hypothesis).

1.1 | The present study

We examined the face-elicited N170 in East-Asians and Caucasians in a cross-cultural study by conducting two ERP experiments, aiming to assess differences in face-elicited N170 amplitudes between these groups. More importantly, we wanted to identify the factor(s) underlying such a difference, if confirmed, namely the role of the acquired script system and/or the experienced social immersion. Experiment 1 was conducted in an East-Asian society (Hong Kong) by recruiting local Hong Kong Chinese (LC) participants and non-Chinese (NC) participants who could not read any logographic scripts and had recently come to Hong Kong from other countries. Experiment 2 was conducted in Western society (Berlin, Germany) by recruiting long-term Berlin residents (LB) who were native German speakers without logographic script reading experience and local residents in Berlin, short-term Berlin residents (SB) who were native German speakers without logographic script reading experience and had recently come to Berlin from other cities in Germany and short-term Chinese visitors (SC) who had recently come to Germany from China. During EEG recordings in both experiments, participants completed a series of one-back tasks using pictures of upright as well as inverted Asian and Caucasian faces and doodle stimuli (complex black and white line-drawings). This task allows to monitor participants' attention and is very easy for most participants (at least in the upright condition). A further reason for choosing this easy task was the comparability with a companion study in 7-year-old children (Ma et al., 2022). Since the task is very easy, we expect ceiling effects in both groups. Nevertheless, reaction time-based group differences may be expected if there are ability differences between the groups, in line with Ma et al. (2022) where a group difference between German and Chinese children was observed in reaction times in a one-back face task. We used both East-Asian and Caucasian faces as stimuli in order to control for other-ethnicity stimulus effects, which were not the research question of the present study. Inverted faces were used to examine the interpretation of possible group differences in the N170 in terms of holistic processing. When faces are inverted, it is difficult to process them holistically or configurationally (Maurer et al., 2002). If an observed group difference in N170 reflects differences in holistic processing, it should be more pronounced for upright than for inverted faces. The control condition with complex abstract patterns without clear relational/configural information (i.e., doodles) serves to examine whether the group differences in N170 amplitudes are specific to faces.

In summary, the script system hypothesis would be supported by larger face-elicited N170 amplitudes in Chinese participants in both Experiment 1 and Experiment 2 as in Ma et al. (2022). The general social immersion hypothesis, however, would be supported by larger face-N170 amplitudes in participants that had moved into their novel social environments only a short time ago (Experiment 1: non-Chinese participants; Experiment 2: short-term Chinese and short-term German participants). In addition, Experiment 2 could further differentiate between the global novel social immersion and the new-ethnicity immersion hypothesis by comparing the two German groups and two short-term groups respectively.

Apart from the N170 we also assessed the visual P1 component. The P1 component is an early occipital positive component peaking at approximately 100 ms following stimulus onset and is thought to originate from the extrastriate brain regions (e.g., Clark et al., 1994; Di Russo et al., 2002). It is sensitive to low-level visual stimulus properties, such as size, luminance or contrast but is also modulated by attention (for a review, see Hillyard et al., 1998). Thus, this component allowed us to assess contributions of low-level processing and attention to any group differences in the following N170. In addition, some studies of face perception suggest that P1 is face-sensitive and larger in response to faces than to other objects (Herrmann et al., 2005; Itier & Taylor, 2004a). Also, larger P1 amplitudes have been reported to inverted than to upright faces, suggesting that P1 might reflect holistic face processing (Itier & Taylor, 2002, 2004b). Therefore, the present study also examined whether the group would be observed in P1.

2 | EXPERIMENT 1: HONG KONG

2.1 | Method

2.1.1 | Participants

Participants were 38 university students living in Hong Kong at the time of the experiment. Prior to commencing the experiment, all participants provided informed consent and completed the Edinburgh Handedness Inventory and a questionnaire regarding demographic information. Two participants had to be excluded because of poor data quality. Of the remaining *N* = 36 participants, 18 were local Hong Kong Chinese (LC group) [mean age = 20.44 years (*SD* = 3.06); 10 females; 16 right-handed] and 18 were non-Chinese visitors (NC group) who had lived in Hong Kong for an average of 10 months (*SD* = 10.66) [mean age = 19.83 years (*SD* = 1.67); 11 females; 14 right-handed]. Non-Chinese participants were alphabetic script (Latin/Cyrillic) readers with no logographic Chinese reading experience and consisted of eight Western Caucasians, four Southeast-Asians, four Eurasians and two Subsaharan Africans. All participants had normal or corrected-to-normal vision. The experiment was approved by The Joint Chinese University of Hong Kong – New Territories East Cluster Clinical Research Ethics Committee (The Joint CUHK-NTEC CREC) in accordance with the Declaration of Helsinki.

2.1.2 | Stimuli

Stimuli consisted of 160 faces, 160 Chinese characters and 160 abstract shapes including 80 doodles and 80 polygons. Face stimuli were grayscale frontal view portraits with neutral expressions (provided by Hildebrandt et al., 2010). Faces were of female and male Chinese and Caucasian adults in equal (see Figure 1). All faces were set to identical luminance and contrast levels and fit into a mask-shaped frame, 4.30° × 5.73° in visual angle at the given viewing distance, which removed any external features (i.e., background, hairline, clothes, and ears). Inverted versions of face stimuli were created by picture-plane rotations of the images by 180°. Doodles were random, highly complex combinations of over-lapping black shapes, curves, and lines (see Figure 1). Polygons were simple bold black outlines of different triangles, quadrangles, pentagons, and hexagons. All doodles and shapes subtended a maximal visual angle of 4.77° × 4.77°. As our hypothesis concerns the processing of faces and other nonverbal stimuli, we will not elaborate on the Chinese character tasks.

All stimuli were presented at the center of a white square (11.9° × 11.9°) on a screen with an otherwise dark gray background.

2.1.3 | Procedure

The experiment was controlled by E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Participants were seated in a dimly lit room at 60 cm distance from the computer screen. They performed a simple repetition detection (1-back) task. If the stimulus shown was the same as the preceding stimulus (target trials), they should press the mouse button. If there was no repetition (non-target trials), no action was required. A brief practice session with houses was used to make sure that participants had understood the task. There were eight blocks, one for every stimulus condition (upright Asian faces, upright Caucasian faces, inverted Asian faces, inverted Caucasian faces, upright Chinese characters, inverted Chinese characters, doodles, and polygons). Each block consisted of 80 non-target trials and eight target trials (i.e., repetitions) presented in pseudo-randomized order. In a given block, each image was presented only once except the targets. Further, we balanced inversion of face and character stimuli so that each image was shown upright to half of the participants and upside-down to the other half. Each

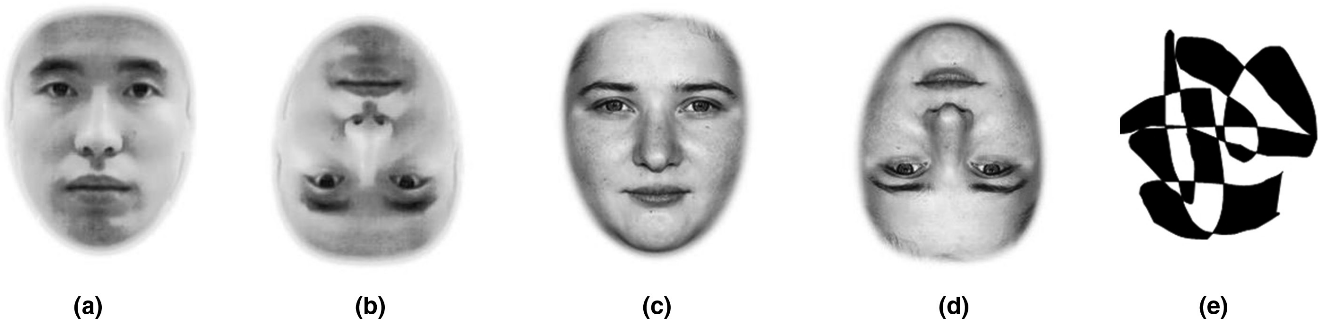

FIGURE 1 Examples of stimuli used in Experiment 1 and 2: (a) upright Asian faces, (b) inverted Asian faces, (c) upright Caucasian faces, (d) inverted Caucasian faces, and (e) doodles.

stimulus condition was presented in a separate block. To control for effects of presentation order, eight sequences of blocks were constructed, where (1) each stimulus condition occupied each possible position and (2) where successive blocks in most cases contained different types of stimuli. The number of participants using each block sequence was matched between groups. In addition, the experiment lasted less than half an hour and included regular breaks in order to counteract fatigue. Each stimulus was presented for 500 ms, followed by an average inter-stimulus interval of 1500 ms (varying between 1250 and 1750 ms). During the inter-stimulus interval, a fixation cross appeared at the center of the screen.

2.1.4 | EEG recording and preprocessing

The EEG was sampled at 500 Hz using a 128-channel geodesic sensor net (Electrical Geodesics Inc.), with 0.1–100 Hz band-pass filter settings. Cz served as the physical reference. Electrode impedances were kept below 50 kΩ throughout recording.

Offline, the EEG data were analyzed with Brain Vision Analyzer 2.0 software and re-calculated to a common average reference. The signals were digitally low-pass filtered at 30 Hz (24 dB/Octave, zerophase-type filter). An automated artifact detection algorithm was run on all channels in each segment. A channel was marked as bad if (1) voltages exceeded ±100 μV, or (2) absolute differences between two adjacent sample points exceeded 75 μV, or if (3) the voltage range of a given channel within the entire segment exceeded 150 μV. A segment was rejected if it contained any bad channels. Channels that contained more than 20% bad segments across the entire recording were replaced through spline interpolation. We only analyzed non-target trials because there were only 8 target trials per condition and we had no hypotheses about them. The non-target trials were epoched at −100 to 500 ms relative to stimulus onset and baseline-corrected to the average of the pre-stimulus interval. On average the accepted trials in each condition were >90%.

2.1.5 | Data analysis

Behavioral data

Performance was measured as response accuracies and reaction times (RTs). Using IBM SPSS Statistics 28, we analyzed these behavioral measures for faces and doodles separately. For faces, we performed ANOVAs with participant group (LC, NC) as a between-subject factor, and stimulus orientation (upright, inverted) and stimulus race (Asian, Caucasian) as within-subject factors. For doodles and polygons, we conducted separate unpaired *t*-tests between the LC and NC group for accuracy and RT.

ERP data

Topographic ERP analyses. We wanted to ensure that possible group differences in observed amplitudes or latencies of the ERP components can be attributed to differential cognitive processing rather than topographic dissimilarities resulting from inconsistent sources or morphological variation. A global way to determine the time period of significant topographic effects including all experimental conditions is the topographic analysis of variance (TANOVA). TANOVA is a non-parametric randomization test of reference-independent topographic difference measure (Murray et al., 2008). When the EEG data are normalized to unit variance across channels, significant differences between conditions can only be accounted for by differences in source distribution, and not by differences in source strength alone (for details see Koenig & Melie-García, 2009; Lehmann & Skrandies, 1980).

We first computed grand mean ERPs of the non-target trials by participants and stimulus conditions, epoched at −100 to 500 ms relative to stimulus onset. Then the P1 and N170 components were identified from Global Field Power (GFP) waveforms of the grand mean ERPs across participants and stimulus conditions. Next, separate mixed TANOVAs with stimulus type (upright Asian faces, inverted Asian faces, upright Caucasian faces, inverted Caucasian faces, doodles) as a within-subject factor and participant group (LC, NC) as a between-subject factor were applied for a ± 30 ms time interval around the corresponding GFP peak of each ERP component in Ragu software (Randomization Graphical User interface; Koenig et al., 2011). We computed 5000 randomization runs on the analyzed data that have been normalized. An effect will be considered statistically significant if the *p*-value is less than .05.

ERP component analyses. Using IBM SPSS Statistics 28, we conducted four-way ANOVAs with a between-subject factor participant group (LC, NC), and within-subject factors stimulus orientation (upright, inverted), stimulus race (Asian, Caucasian) and hemisphere (left, right) on amplitudes and latencies of each ERP component to face stimuli. For doodle stimuli, two-way ANOVAs with a between-subject factor participant group (LC, NC) and a within-subject factor hemisphere (left, right) were performed on amplitudes and latencies of each ERP component. Effect sizes are reported as partial eta-square. In addition, Bonferroni correction was applied to account for multiple comparisons in *post-hoc* analysis.

2.2 | Results

2.2.1 | Behavioral results

Due to technical problems, behavioral data was only available for 15 out of 18 local Chinese participants and 14 out of 18 non-Chinese participants. For faces, accuracies and RTs were submitted to three-way ANOVAs, which revealed a significant main effect of orientation for both accuracy ($F(1, 27) = 75.97$, $p < .001$, $\eta_p^2 = 0.74$) and RT ($F(1, 27) = 11.99$, $p = .002$, $\eta_p^2 = 0.31$); participants showed higher accuracy and faster responses for upright than for inverted faces (Accuracy: $M = 0.98$ vs. 0.93, $SD = 0.02$ vs. 0.03; RT: $M = 631.48$ vs. 690.20, $SD = 123.86$ vs. 148.79). For doodles and polygons, *t*-tests showed that no significant group difference was observed for both accuracy and RT ($ps > .05$).

2.2.2 | ERP results

TANOVA

The TANOVAs did not show significant main effects of participant group for P1 ($p = .679$) or N170 ($p = .618$), nor interactions between participant group and stimulus condition for P1 ($p = .627$) or N170 ($p = .142$). These results indicate that the topographies of both ERP components to any stimulus type were indistinguishable between the LC and NC group (see Figure 2). Thus, the following analyses were conducted on the assumption of topographic invariance of these components between groups.

ERP component analyses

The N170 was measured at the occipitotemporal electrode sites P7 (left hemisphere) and P8 (right hemisphere), as frequently used in other studies (e.g., Dundas et al., 2014; Eimer, 2011; Eimer et al., 2011; Latinus & Taylor, 2005; Rossion & Jacques, 2008) and by Ma et al. (2022). The P1 was scored at the occipital electrodes O1 (left hemisphere) and O2 (right hemisphere). We analyzed the data from the electrodes of the EGI sensor net that corresponded to these electrodes in the 10–20 system. Thus, adaptive mean amplitudes were averaged within a ±30 ms window centered on the peaks with maximum voltages detected automatically between 110 and 210 ms after stimulus onset for N170 (negative peak) from E58/E96 (P7/P8) sites and between 50 and 150 ms after stimulus onset for P1 (positive peak) from E70/E83 (O1/O2) sites. Peak latencies were measured as the time point of the peak maximum. In addition, ERP latencies in the HK data had to be corrected by a global shift of 18 ms due to the effects of anti-aliasing filters in EGI NA300 at 500 Hz sampling rate (Pegado et al., 2014; Advisory Notice, 29 August 2014, Electrical Geodesics Inc). This correction had no effects on data quality.

P1. The ANOVAs of the P1 to faces (see Figure 3) showed a significant main effect of stimulus orientation for amplitude ($F(1, 34) = 9.83$, $p = .004$, $\eta_p^2 = 0.22$) but not for latency ($p > 0.05$), indicating a larger P1 amplitude for inverted than for upright faces ($M = 4.53$ vs. 3.97 µV, $SD = 2.55$ vs. 2.23). The main effect of hemisphere was significant for both amplitude ($F(1, 34) = 9.83$, $p = .004$, $\eta_p^2 = 0.22$) and latency ($F(1, 34) = 6.46$, $p = .016$, $\eta_p^2 = 0.16$), indicating larger amplitude and longer latency in the left than right hemisphere (Amplitude: $M = 4.50$ vs. 4.00 µV, $SD = 2.50$ vs. 2.26, Latency: $M = 108.99$ vs. 105.75 ms, $SD = 8.13$ vs. 9.62).

For P1 amplitudes and latencies to doodles and polygons (see Figure S1 in Supporting Information), ANOVAs did not reveal any significant effects ($ps > .05$).

N170. For the N170 amplitude to faces (see Figure 3), the ANOVA showed a significant main effect of participant group ($F(1, 34) = 5.52$, $p = .025$, $\eta_p^2 = 0.14$), indicating that the NC participants showed the larger face N170 amplitude than the LC participants ($M = -2.04$ vs. -0.42 µV, $SD = 2.41$ vs. 1.62). In addition, there was a significant interaction between participant group, stimulus orientation and hemisphere ($F(1, 34) = 4.28$, $p = .046$, $\eta_p^2 = 0.11$). To decompose this interaction, the simple main effect of participant group was analyzed in each hemisphere. The results revealed a significant simple main effect of group in the right hemisphere ($F(1, 34) = 5.33$, $p = .027$, $\eta_p^2 = 0.14$), but not in the left hemisphere ($F(1, 34) = 3.46$, $p = .072$, $\eta_p^2 = 0.09$). In the right hemisphere the NC group showed a significantly larger face N170 amplitude than LC group ($M = -2.57$ vs. -0.58 µV, $SD = 3.13$ vs. 1.89) whereas in the left hemisphere the NC group showed only numerically (statistically non-significant) larger face N170 amplitudes than the LC group ($M = -1.50$ vs. -0.26 µV, $SD = 2.09$ vs. 1.88). The simple effect of stimulus orientation was also only significant in the right hemisphere ($F(1, 34) = 4.34$, $p = .045$, $\eta_p^2 = 0.11$), indicating a larger N170 for inverted than for upright faces ($M = -1.86$ vs. -1.30 µV, $SD = 3.19$ vs. 2.49). The simple two-way interaction between these two factors was not significant for either hemisphere ($ps > .05$).

For N170 latency to faces, the ANOVA showed that the main effect of group was not significant ($F(1, 34) = 1.77$, $p = .192$, $\eta_p^2 = 0.05$), suggesting the N170 latency to faces was indistinguishable between LC and NC participants ($M = 159.84$ vs. 155.10 ms, $SD = 10.27$ vs. 11.11). There were significant main effects of stimulus orientation ($F(1, 34) = 73.35$, $p < .001$, $\eta_p^2 = 0.68$), with shorter latency for upright than inverted faces ($M = 153.57$ vs. 161.38 ms,

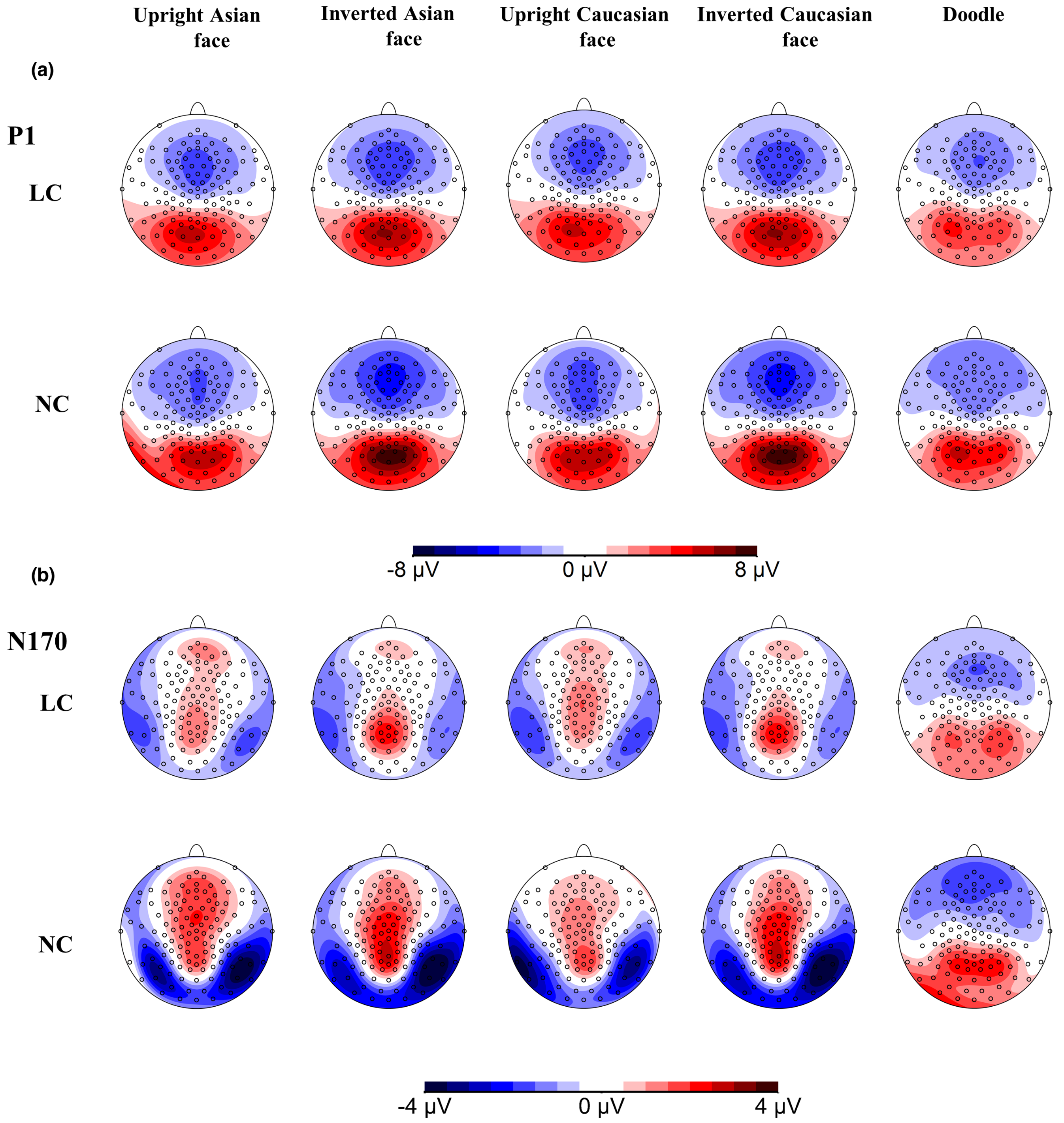

FIGURE 2 Experiment 1: Topographies of grand-average peak amplitudes of P1 (108 ms, panel a) and N170 (154 ms, panel b) of Chinese local residents (LC) and non-Chinese residents (NC) in Hong Kong elicited by upright Asian faces, inverted Asian faces, upright Caucasian faces, inverted Caucasian faces, and doodles.

SD = 10.36 vs. 11.89), and of stimulus race ($F(1, 34) = 7.24$, $p = .011$, $\eta_p^2 = 0.18$), with shorter latency for Caucasian faces than Asian faces (*M* = 156.57 vs. 158.38 ms, *SD* = 11.09 vs. 10.90), and of hemisphere ($F(1, 34) = 10.35$, $p = .003$, $\eta_p^2 = 0.23$), with shorter latencies in the right than in the left hemisphere (*M* = 156.08 vs. 159.79 ms, *SD* = 10.64 vs. 11.90). No significant interactions were observed (*ps* > .05).

The ANOVAs for doodles did not reveal significant main effects of participant group in amplitude ($F(1, 34) = 0.00$, $p = .971$, $\eta_p^2 = 0.00$) or latency ($F(1, 34) = 0.64$, $p = .430$, $\eta_p^2 = 0.02$), indicating that these parameters were indistinguishable between LC and NC groups (Amplitude: *M* = 1.79 vs. 1.77 µV, *SD* = 1.90 vs. 2.11; Latency: *M* = 150.17 vs. 148.89 ms, *SD* = 16.49 vs. 19.56). However,

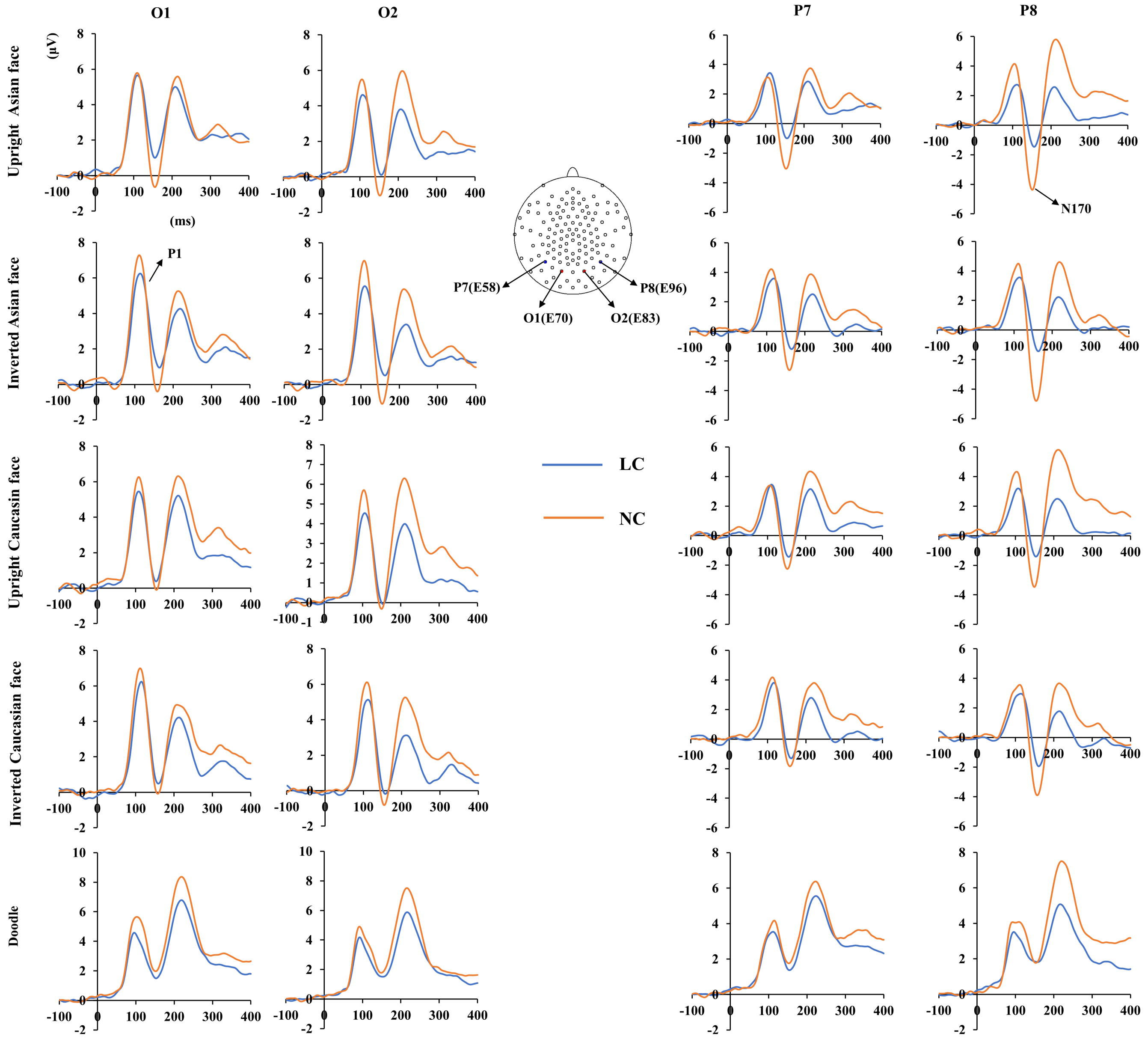

FIGURE 3 Experiment 1: Grand-average ERP waveforms of Chinese local residents (LC, blue) and non-Chinese residents (NC, orange) in Hong Kong elicited by upright Asian faces, inverted Asian faces, upright Caucasian faces, inverted Caucasian faces, and doodles at two occipital sites showing the P1 amplitude (O1, left hemisphere; O2, right hemisphere) and two occipitotemporal sites showing the N170 amplitude (P7, left hemisphere; P8, right hemisphere).

the main effect of hemisphere was significant for latency ($F(1, 34) = 4.73$, $p = .037$, $\eta_p^2 = 0.12$) but not for amplitude ($p > 0.05$), suggesting the latency was shorter for the right than for the left hemisphere (M = 145.67 vs. 153.39 ms, SD = 21.83 vs. 19.61). No interactions approached significance ($ps > .05$). The ANOVAs of the polygon-elicited N1 (see Figure S2 in Supporting Information) did not reveal significant main effects of participant group in amplitude ($F(1, 34) = 1.40$, $p = .245$, $\eta_p^2 = 0.04$) or latency ($F(1, 34) = 0.03$, $p = .868$, $\eta_p^2 = 0.00$), indicating that these parameters were indistinguishable between groups (amplitude: M = 0.19 vs. 1.76 μV, SD = −0.59 vs. 2.14; latency: M = 149.56 vs. 150.67 ms, SD = 16.48 vs. 19.43). In addition, there were not significant interactions ($ps > .05$).

2.3 | Discussion

Experiment 1 aimed to replicate differences in N170 amplitude between East-Asian and Caucasian participants that were observed in previous reports and to distinguish between the script system hypothesis and the social immersion hypothesis of the effect. The script system hypothesis would predict a replication of larger N170 amplitudes in East-Asian (Hong Kong Chinese) than in non-Chinese participants, whereas the social immersion hypothesis would predict the opposite, that is, a smaller N170 in Chinese than non-Chinese participants.

Experiment 1 showed smaller N170 amplitudes to faces in local Hong Kong Chinese than in non-Chinese participants. Importantly, this difference was not modulated by stimulus race, excluding the contribution of the differences of facial physiognomic information between races of faces. In addition, the absence of similar group differences in P1 makes it unlikely that the observed N170 difference was caused by low-level stimulus properties.

The results strongly argue against the script system hypothesis but support the social immersion hypothesis. The groups showing enhanced face N170 amplitudes in both Experiment 1 and previous studies had been immersed in new social environments. Thus, they likely had been exposed to many new faces, which they needed to perceive, remember and recognize, which might explain their enhanced N170 amplitudes to faces as a consequence of temporary training experience. In addition, the absence of significant group differences for both doodles and polygons in the N170 time window might indicate that the social immersion effect is specific to face processing; however, due to the relatively small sample size, an independent replication would be desirable.

3 | EXPERIMENT 2: BERLIN

Experiment 1 had provided evidence against the script system account for previous findings from western labs of larger N170 in Chinese than Non-Chinese participants, by showing smaller N170 in the Chinese. Hence, Experiment 2 aimed to both confirm the rejection of the script system hypothesis and support the social immersion effect on the face processing system. A limitation of Experiment 1 was that four non-Chinese participants were of Asian descent. Hence, for these participants (who had not learned a logographic script system), the effects of immersion into a new other-ethnicity society may be weaker than for the non-Asians. Although this might make the finding of larger N170 in this group as a whole even more impressive, it blurs the distinction between the global social immersion and social immersion into other-ethnicity environment. Experiment 2 attempted to make this distinction.

We conducted Experiment 2, closely adhering to the procedure of Experiment 1 in Berlin, Germany. Three groups of participants were tested: two German groups, consisting of long-term Berlin residents (LB) and short-term Berlin residents (SB), and short-term Chinese foreigners (SC). If the short-term immersion experience in a different ethnic environment is a major factor driving the size of the face N170, we expected the SC group to show larger face-elicited N170 amplitudes than the SB group. If the short-term immersion experience in a new social context is the major factor, the SB group should show larger face-elicited N170 amplitudes than the LB group.

3.1 | Method

3.1.1 | Participants

Participants were recruited in Berlin, Germany, and fell into three groups: 32 long-term Berlin residents (LB group) who grew up or had lived for at least 2 years in Berlin [mean age = 25.97 years (*SD* = 5.55); 19 females; 32 right-handed], 29 short-term Berlin residents (SB group) who had lived in Berlin for average of 6.54 months (*SD* = 3.48, range: 2.5–14 months) [mean age = 23.86 years (*SD* = 4.79); 18 females; 27 right-handed], and 32 short-term Chinese participants (SC group) who came from mainland China and had lived in Berlin for an average duration of 6.35 months (*SD* = 3.24, range: 2.5–13 months) [mean age = 24.06 years (*SD* = 2.46); 19 females; 32 right-handed]. LB and SB group were native German speakers and did not have logographic Chinese reading experience.

Prior to the experiment, all participants provided informed consent and completed the Edinburgh Handedness Inventory and a questionnaire regarding their demographic information. All participants had normal or corrected-to-normal vision. The experiment was approved by the ethics committee of the Department of Psychology of the Humboldt-University at Berlin in accordance with the Declaration of Helsinki.

3.1.2 | Stimuli

Stimuli consisted of faces, Chinese characters, German words and doodles. Except for doodles, all stimuli were presented in both upright and inverted orientations. The polygon condition was omitted in this experiment due to its small and unsystematic ERPs in Experiment 1 (see Figures S1 and S2 in Supporting Information). Since the Chinese characters and German words do not address the current questions, we will not elaborate on them. The details of face and doodle stimuli are the same as in Experiment 1.

3.1.3 | Procedure

Presentation 1.0 software controlled the procedure of Experiment 2. It consisted of nine blocks, one for each stimulus condition: upright Asian faces, upright Caucasian faces, inverted Asian faces, inverted Caucasian faces, upright Chinese characters, inverted Chinese characters, upright German words, inverted German words, and doodles. The principles to control the effects of presentation order were the same as in Experiment 1 except there were nine sequences of blocks. The number of participants using each block sequence was closely matched between groups. Other details of the procedure were the same as in Experiment 1.

3.1.4 | EEG recording and preprocessing

EEG was recorded with 39 Ag/AgCl electrodes placed within an elastic cap (Easycap GmbH, Herrsching, Germany) according to the extended International 10–20 System. Two additional electrodes below each eye measured vertical electroocular (EOG) activity. During recordings all channels were referenced to the Cz electrode; AFz served as ground electrode. Impedances were kept <10 kΩ at a uniform level. Signals were amplified using Brain Amps (Brain products) without additional filter settings during recordings and sampled at 1000 Hz.

Offline EEG data preprocessing was the same as in Experiment 1 except that data was digitally high-pass filtered at 0.1 Hz (12 dB/Octave, zerophase-type filter) and low-pass filtered at 30 Hz (24 dB/Octave, zerophase-type filter).

3.1.5 | Data analysis

Behavioral data

The Accuracies and RTs for face tasks were submitted to two three-way ANOVAs with a between-subject factor participant group (SC, SB, LB), and within-subject factors stimulus orientation (upright, inverted) and stimulus race (Asian, Caucasian). For doodle task, two-one-way ANOVAs with a between factor participant group (SC, SB, LB) were conducted for accuracy and RT.

ERP data

Topographic ERP analyses. Again, we first checked scalp field homogeneity of ERPs across groups and conditions by TANOVA with a within-subject factor stimulus condition (upright Asian faces, inverted Asian faces, upright Caucasian faces, inverted Caucasian faces, doodles) and a between-subject factor participant group (SC, SB, LB).

ERP component analyses. The four-way ANOVAs with a between-subject factor participant group (SC, SB, LB), and within-subject factors stimulus orientation (upright, inverted), stimulus race (Asian, Caucasian) and hemisphere (left, right) on amplitudes and latencies of each ERP component to face stimuli. For doodle stimuli, two-way ANOVAs with a between-subject factor participant group (SC, SB, LB) and a within-subject factor hemisphere (left, right) were performed on amplitudes and latencies of each ERP component.

In all analyses, effect sizes are reported as partial eta-square. In addition, Bonferroni correction was applied to account for multiple comparisons in *post-hoc* analysis.

3.2 | Results

3.2.1 | Behavioral results

ANOVAs showed significant main effects of stimulus orientation for both accuracy ($F(1, 90) = 117.71$, $p < .001$, $\eta_p^2 = 0.57$) and RT ($F(1, 90) = 29.39$, $p < .001$, $\eta_p^2 = 0.25$), participants across groups showed higher accuracies and faster responses for upright than for inverted faces (accuracy: $M = 0.98$ vs. 0.94, $SD = 0.02$ vs. 0.04; RT: $M = 618.04$ vs. 673.61 ms, $SD = 106.70$ vs. 111.73). All other main effects and interactions were not significant ($ps > .05$)

The ANOVAs on accuracies and RTs in doodle task did not reveal main effects of group ($ps > .05$).

3.2.2 | ERP results

TANOVA

The TANOVAs showed that neither the main effect of group for P1 ($p = .219$) or N170 ($p = .239$) nor the interactions between group and stimulus condition for P1 ($p = .376$) or N170 ($p = .796$) approached significance. Thus, the following component analyses were continued since the absence of group differences on the topographies of ERP components in all stimulus conditions (see Figure 4).

ERP component analyses

The electrodes for analyses of P1 (O1/O2) and N170 (P7/P8) were chosen as in Experiment 1 and the amplitudes and latencies were derived in the same way.

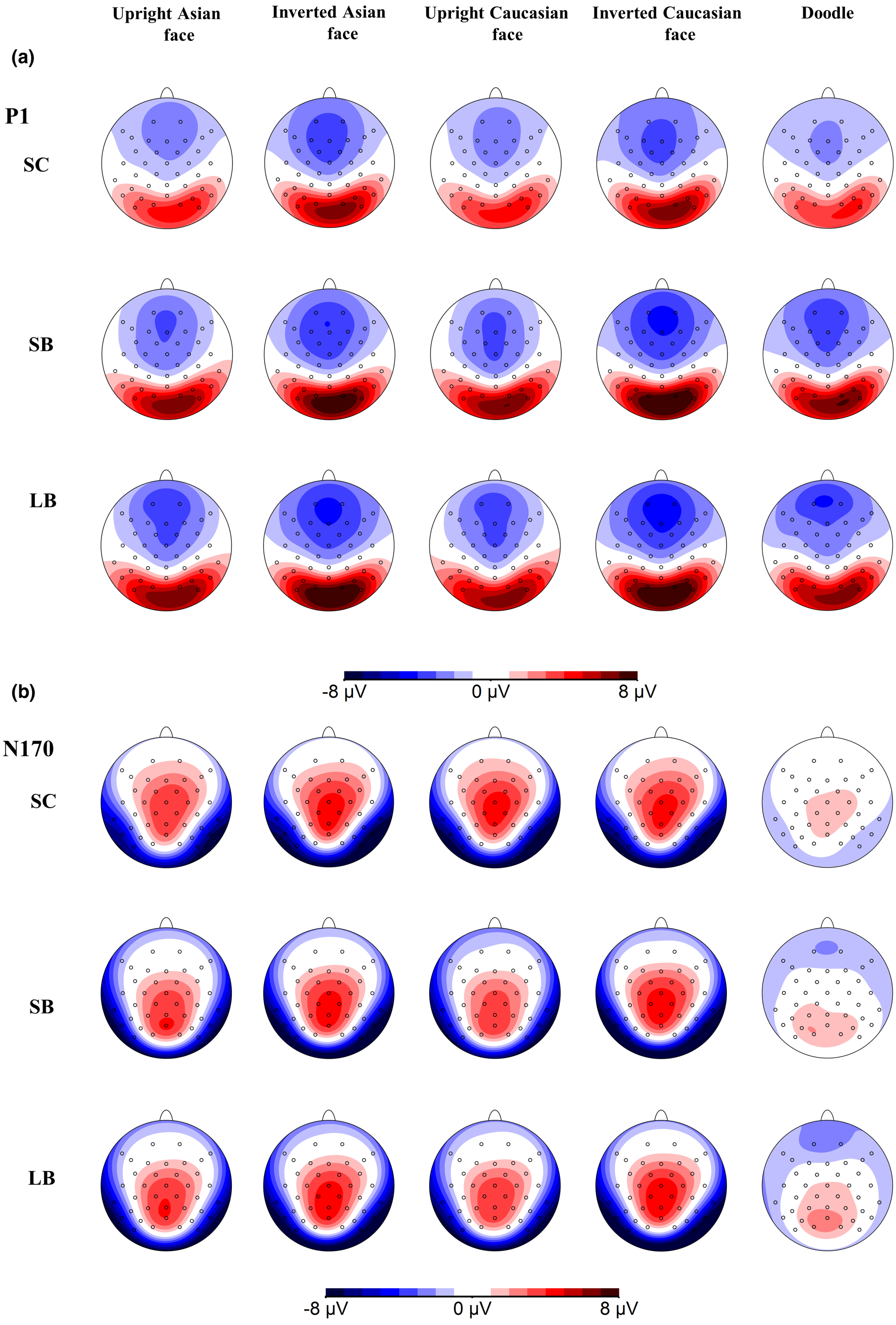

FIGURE 4 Experiment 2: Topographies of grand-average peak amplitudes of P1 (103 ms, panel a) and N170 (150 ms, panel b) of Chinese short-term residents (SC), and German short-term and long-term residents (SB vs. LB) in Berlin elicited by upright Asian faces, inverted Asian faces, upright Caucasian faces, inverted Caucasian faces, and doodles.

P1. The ANOVAs results of P1 amplitudes and latencies to faces showed significant main effects of stimulus orientation for both amplitude ($F(1, 90) = 84.06$, $p < .001$, $\eta_p^2 = 0.48$) and latency ($F(1, 90) = 31.54$, $p < .001$, $\eta_p^2 = 0.26$). The inverted faces elicited larger amplitudes and longer latencies than upright faces (Amplitude: $M = 5.85$ vs. $4.50\,\mu V$, $SD = 3.79$ vs. 3.34; Latency: $M = 102.48$ vs. 96.86 ms, $SD = 14.53$ vs. 14.96). All other main effects or interactions were not significant ($ps > .05$).

The ANOVAs performed on P1 amplitudes and latencies to doodles did not yield any significant effects ($ps > .05$).

N170. The ANOVA on N170 amplitudes to faces (see Figure 5) indicated a significant main effect of participant group ($F(1, 90) = 3.89$, $p = .024$, $\eta_p^2 = 0.08$). A Bonferroni corrected *post-hoc* pairwise comparison between SC and SB groups, testing the new-ethnicity immersion hypothesis, showed that the face-elicited N170 amplitude in the SC group was larger than in the SB group ($M = -2.74$ vs. $-1.03\,\mu V$, $SD = 2.90$ vs. 2.57, $p = .027$, Cohen's $d = 0.62$). In contrast, the pairwise comparison between SB and LB group, testing the global new social immersion hypothesis failed significance ($M = -1.03$ vs. $-1.50\,\mu V$, $SD = 2.57$ vs. 1.89, $p = 1$, Cohen's $d = 0.21$). In addition, without

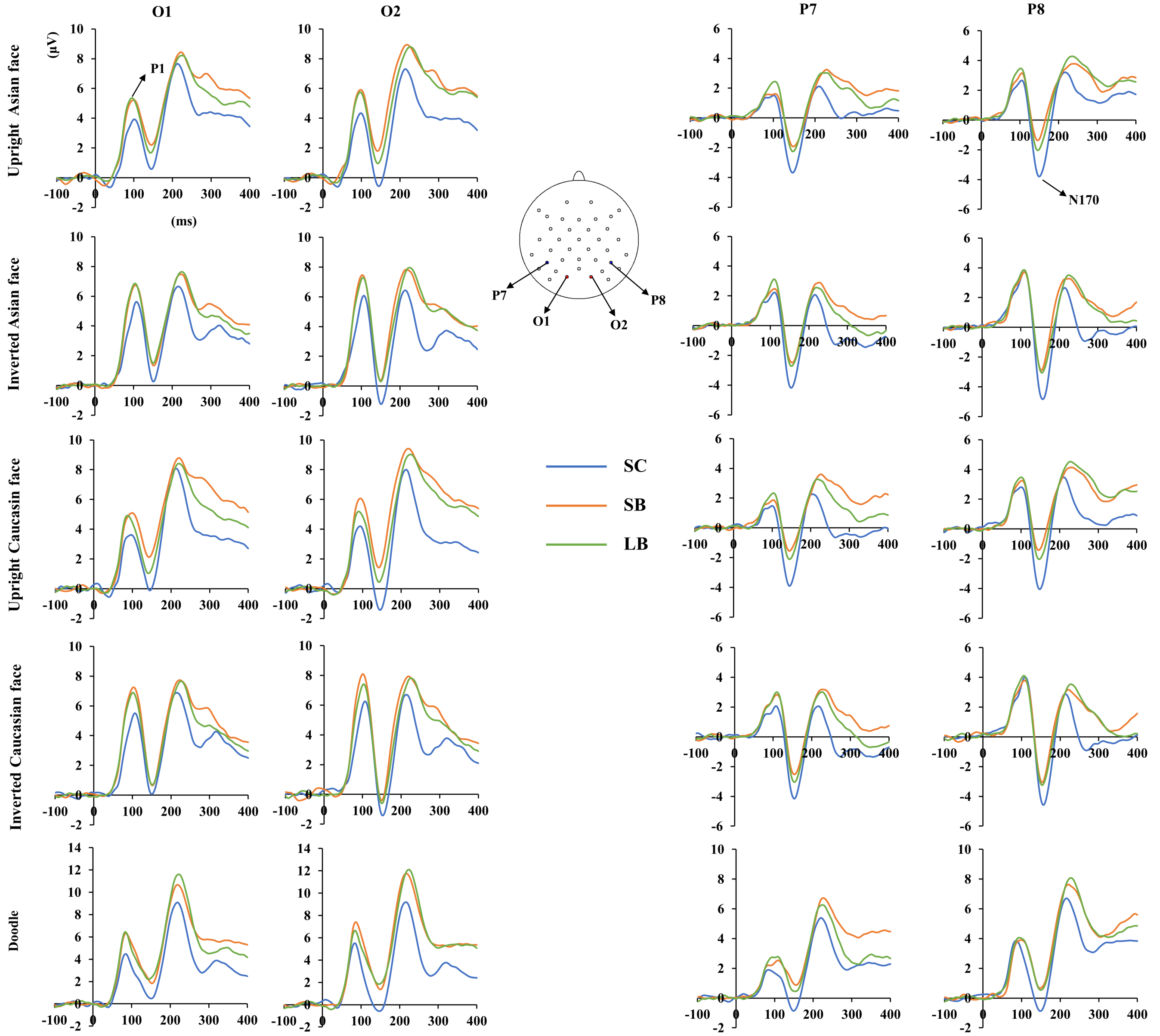

FIGURE 5 Experiment 2: Grand-average ERP waveforms of Chinese short-term residents (SC, blue), and German short-term (orange) and long-term (green) residents (SB vs. LB) in Berlin elicited by upright Asian faces, inverted Asian faces, upright Caucasian faces, inverted Caucasian faces and doodles at two occipital sites showing the P1 amplitude (O1, left hemisphere; O2, right hemisphere) and two occipitotemporal sites showing the N170 amplitude (P7, left hemisphere; P8, right hemisphere).

correction the pairwise comparison between the SC and LB groups, combining the two immersion types was significant ($p = .049$) and showed a medium effect size (Cohen's $d = 0.51$), but failed significance after Bonferroni correction ($p = .148$).

The main effect of stimulus orientation in N170 amplitude was significant ($F(1, 90) = 28.31$, $p < .001$, $\eta_p^2 = 0.24$), due to larger N170 amplitudes to inverted as compared to upright faces ($M = -2.05$ vs. $-1.51\,\mu$V, $SD = 2.75$ vs. 2.48). No other main effects and interactions were significant ($ps > .05$).

The ANOVA on N170 latency to faces revealed that the main effect of group was not significant ($F(1, 90) = 0.08$, $p = .927$, $\eta_p^2 = 0.02$), suggesting indistinguishable latencies to faces between SC, SB and LB participants ($M = 153.83$ vs. 153.98 vs. 153.02 ms, $SD = 10.36$ vs. 10.42 vs. 11.26). The main effect of orientation was significant ($F(1, 90) = 95.96$, $p < .001$, $\eta_p^2 = 0.52$), indicating longer latencies for inverted than for upright faces ($M = 157.34$ vs. 149.85 ms, $SD = 10.14$ vs. 11.88). No other effects and interactions reached significance ($ps > .05$).

For N170 to doodles, the ANOVAs revealed a main effect of participant group for amplitudes ($F(1, 90) = 3.20$, $p = .045$, $\eta_p^2 = 0.07$), but not for latencies ($F(1, 90) = 0.47$, $p = .625$, $\eta_p^2 = 0.01$). The *post-hoc* multiple comparisons with a Bonferroni adjustment showed a more negative N170 amplitude to doodles for SC participants than SB participants ($M = -0.23$ vs. $1.33\,\mu$V, $SD = 2.77$ vs. 2.35, $p = .049$, Cohen's $d = 0.61$). However, the other two comparisons (SC vs. LB and SB vs. LB) were not significant after Bonferroni correction ($ps > .05$). There was a significant main effect of hemisphere for latency ($F(1, 90) = 8.50$, $p = .004$, $\eta_p^2 = 0.09$), which was shorter in the right than in the left ($M = 147.54$ vs. 152.53 ms, $SD = 17.57$ vs. 17.57). No significant interactions were observed ($ps > .05$).

3.3 | Discussion

Overall, Experiment 2 demonstrated that the SC participants with short-term immersion experience in a new-ethnicity environment (Germany) show significantly larger face-elicited N170 amplitudes than SB participants with social immersion experience in Berlin. This finding replicates the group difference between residents and foreigners of Experiment 1 and provides further supporting evidence for the new-ethnicity immersion hypothesis. Meanwhile, Experiment 2 showed that the face N170 was indistinguishable between SB group with short-term immersion experience in Berlin and LB group without any social immersion experience, arguing against the global new social immersion hypothesis. Importantly, as in Experiment 1 the group difference was not related to stimulus race since the group differences did not interact with this factor. In addition, the absence of group differences in P1 rules out contributions of low-level stimulus factors and attention.

4 | THE OVERALL ANALYSES OF EXPERIMENT 1 AND 2

To increase the power of the results from two individual experiments, we performed a combined analysis on the face N170 amplitudes across two experiments. Since the N170 group differences in the individual experiments were not modulated by stimulus orientation and stimulus race, data were pooled across these factors. Since the results on N170 amplitude to face stimuli in each experiment support the new-ethnicity immersion hypothesis but together seem to be at variance with the script system hypothesis, we aimed to support this conclusion by a joint ANOVA with between-subject factors group, where groups are coded as locals versus foreigners, and location of lab (HK, Berlin); we also included a within-subject factor hemisphere (left, right). In HK data, the local Chinese and non-Chinese groups were coded as locals and foreigners, respectively. In Berlin data, the short-term Chinese were the foreigner group whereas the local group consisted of the combined short-term Berlin residents and long-term residents. The new-ethnicity immersion hypothesis would be supported by a main effect of group whereas the script system hypothesis would be supported by an interaction between group and location. Indeed, the results revealed a significant main effect of participant group ($F(1, 125) = 10.07$, $p = .002$, $\eta_p^2 = 0.08$), confirming larger N170 amplitudes to faces in the foreigner groups than in the local groups across experiments (see Figure 6). Importantly, any interactions involving factors group and location of lab, which might support the script system account, were not significant ($ps > .05$).

Overall, across experiments, the observed group differences in face-elicited N170 support an effect of the social immersion experience in a new ethnic social environment but do not align with the script system account.

5 | GENERAL DISCUSSION

In previous reports of cross-cultural ERP studies conducted in Western labs, we had noticed a consistent yet inconclusive pattern of larger face-elicited N170 amplitudes in East-Asian adults (mainly Chinese) than in Caucasian adults. The pattern was inconclusive because only in one experiment (Dering et al., 2013) it was statistically significant while the numerical (non-significant) differences were consistent across the other studies (e.g., Vizioli et al., 2010; Wiese et al., 2014). Larger N170 amplitudes in

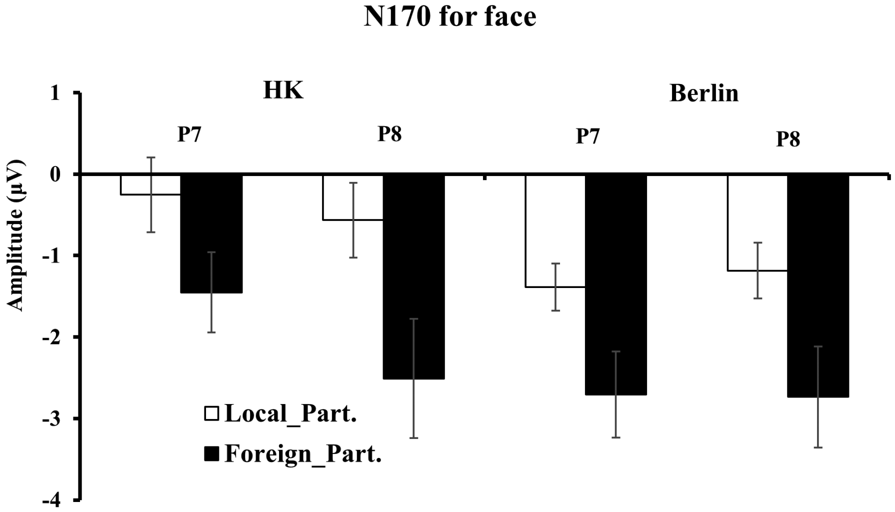

FIGURE 6 Amplitudes of N170 (P7, left hemisphere; P8, right hemisphere) elicited by faces for the local (white) and foreign (black) participants from HK and Berlin labs. Error bars indicate standard error of the means.

East-Asian participants were supported by a recent cross-cultural study in early Chinese and German readers (Ma et al., 2022). Therefore, the present study aimed to reassess this evidence and elucidate its possible underlying cause. Specifically, the difference might be due to cultural factors, for example due to the differential effects of the acquired script systems (script system hypothesis) or due to short-term immersion experience with a novel social and/or ethnic environment (social immersion hypothesis). Experiment 1, conducted in Hong Kong, revealed smaller face N170 amplitudes in local Chinese participants than in non-Chinese foreign participants. Since this effect is opposite in direction to the effects observed in previous studies, it contradicts the script system hypothesis. However, it is in line with the social immersion account. This was confirmed by Experiment 2, conducted in Berlin, where short-term Chinese visitors showed larger face-elicited N170 amplitudes than German natives. In addition, Experiment 2 allows the further specification that it is not any novel environment that drives the effect but it seems to be the immersion into a novel ethnic environment because long-term German residents and the short-term German residents were very similar in N170 amplitude. Taken together, the present study verifies a significant difference between Chinese and Caucasian participants but not as a consistent cultural difference but depending on whether the ethnic social environment had changed in the recent past.

5.1 | The script system account of N170 differences

The results from Experiment 1 conducted in HK and the observations from previous cross-cultural ERP studies are contradictory and cannot be consistently explained by the script system hypothesis. According to the script system hypothesis, Chinese participants should have larger N170 to faces than non-Chinese participants in Experiment 1 as in the previous adult studies. However, the smaller face-elicited N170 in Chinese participants compared with non-Chinese participants in the HK lab is at variance with the script system hypothesis. This finding is also inconsistent with the results in children, reported by Ma et al. (2022). Ma et al. (2022) has shown that native logographic Chinese readers had larger face-elicited N170 than native alphabetic readers, suggesting the contribution of perceptual experiences with visually complex logographic Chinese characters during reading acquisition in Chinese readers.

The inconsistency of findings might be due to participants' age, that is, adults in the present Experiment 1 versus children in the experiment of Ma et al. (2022). In adults, many ERP studies have consistently reported larger N170 amplitudes in experts to both faces and scripts (Maurer et al., 2008; Rossion et al., 2003), suggesting that the N170 reflects visual expertise for both faces and scripts. Furthermore, previous research indicated that acquisition of script reading involves the "recycling" of the neural system underlying face processing, and might in turn influence the face processing system (e.g., Dehaene et al., 2010). For instance, developmental studies found that the development of face expertise and script expertise reflected in the N170 during reading acquisition were dependent on each other (e.g., Dundas et al., 2014; Li et al., 2013). However, growing evidence suggests an inverted "U" model of script expertise effects on the N170; perceptual learning appears to be critically important during the first 2 or 3 years of reading acquisition and then gradually declines as expertise consolidates (e.g., Brem et al., 2009; Cao et al., 2011; Maurer et al., 2011). For example, Cao et al. (2011) found that the N170 amplitude to Chinese characters in 2nd grade children showed the largest amplitude among all age groups, but thereafter declined with increasing age, suggesting that the neural mechanisms for script expertise develop rapidly during the early primary school years. Thus, it is plausible that the effects of reading acquisition on face processing appear in early second-grade readers as found by Ma et al. (2022) and then decline and might even disappear in adult expert readers. In this case, we would not expect any effects of the script system on adult, expert readers and have to resort to alternative accounts for the effects observed in adults.

5.2 | The social immersion account of N170 differences

As predicted by the social immersion account, our findings indicate that independent of lab location, foreigners showed larger N170 amplitudes to faces than locals. Thus, the enhanced face-elicited N170 in East-Asians as compared to Caucasians at least numerically indicated by previous study results may derive from the social immersion experience of East-Asians. Similar to the East-Asian participants in previous studies (e.g., Dering et al., 2013), our non-Chinese participants in the HK lab and the Chinese participants in the Berlin lab were foreigners to the geographical region and social environment where the study was conducted. During their visit they were probably exposed to many new faces of a different ethnicity as mostly encountered at home, which they needed to encode and recognize. Hence, it is conceivable that a sudden surge in the exposure to novel faces may have enhanced their N170 amplitudes to faces, similar to what has been shown in training studies with novel objects (Rossion et al., 2002, 2004; Scott et al., 2006, 2008). Therefore, although at variance with the script system account, the increase of face N170 in foreigner groups in our study supports the social immersion account.

Importantly, there were no comparable group differences in the P1 – a component, which is sensitive to low-level stimulus properties and attention (for a review, see Hillyard et al., 1998), ruling out contributions of low-level stimulus properties and general attention in the N170 differences for both faces and doodles. As in most experiments, fatigue, practice or habituation effects might be involved as participants are exposed to a multitude of stimuli. Previous studies indicated that short-term adaptation or habituation effects may occur in performance and ERPs even within short experiments (e.g., Maurer et al., 2008; Schinkel et al., 2014). However, our countermeasures against such time on task effects confounding with the effects of interest should have been adequate, because our main aim was to compare single (e.g., doodles) or at most pairs of conditions (upright vs. inverted) across groups. The paired conditions were (almost) never directly adjacent but separated by other conditions and changed orders across sequences. Moreover, the number of participants using each block sequence was comparable between groups in both studies. Therefore, group comparisons always involved matched positions in the sequences, ruling out short term effects of time on task. Additionally, an empirical indication for the efficiency of our control procedure is the P1 component, which is typically sensitive to adaptation effects (Obrig et al., 2002; Wastell & Kleinman, 1980) but did not show any group differences in the present data. In addition, the TANOVA showed the same topographies of N170 across groups ruling out a contribution of heterogeneity of scalp distributions in the N170 differences.

Additionally, the present study examined whether the observed effects are specific to face perception or transfer to other stimulus domains. This question was pursued by including doodles representing complex visual non-face stimuli in both studies and polygons in Experiment 1, representing simple visual stimuli. In Experiment 1 the absence of group differences in the N170 for both doodles and polygons seems to argue in favor of the face specificity of the observed group effects in N1/N170. However, the findings of Experiment 2 that similar group differences as for the face-elicited N170 were observed for doodles are at variance with the idea that the social immersion effects are limited to faces. Instead, these findings might be accounted for by a more general effect on the neurocognitive generators of the N1/N170 component. Specifically, it might indicate that social immersion into another ethnicity environment influences higher-order structural analysis of complex visual stimuli reflected in the N170/N1 (Rossion et al., 2003; Schendan et al., 1998). However, doodles are meaningless and unfamiliar stimuli for participants and the neurocognitive processes underlying the N1/N170 elicited by these stimuli are not entirely clear, hampering a conclusive interpretation for the group effects in doodle-elicited N170 amplitudes. Future studies should test more familiar non-face stimuli (e.g., cars, houses) to examine the specificity or generality of social immersion effects.

The present findings are consistent with previous research indicating the experience in a new ethnic environment increases the neural actives underlying the processing facial emotion (Derntl et al., 2009; Elfenbein & Ambady, 2002). However, this finding is not in line with the results of Gajewski et al. (2008) of a negative association between the N170 latency to faces and the duration of stay for East-Asians in Western society. This inconsistency might be due to the length of social immersion experience, which on average was 6 months in the present study versus 5.5 years in Gajewski et al. (2008). This explanation needs to be examined in future studies.

For foreigners, the geographical region into which they were immersed constituted not only a different ethnic environment but also a new social environment. Therefore, the social immersion account might hold for a new social immersion without new ethnicity immersion. In order to distinguish these two aspects of social immersion we compared short-term Berlin residents with long-term Berlin residents in Experiment 2; however, the group difference on face N170 amplitudes was not significant. Thus, the enhanced face N170 for foreigners may not be accounted for by the immersion experience in a new social context. Possibly an abundance of new same ethnicity faces is not a comparable challenge to the visual system as an abundance of other ethnicity faces with more different features and configurations as will be discussed next.

5.3 | Massed exposure to other-race faces as a modulator of face processing?

The other-race effect is a well-known phenomenon whereby individuals discriminate, memorize, or identify other-race faces less effectively than for same-race faces (Byatt & Rhodes, 2004; Meissner & Brigham, 2001; Walker & Tanaka, 2003). However, the present results did not show any race effects on the behavioral or neural level. This is consistent with Senholzi and Ito (2013) using a similar 1-back task and might be due to low task difficulty since all performance was at or close to ceiling (e.g., mean accuracy for both East-Asian and Caucasian faces was 98%). In addition, since previous findings about race effects in the N170 are mixed, the absence of such an effect in the present study is also not unique. For instance, some researchers argue that the heterogeneity of N170 race effects might be due to methodological differences such as different task demands (Wiese, 2013). Nevertheless, the absence of N170 race effect in the present study is at variance with Senholzi and Ito (2013) who observed larger amplitudes for other-race than own-race faces in a 1-back identity repetition detection task. Here, the inconsistency might be due to the face stimuli compared, Caucasian versus East-Asian faces in the present study but Caucasian versus Black faces in Senholzi and Ito (2013). In sum, while the exact reason for the absence of OREs at behavioral and neural levels in the present study remains unclear, this is not uncommon and may initiate more research in order to understand the presence and causes of other-race effects.

On the other hand, the present study suggests that the massed exposure to new other-race faces is critical for enhancing the N170 amplitudes to faces in general. This is evidenced by the results of Experiment 2, indicating no group difference in the N170 between short-term and long-term German residents in Berlin. This view might be accounted for by the face space theory (Valentine, 1991), assuming that the substantial new other-race faces exposure may modify the representation system of face processing, such as influencing the average face weighted by the frequency of the encounter. This is supported by perceptual training studies in which training individuals in facial dimensions of other-race faces improve the performance of other-race faces (Hills & Lewis, 2006). Importantly, there was no modulation of the race on the N170 group differences in the present study, implying that increased experience with other-race faces in adults affects the neural level underlying the processing of both same- and other-race faces. The conclusion resonates with the problems of improving face recognition abilities in normotypical adults, where even extensive memory training with same-race faces did not lead to a notable improvement (Dolzycka et al., 2014). According to the present findings, other-race faces as training material might provide a better option.

5.4 | Expertise effects of N170 enhancements

The results of the present study also yield insight into the neural plasticity of expert face processing in adults. Firstly, the increased N170 amplitudes in participants who had social immersion experience in a novel ethnic social environment may reflect their perceptual problems in processing faces. Perceptual problem in face processing is exemplified by the face inversion effect of increases in the latency of the N170, and in many, but not all cases, increases in amplitude as compared to upright faces (Caharel et al., 2013; Jacques & Rossion, 2010; Rossion et al., 2000; Sadeh & Yovel, 2010). However, this suggestion was not supported by the current results, where larger N170 amplitudes in the foreign groups were not accompanied by longer latencies – despite the standard effect of face inversion on both N170 amplitude and latency was found in the present study. By contrast, consistent with previous studies (e.g., Tanaka & Curran, 2001) where the enhanced N170 amplitudes are generally found as a correlate of better visual expertise for certain stimuli, the larger N170 amplitudes in our foreigner groups may reflect their greater expertise in face processing. Thus, the social immersion experience in a novel ethnic social environment improves one's face expertise reflected by increased N170 amplitudes.

The greater visual expertise reflected by the increased N170 in many cases goes along with more pronounced configural perception (e.g., Gauthier et al., 2003; Rossion et al., 2002). Therefore, the group differences in the N170 may reflect the degree of configural visual processing. To address this issue, we used both upright and inverted faces in the present experiments. We expected that the group difference in the N170 might be smaller for inverted faces than for upright faces or there should be a larger face inversion effect in the N170 in foreign than in local participants. However, the critical interaction between group and orientation was not observed, that is, the observed group differences in the N170 were indistinguishable between upright and inverted faces. Hence, our findings do not provide evidence that the observed N170 increase due to social/ethnic immersion reflects differences in configural visual processing. In addition, the behavioral results also do not support the notion that the group differences in the N170 indicate differences in configural face processing as no group effects were observed. As the behavioral task used in the present was a very easy 1-back task – merely serving the monitoring of attention and controlling for the task difficulty across groups, future studies should investigate the effects of social immersion at the behavioral level by using suitable tasks.

Nevertheless, what remains to be discussed are the exact processes reflected by the group differences in the face-elicited N170 of the current study. As inversion of faces impairs configural, but not featural processing (e.g., Bartlett et al., 2003), the observed N170 differences may indicate the differences in facial feature processing. More specifically, we suggest that participants who are immersing in a new ethnic environment recognize unfamiliar faces in a feature-based process, which relies on the comparison of individual facial features such as the eyes, nose or mouth. This claim is supported by previous studies where the recognition of new faces, compared to old ones, relies relatively more on the processing of featural information (e.g., Lobmaier & Mast, 2007). In addition, perceptual training studies indicate that feature-by-feature strategies may improve unfamiliar face matching (Towler et al., 2017; White et al., 2015). Also, similar group differences as in the face-elicited N170 were observed for the control condition in Exp. 2 —doodles which are complex abstract patterns without clear relational/configural information; this observation, although not significant in Exp. 1, may indicate that the social immersion in a different ethnic environment may influence feature analysis rather than configural visual analysis.

Overall, the present findings suggest that the enhanced face-elicited N170 in foreigners as compared to locals might imply the effects of social immersion in facial feature processing rather than configural processing. This suggestion is not consistent with Ma et al. (2022) where the increased face-elicited N170 in Chinese children as compared to German children indicates a superiority of holistic processing in Chinese script readers. This inconsistency may suggest that there are dissociated underlying face processes affected by the script system acquisition and the social immersion experience. In addition, the current findings do not support claims that East-Asian participants show a general superiority of holistic processing as compared to Caucasian participants (e.g., Blais et al., 2008; Markus & Kitayama, 1991; Miyamoto et al., 2011). Since the evidence for this claim is heterogeneous (see introduction), our findings indicate that it may have to be qualified by the factor social/ethnic immersion.

5.5 | Limitations and perspectives

The present experiment has some shortcomings that might be dealt with in future studies. Firstly, we examined the effects of immersion experience only for a relatively narrow range of immersion durations. Therefore, it would be interesting to explore the time-course of immersion experience effects. Furthermore, this might be combined with, a more direct proof of the immersion account by using a longitudinal design. Secondly, the sample size of Study 1 was smaller than 20 participants per group, which raises the concern of power. However, the critical results, i.e., the main effect of group ($F(1, 34) = 5.52$, $p = .025$, $\eta_p^2 = 0.14$) and the significant interaction between group, stimulus orientation and hemisphere ($F(1, 34) = 4.28$, $p = .046$, $\eta_p^2 = 0.11$), showed that the effect sizes estimated by η_p^2 were equal or close to 0.14, corresponding to large effects (Miles & Shevlin, 2001). Thus, the sample size of Study 1 seems to be appropriate to reveal the group differences observed. The third limitation of the present study is the absence of a control group, testing whether social immersion in a foreign country (that is, foreign in language and culture) might influence face processing even if ethnicity of the social environment is constant. Future studies should address this issue by comparing local participants with participants who are foreigners but share the same ethnicity as the locals.

The fourth shortcoming in the present study is the lack of high-level performance data – it would be very interesting to see whether the enhanced N170 during other-ethnicity immersion is accompanied by changes in visual performance or whether the enhanced N170 is merely an epiphenomenon of an overexcited fusiform face area without functional consequences. Finally, our study only focused on the effects of social immersion in Asian-Caucasian settings (i.e., Asians in Caucasian countries and vice versa); thus, the results may not generalize to other settings. For instance, African participants who have immersion experience in Caucasian/Asian countries and vice versa, because of potential differences in associated racial attitudes (e.g., positive and negative social attitudes toward specific ethnicities) and race-related physical differences (e.g., the shape of the eye region seems more similar between African and Caucasian faces than it is between Caucasian and Asian faces). In addition, comparing to Asian-Caucasian setting, the African-Caucasian setting would separate the social immersion account from the script system account and the holistic vs. analytic culture account. Therefore, future studies could test whether the social immersion account applies also to other cultural settings such as African participants with immersion experience in Caucasian/Asian countries and vice versa.

The present findings suggest a fascinating application perspective. Given that immersion in a different ethnic environment activates the face processing system, making it more plastic at least for a while, might provide the chance to use other-race faces as training material to improve face-specific abilities.

6 | CONCLUSIONS

In the present study we investigated two possible experience effects on face processing at the neural level, a culture-specific effect – possibly due to exposure to the logographic script, and a more specific effect of immersion into a novel social environment. We found larger N170 amplitudes to faces in participants that were foreigners to the lab locations as compared to local participants; importantly, this difference was independent of the location of residence (East-Asian society vs. Western society). In addition, the observed group difference was indistinguishable between same-and other-race faces. We conclude that immersion into a novel environment of different ethnicity may have an impact on the underlying neural mechanism for faces in general, independent of the ethnicity of stimulus faces. Nevertheless, the N170 group effects were unaffected by stimulus orientation, suggesting the observed N170 increase due to social/ethnic immersion does not reflect differences in configural visual processing. These findings offer novel insights into the effect of visual experience on face processing in times of globalization and increasing international exchange and interactions.

AUTHOR CONTRIBUTIONS

Xiaoli Ma: Conceptualization; investigation; methodology; software; validation; visualization. **Nick Modersitzki:** Conceptualization; investigation; methodology; software. **Urs Maurer:** Conceptualization; methodology; resources; supervision. **Werner Sommer:** Conceptualization; methodology; resources; supervision.

ACKNOWLEDGMENTS

This research was supported by the Germany-Hong Kong Joint Research Scheme of the Research Grants Council (G-CUHK409/18) and the German Academic Exchange Service (DAAD, Project 57447990), the Erasmus+ student exchange programme, and the China Scholarship Council under Grant No. 201708330288. We thank Lut Ching Au, Sophie Dunn, Jing Kang, Tak Hin Lee, Xinran Li, Tin Yan Ng, Elif Salur and Fang Wang for their assistance in data collection, and Ulrike Bunzenthal, Rainer Kniesche and Thomas Pinkpank for technical support. Open Access funding enabled and organized by Projekt DEAL.

CONFLICT OF INTEREST

None.

ORCID

Xiaoli Ma https://orcid.org/0000-0002-2335-9812

REFERENCES

Ashworth, A. R. S., Vuong, Q. C., Rossion, B., & Tarr, M. J. (2008). Recognizing rotated faces and greebles: What properties drive the face inversion effect? *Visual Cognition*, *16*(6), 754–784. https://doi.org/10.1080/13506280701381741

Bartlett, J. C., Searcy, J. H., & Abdi, H. (2003). What are the routes to face recognition? In M. Peterson & G. Rhodes (Eds.), *Perception of faces, objects and scenes: Analytic and holistic processes* (pp. 21–52). Oxford University Press.

Blais, C., Jack, R. E., Scheepers, C., Fiset, D., & Caldara, R. (2008). Culture shapes how we look at faces. *PLoS ONE*, *3*(8), e3022. https://doi.org/10.1371/journal.pone.0003022

Brem, S., Halder, P., Bucher, K., Summers, P., Martin, E., & Brandeis, D. (2009). Tuning of the visual word processing system: Distinct developmental ERP and fMRI effects. *Human Brain Mapping*, *30*(6), 1833–1844. https://doi.org/10.1002/hbm.20751

Busey, T. A., & Vanderkolk, J. R. (2005). Behavioral and electrophysiological evidence for configural processing in fingerprint experts. *Vision Research*, *45*(4), 431–448. https://doi.org/10.1016/j.visres.2004.08.021

Byatt, G., & Rhodes, G. (2004). Identification of own-race and other-race faces: Implications for the representation of race in face space. *Psychonomic Bulletin & Review*, *11*(4), 735–741. https://doi.org/10.3758/BF03196628

Caharel, S., Leleu, A., Bernard, C., Viggiano, M.-P., Lalonde, R., & Rebaï, M. (2013). Early holistic face-like processing of Arcimboldo paintings in the right occipito-temporal cortex: Evidence from the N170 ERP component. *International Journal of Psychophysiology*, *90*(2), 157–164. https://doi.org/10.1016/j.ijpsycho.2013.06.024

Caldara, R., Rossion, B., Bovet, P., & Hauert, C. A. (2004). Event-related potentials and time course of the "other-race" face classification advantage. *Neuroreport*, *15*, 905–910. https://doi.org/10.1097/00001756-200,404,090-00034

Caldara, R., Thut, G., Servoir, P., Michel, C. M., Bovet, P., & Renault, B. (2003). Face versus non-face object perception and the 'other-race' effect: A spatiotemporal event-related potential study. *Clinical Neurophysiology*, *114*, 515–528. https://doi.org/10.1016/S1388-2457(02)00407-8

Cao, X., Li, S., Zhao, J., Lin, S., & Weng, X. (2011). Left-lateralized early neurophysiological response for Chinese characters in young primary school children. *Neuroscience Letters*, *492*(3), 165–169. https://doi.org/10.1016/j.neulet.2011.02.002

Chang, L.-Y., Plaut, D. C., & Perfetti, C. A. (2016). Visual complexity in orthographic learning: Modeling learning across writing system variations. *Scientific Studies of Reading*, *20*(1), 64–85. https://doi.org/10.1080/10888438.2015.1104688

Chuk, T., Crookes, K., Hayward, W. G., Chan, A. B., & Hsiao, J. H. (2017). Hidden Markov model analysis reveals the advantage of analytic eye movement patterns in face recognition across cultures. *Cognition*, *169*, 102–117. https://doi.org/10.1016/j.cognition.2017.08.003

Clark, V. P., Fan, S., & Hillyard, S. A. (1994). Identification of early visual evoked potential generators by retinotopic and topographic analyses. *Human Brain Mapping*, *2*(3), 170–187. https://doi.org/10.1002/hbm.460020306

Dehaene, S., & Cohen, L. (2007). Cultural recycling of cortical maps. *Neuron*, *56*(2), 384–398. https://doi.org/10.1016/j.neuron.2007.10.004

Dehaene, S., Cohen, L., Morais, J., & Kolinsky, R. (2015). Illiterate to literate: Behavioural and cerebral changes induced by reading acquisition. *Nature Reviews Neuroscience*, *16*(4), 234–244. https://doi.org/10.1038/nrn3924

Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Filho, G. N., Jobert, A., Dehaene-Lambertz, G., Kolinsky, R., Morais, J., & Cohen, L. (2010). How learning to read changes the cortical networks for vision and language. *Science*, *330*(6009), 1359–1364. https://doi.org/10.1126/science.1194140

Demetriou, A., Kui, Z. X., Spanoudis, G., Christou, C., Kyriakides, L., & Platsidou, M. (2005). The architecture, dynamics, and development of mental processing: Greek, Chinese, or universal? *Intelligence*, *33*(2), 109–141. https://doi.org/10.1016/j.intell.2004.10.003

Dering, B., Hoshino, N., & Theirry, G. (2013). N170 modulation is expertise driven: Evidence from word-inversion effects in speakers of different languages. *Neuropsycholo Trend*, *13*, 1–16.

Derntl, B., Habel, U., Robinson, S., Windischberger, C., Kryspin-Exner, I., Gur, R. C., & Moser, E. (2009). Amygdala activation during recognition of emotions in a foreign ethnic group is associated with duration of stay. *Social Neuroscience*, *4*(4), 294–307. https://doi.org/10.1080/17470910802571633

Di Russo, F., Martínez, A., Sereno, M. I., Pitzalis, S., & Hillyard, S. A. (2002). Cortical sources of the early components of the visual evoked potential: Cortical sources of VEP. *Human Brain Mapping*, *15*(2), 95–111. https://doi.org/10.1002/hbm.10010

Diamond, R., & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology: General*, *115*(2), 107–117. https://doi.org/10.1037/0096-3445.115.2.107

Dolzycka, D., Herzmann, G., Sommer, W., & Wilhelm, O. (2014). Can training enhance face cognition abilities in middle-aged adults? *PLoS ONE*, *9*(3), e90249. https://doi.org/10.1371/journal.pone.0090249

Dundas, E. M., Plaut, D. C., & Behrmann, M. (2014). An ERP investigation of the co-development of hemispheric lateralization of face and word recognition. *Neuropsychologia*, *61*, 315–323. https://doi.org/10.1016/j.neuropsychologia.2014.05.006

Eimer, M. (2011). The face-sensitive N170 component of the event-related brain potential. In A. J. Calder, G. Rhodes, M. Johnson, & J. Haxby (Eds.), *The Oxford handbook of face perception* (Vol. *28*, pp. 329–344). Oxford University Press.

Eimer, M., Gosling, A., Nicholas, S., & Kiss, M. (2011). The N170 component and its links to configural face processing: A rapid neural adaptation study. *Brain Research*, *1376*, 76–87. https://doi.org/10.1016/j.brainres.2010.12.046

Elfenbein, H. A., & Ambady, N. (2002). On the universality and cultural specificity of emotion recognition: A meta-analysis. *Psychological Bulletin*, *128*(2), 203–235. https://doi.org/10.1037/0033-2909.128.2.203

Gajewski, P. D., Schlegel, K., & Stoerig, P. (2008). Effects of human race and face inversion on the N170: A cross-race study. *Journal of Psychophysiology*, *22*(4), 157–165. https://doi.org/10.1027/0269-8803.22.4.157

Gauthier, I., Curran, T., Curby, K. M., & Collins, D. (2003). Perceptual interference supports a non-modular account of face processing. *Nature Neuroscience*, *6*(4), 428–432. https://doi.org/10.1038/nn1029

Herrmann, M. J., Ehlis, A.-C., Muehlberger, A., & Fallgatter, A. J. (2005). Source localization of early stages of face processing. *Brain Topography*, *18*(2), 77–85. https://doi.org/10.1007/s10548-005-0277-7

Herrmann, M. J., Schreppel, T., Jäger, D., Koehler, S., Ehlis, A.-C., & Fallgatter, A. J. (2007). The other-race effect for face perception: An event-related potential study. *Journal of Neural Transmission*, *114*(7), 951–957. https://doi.org/10.1007/s00702-007-0624-9

Hervais-Adelman, A., Kumar, U., Mishra, R. K., Tripathi, V. N., Guleria, A., Singh, J. P., Eisner, F., & Huettig, F. (2019). Learning to read recycles visual cortical networks without destruction. *Science. Advances*, *5*(9), eaax0262. https://doi.org/10.1126/sciadv.aax0262

Herzmann, G., Willenbockel, V., Tanaka, J. W., & Curran, T. (2011). The neural correlates of memory encoding and recognition for own-race and other-race faces. *Neuropsychologia*, *49*(11), 3103–3115. https://doi.org/10.1016/j.neuropsychologia.2011.07.019

Hildebrandt, A., Sommer, W., Herzmann, G., & Wilhelm, O. (2010). Structural invariance and age-related performance differences in face cognition. *Psychology and Aging*, *25*(4), 794–810. https://doi.org/10.1037/a0019774

Hills, P. J., & Lewis, M. B. (2006). Short Article: Reducing the Own-Race Bias in Face Recognition by Shifting Attention. *Quarterly Journal of Experimental Psychology*, *59*(6), 996–1002. https://doi.org/10.1080/17470210600654750

Hillyard, S. A., Teder-Sälejärvi, W. A., & Münte, T. F. (1998). Temporal dynamics of early perceptual processing. *Current Opinion in Neurobiology*, *8*(2), 202–210. https://doi.org/10.1016/S0959-4388(98)80141-4

Huang, H. S., & Hanley, J. R. (1995). Phonological awareness and visual skills in learning to read Chinese and English. *Cognition*, *54*(1), 73–98. https://doi.org/10.1016/0010-0277(94)00641-W

Hugenberg, K., & Corneille, O. (2009). Holistic processing is tuned for in-group faces. *Cognitive Science*, *33*(6), 1173–1181. https://doi.org/10.1111/j.1551-6709.2009.01048.x

Hugenberg, K., Young, S. G., Bernstein, M. J., & Sacco, D. F. (2010). The categorization-individuation model: An integrative account of the other-race recognition deficit. *Psychological Review*, *117*(4), 1168–1187. https://doi.org/10.1037/a0020463

Hussain, Z., Sekuler, A. B., & Bennett, P. J. (2009). Perceptual learning modifies inversion effects for faces and textures.

Vision Research, *49*(18), 2273–2284. https://doi.org/10.1016/j.visres.2009.06.014

Itier, R. J., & Taylor, M. J. (2002). Inversion and contrast polarity reversal affect both encoding and recognition processes of unfamiliar faces: A repetition study using ERPs. *NeuroImage*, *15*(2), 353–372. https://doi.org/10.1006/nimg.2001.0982

Itier, R. J., & Taylor, M. J. (2004a). N170 or N1? Spatiotemporal differences between object and face processing using ERPs. *Cerebral Cortex*, *14*(2), 132–142. https://doi.org/10.1093/cercor/bhg111

Itier, R. J., & Taylor, M. J. (2004b). Effects of repetition learning on upright, inverted and contrast-reversed face processing using ERPs. *NeuroImage*, *21*(4), 1518–1532. https://doi.org/10.1016/j.neuroimage.2003.12.016

Ito, T. A., & Urland, G. R. (2005). The influence of processing objectives on the perception of faces: An ERP study of race and gender perception. *Cognitive, Affective, & Behavioral Neuroscience*, *5*(1), 21–36. https://doi.org/10.3758/CABN.5.1.21

Jacques, C., & Rossion, B. (2010). Misaligning face halves increases and delays the N170 specifically for upright faces: Implications for the nature of early face representations. *Brain Research*, *1318*, 96–109. https://doi.org/10.1016/j.brainres.2009.12.070

Koenig, T., Kottlow, M., Stein, M., & Melie-García, L. (2011). Ragu: A free tool for the analysis of EEG and MEG event-related scalp field data using global randomization statistics. *Computational Intelligence and Neuroscience*, *2011*, 1–14. https://doi.org/10.1155/2011/938925

Koenig, T., & Melie-García, L. (2009). Statistical analysis of multichannel scalp field data. In C. M. Michel, T. Koenig, D. Brandeis, L. R. R. Gianotti, & J. Wackermann (Eds.), *Electrical neuroimaging* (pp. 169–190). Cambridge University Press. https://doi.org/10.1017/CBO9780511596889.009

Latinus, M., & Taylor, M. J. (2005). Holistic processing of faces: Learning effects with Mooney faces. *Journal of Cognitive Neuroscience*, *17*(8), 1316–1327. https://doi.org/10.1162/0898929055002490

Lehmann, D., & Skrandies, W. (1980). Reference-free identification of components of checkerboard-evoked multichannel potential fields. *Electroencephalography and Clinical Neurophysiology*, *48*(6), 609–621. https://doi.org/10.1016/0013-4694(80)90419-8

Li, S., Lee, K., Zhao, J., Yang, Z., He, S., & Weng, X. (2013). Neural competition as a developmental process: Early hemispheric specialization for word processing delays specialization for face processing. *Neuropsychologia*, *51*(5), 950–959. https://doi.org/10.1016/j.neuropsychologia.2013.02.006

Liu, J., Tian, J., Li, J., Gong, Q., & Lee, K. (2009). Similarities in neural activations of face and Chinese character discrimination. *NeuroReport*, *20*(3), 273–277. https://doi.org/10.1097/WNR.0b013e32832000f8

Lobmaier, J. S., & Mast, F. W. (2007). Perception of novel faces: The parts have it! *Perception*, *36*(11), 1660–1673. https://doi.org/10.1068/p5642

Ma, X., Kang, J., Li, X., Maurer, U., Cao, X., & Sommer, W. (2022). Does learning different script systems affect configural visual processing? ERP evidence from early readers of Chinese and German. *Psychophysiology*, *59*(6), e14006. https://doi.org/10.1111/psyp.14006

Markus, H. R., & Kitayama, S. (1991). Culture and the self: Implications for cognition, emotion, and motivation. *Psychological Review*, *98*(2), 224–253. https://doi.org/10.1037/0033-295X.98.2.224

Maurer, D., Grand, R. L., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences*, *6*(6), 255–260. https://doi.org/10.1016/S1364-6613(02)01903-4

Maurer, U., Rossion, B., & McCandliss, B. D. (2008). Category specificity in early perception: Face and word n170 responses differ in both lateralization and habituation properties. *Frontiers in Human Neuroscience*, *2*, 18. https://doi.org/10.3389/neuro.09.018.2008

Maurer, U., Schulz, E., Brem, S., van der Mark, S., Bucher, K., Martin, E., & Brandeis, D. (2011). The development of print tuning in children with dyslexia: Evidence from longitudinal ERP data supported by fMRI. *NeuroImage*, *57*(3), 714–722. https://doi.org/10.1016/j.neuroimage.2010.10.055

McBride-Chang, C., Zhou, Y., Cho, J.-R., Aram, D., Levin, I., & Tolchinsky, L. (2011). Visual spatial skill: A consequence of learning to read? *Journal of Experimental Child Psychology*, *109*(2), 256–262. https://doi.org/10.1016/j.jecp.2010.12.003

Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy, and Law*, *7*(1), 3–35. https://doi.org/10.1037/1076-8971.7.1.3

Michel, C., Caldara, R., & Rossion, B. (2006). Same-race faces are perceived more holistically than other-race faces. *Visual Cognition*, *14*(1), 55–73. https://doi.org/10.1080/13506280500158761

Miellet, S., Vizioli, L., He, L., Zhou, X., & Caldara, R. (2013). Mapping face recognition information use across cultures. *Frontiers in Psychology*, *4*, 34. https://doi.org/10.3389/fpsyg.2013.00034

Miles, J., & Shevlin, M. (2001). *Applying regression and correlation: A guide for students and researchers*. Sage.

Miyamoto, Y., Yoshikawa, S., & Kitayama, S. (2011). Feature and configuration in face processing: Japanese are more configural than Americans. *Cognitive Science*, *35*(3), 563–574. https://doi.org/10.1111/j.1551-6709.2010.01163.x

Mooney, C. M. (1957). Age in the development of closure ability in children. *Canadian Journal of Psychology/Revue Canadienne de Psychologie*, *11*(4), 219–226. https://doi.org/10.1037/h0083717

Murray, M. M., Brunet, D., & Michel, C. M. (2008). Topographic ERP analyses: A step-by-step tutorial review. *Brain Topography*, *20*(4), 249–264. https://doi.org/10.1007/s10548-008-0054-5

Nisbett, R. E., Peng, K., Choi, I., & Norenzayan, A. (2001). Culture and systems of thought: Holistic versus analytic cognition. *Psychological Review*, *108*(2), 291–310. https://doi.org/10.1037/0033-295X.108.2.291

Obrig, H., Israel, H., Kohl-Bareis, M., Uludag, K., Wenzel, R., Muller, B., Arnold, G., & Villringer, A. (2002). Habituation of the visually evoked potential and its vascular response: Implications for neurovascular coupling in the healthy adult. *Neuroimage*, *17*(1), 1–18. https://doi.org/10.1006/nimg.2002.1177

Or, C. C.-F., Peterson, M. F., & Eckstein, M. P. (2015). Initial eye movements during face identification are optimal and similar across cultures. *Journal of Vision*, *15*(13), 12. https://doi.org/10.1167/15.13.12

Oruc, I., Shafai, F., Murthy, S., Lages, P., & Ton, T. (2019). The adult face-diet: A naturalistic observation study. *Vision Research*, *157*, 222–229. https://doi.org/10.1016/j.visres.2018.01.001

Pegado, F., Comerlato, E., Ventura, F., Jobert, A., Nakamura, K., Buiatti, M., Ventura, P., Dehaene-Lambertz, G., Kolinsky, R., Morais, J., Braga, L. W., Cohen, L., & Dehaene, S. (2014). Timing the impact of literacy on visual processing. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(49), E5233–E5242. https://doi.org/10.1073/pnas.1417347111

Rayner, K., Li, X., Williams, C. C., Cave, K. R., & Well, A. D. (2007). Eye movements during information processing tasks: Individual differences and cultural effects. *Vision Research*, *47*(21), 2714–2726. https://doi.org/10.1016/j.visres.2007.05.007

Rhodes, G., Brake, S., Taylor, K., & Tan, S. (1989). Expertise and configural coding in face recognition. *British Journal of Psychology*, *80*(3), 313–331. https://doi.org/10.1111/j.2044-8295.1989.tb02323.x

Rhodes, G., Ewing, L., Hayward, W. G., Maurer, D., Mondloch, C. J., & Tanaka, J. W. (2009). Contact and other-race effects in configural and component processing of faces. *British Journal of Psychology*, *100*(4), 717–728. https://doi.org/10.1348/000712608X396503

Rodger, H., Kelly, D. J., Blais, C., & Caldara, R. (2010). Inverting faces does not abolish cultural diversity in eye movements. *Perception*, *39*(11), 1491–1503. https://doi.org/10.1068/p6750

Rossion, B., & Curran, T. (2010). Visual expertise with pictures of cars correlates with RT magnitude of the car inversion effect. *Perception*, *39*(2), 173–183. https://doi.org/10.1068/p6270

Rossion, B., Gauthier, I., Goffaux, V., Tarr, M. J., & Crommelinck, M. (2002). Expertise training with novel objects leads to left-lateralized Facelike electrophysiological responses. *Psychological Science*, *13*(3), 250–257. https://doi.org/10.1111/1467-9280.00446

Rossion, B., Gauthier, I., Tarr, M. J., Despland, P., Bruyer, R., Linotte, S., & Crommelinck, M. (2000). The N170 occipito-temporal component is delayed and enhanced to inverted faces but not to inverted objects: An electrophysiological account of face-specific processes in the human brain. *NeuroReport*, *11*(1), 69–72. https://doi.org/10.1097/00001756-200001170-00014

Rossion, B., & Jacques, C. (2011). The N170: Understanding the time course of face perception in the human brain. In S. J. Luck & E. S. Kappenman (Eds.), *The Oxford handbook of event-related potential components* (pp. 115–141). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780195374148.013.0064

Rossion, B., & Jacques, C. (2008). Does physical interstimulus variance account for early electrophysiological face sensitive responses in the human brain? Ten lessons on the N170. *NeuroImage*, *39*(4), 1959–1979. https://doi.org/10.1016/j.neuroimage.2007.10.011

Rossion, B., Joyce, C. A., Cottrell, G. W., & Tarr, M. J. (2003). Early lateralization and orientation tuning for face, word, and object processing in the visual cortex. *NeuroImage*, *20*(3), 1609–1624. https://doi.org/10.1016/j.neuroimage.2003.07.010

Rossion, B., Kung, C.-C., & Tarr, M. J. (2004). Visual expertise with nonface objects leads to competition with the early perceptual processing of faces in the human occipitotemporal cortex. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(40), 14521–14526. https://doi.org/10.1073/pnas.0405613101

Sadeh, B., & Yovel, G. (2010). Why is the N170 enhanced for inverted faces? An ERP competition experiment. *NeuroImage*, *53*(2), 782–789. https://doi.org/10.1016/j.neuroimage.2010.06.029

Sagiv, N., & Bentin, S. (2001). Structural encoding of human and schematic faces: Holistic and part-based processes. *Journal of Cognitive Neuroscience*, *13*(7), 937–951. https://doi.org/10.1162/089892901753165854

Schendan, H. E., Ganis, G., & Kutas, M. (1998). Neurophysiological evidence for visual perceptual categorization of words and faces within 150 ms. *Psychophysiology*, *35*(3), 240–251. https://doi.org/10.1111/1469-8986.3530240

Schinkel, S., Ivanova, G., Kurths, J., & Sommer, W. (2014). Modulation of the N170 adaptation profile by higher level factors. *Biological psychology*, *97*, 27–34. https://doi.org/10.1016/j.biopsycho.2014.01.003

Scott, L. S., Tanaka, J. W., Sheinberg, D. L., & Curran, T. (2006). A reevaluation of the rlectrophysiological correlates of expert object processing. *Journal of Cognitive Neuroscience*, *18*(9), 1453–1465. https://doi.org/10.1162/jocn.2006.18.9.1453

Scott, L. S., Tanaka, J. W., Sheinberg, D. L., & Curran, T. (2008). The role of category learning in the acquisition and retention of perceptual expertise: A behavioral and neurophysiological study. *Brain Research*, *1210*, 204–215. https://doi.org/10.1016/j.brainres.2008.02.054

Senholzi, K. B., & Ito, T. A. (2013). Structural face encoding: How task affects the N170's sensitivity to race. *Social Cognitive and Affective Neuroscience*, *8*(8), 937–942. https://doi.org/10.1093/scan/nss091

Sigman, M., & Gilbert, C. D. (2000). Learning to find a shape. *Nature Neuroscience*, *3*(3), 264–269. https://doi.org/10.1038/72979

Stahl, J., Wiese, H., & Schweinberger, S. R. (2008). Expertise and own-race bias in face processing: An event-related potential study. *NeuroReport*, *19*(5), 583–587. https://doi.org/10.1097/WNR.0b013e3282f97b4d

Szwed, M., Dehaene, S., Kleinschmidt, A., Eger, E., Valabrègue, R., Amadon, A., & Cohen, L. (2011). Specialization for written words over objects in the visual cortex. *NeuroImage*, *56*(1), 330–344. https://doi.org/10.1016/j.neuroimage.2011.01.073

Tanaka, J. W., & Curran, T. (2001). A neural basis for expert object recognition. *Psychological Science*, *12*(1), 43–47. https://doi.org/10.1111/1467-9280.00308

Tanaka, J. W., Kiefer, M., & Bukach, C. M. (2004). A holistic account of the own-race effect in face recognition: Evidence from a cross-cultural study. *Cognition*, *93*, B1–B9.

Tanaka, J. W., & Pierce, L. J. (2009). The neural plasticity of other-race face recognition. *Cognitive, Affective, & Behavioral Neuroscience*, *9*(1), 122–131. https://doi.org/10.3758/CABN.9.1.122

Towler, A., Kemp, R. I., & White, D. (2017). Unfamiliar face matching systems in applied settings. In M. Bindemann & A. M. Megreya (Eds.), *Face processing: Systems, disorders and cultural differences* (pp. 21–40). Nova Science Publishing, Inc.

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *The Quarterly Journal of Experimental Psychology Section A*, *43*(2), 161–204. https://doi.org/10.1080/14640749108400966

van Paridon, J., Ostarek, M., Arunkumar, M., & Huettig, F. (2021). Does neuronal recycling result in destructive competition? The influence of learning to read on the recognition of faces. *Psychological Science*, *32*(3), 459–465. https://doi.org/10.1177/0956797620971652

Varnum, M. E. W., Grossmann, I., Kitayama, S., & Nisbett, R. E. (2010). The origin of cultural differences in cognition: The social orientation hypothesis. *Current Directions in Psychological Science*, *19*(1), 9–13. https://doi.org/10.1177/0963721409359301

Vizioli, L., Rousselet, G. A., & Caldara, R. (2010). Neural repetition suppression to identity is abolished by other-race faces. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(46), 20081–20086. https://doi.org/10.1073/pnas.1005751107

Walker, P. M., & Tanaka, J. W. (2003). An encoding advantage for own-race versus oher-race faces. *Perception*, *32*(9), 1117–1125. https://doi.org/10.1068/p5098

Wang, M.-Y., Kuo, B.-C., & Cheng, S.-K. (2011). Chinese characters elicit face-like N170 inversion effects. *Brain and Cognition*, *77*(3), 419–431. https://doi.org/10.1016/j.bandc.2011.08.016

Wastell, D. G., & Kleinman, D. (1980). Potentiation of the habituation of human brain potentials. *Biological Psychology*, *10*(1), 21–29. https://doi.org/10.1016/0301-0511(80)90004-6

White, D., Phillips, P. J., Hahn, C. A., Hill, M., & O'Toole, A. J. (2015). Perceptual expertise in forensic facial image comparison. *Proceedings of the Royal Society B: Biological Sciences*, *282*(1814), 20151292. https://doi.org/10.1098/rspb.2015.1292

Wiese, H. (2013). Do neural correlates of face expertise vary with task demands? Event-related potential correlates of own- and other-race face inversion. *Frontiers in Human Neuroscience*, *7*, 898. https://doi.org/10.3389/fnhum.2013.00898

Wiese, H., Kaufmann, J. M., & Schweinberger, S. R. (2014). The neural signature of the own-race bias: Evidence from event-related potentials. *Cerebral Cortex*, *24*(3), 826–835. https://doi.org/10.1093/cercor/bhs369

Yi, D.-J., Olson, I. R., & Chun, M. M. (2006). Shape-specific perceptual learning in a figure-ground segregation task. *Vision Research*, *46*(6–7), 914–924. https://doi.org/10.1016/j.visres.2005.09.009

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology*, *81*(1), 141–145. https://doi.org/10.1037/h0027474

Young, S. G., Hugenberg, K., Bernstein, M. J., & Sacco, D. F. (2012). Perception and motivation in mace recognition: A critical review of theories of the cross-race effect. *Personality and Social Psychology Review*, *16*(2), 116–142. https://doi.org/10.1177/1088868311418987

Zhong, N., Hsiao, J., Zhou, G., & Hayward, W. (2021). Idiosyncratic eye-movement patterns modulate holistic processing of faces: Evidence from the composite face effect and the inverted face effect. *Journal of Vision*, *21*(9), 1851. https://doi.org/10.1167/jov.21.9.1851

Zion-Golumbic, E., & Bentin, S. (2007). Dissociated neural mechanisms for face detection and configural encoding: Evidence from N170 and induced gamma-band oscillation effects. *Cerebral Cortex*, *17*(8), 1741–1749. https://doi.org/10.1093/cercor/bhl100

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix S1

How to cite this article: Ma, X., Modersitzki, N., Maurer, U., & Sommer, W. (2023). Neural sensitivity to faces is increased by immersion into a novel ethnic environment: Evidence from ERPs. *Psychophysiology*, *60*, e14147. https://doi.org/10.1111/psyp.14147