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Asymmetric neurocognitive representation of ethnic in-group/out-group faces

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To investigate asymmetric neurocognitive representation of ethnic in-group and out-group members, we recorded event-related potentials (ERPs) to faces in a perceptual task after the faces had been primed with positive or negative affective links. The affective link priming did not influence the ERPs to ethnic out-group faces. However, relative to the positive affective link priming, the negative affective link priming increased the amplitudes of an early frontal negativity (N100) and a following central negativity but decreased the amplitude of a late positive potential elicited by ethnic in-group faces. Moreover, the N100 amplitude correlated with the degree of negative attitudes towards ethnic in-group faces. The findings suggest that multiple-level neural mechanisms are involved in individuation of heterogeneous ethnic in-group faces.

affective link, ERP, ethnicity, face

Social categorization of others helps to simplify the person perception process and is of fundamental importance for humans to take appropriate actions during social interactions[1]. Social categories are perceived differently depending on whether a perceiver is included or excluded[2]. For example, people categorize those of the same race as in-group members whereas those of other races as out-group members[3]. Such ethnic in-group/out-group categorization occurs independent of task and attention demands[4]. Recent neuroimaging studies demonstrate that multiple-level neural mechanisms are involved in categorization of ethnic in-group and out-group faces. The fusiform activity increases to ethnic in-group than out-group faces[5] whereas the amygdala activity showed a reverse pattern[6]. Event-related potential (ERP) studies showed that amplitudes of a short-latency frontal negativity (N100) and long-latency ERP components (N2 and LPP) also differentiated between ethnic in-group and out-group faces[7]. While the neuroimaging findings identified neural substrates involved in categorization of faces into the ethnic in-group and out-group, the neural mechanism mediating differentiation of sub-categories in the ethnic in-group or out-group remains poorly understood.

Social psychologists argue that an in-group is construed more in terms of an aggregate of separate entities rather than in terms of a social category, whereas an out-group is construed more in terms of a category since all members share at least one salient feature[8]. The asymmetric cognitive representation of in-group and out-group members is characterized respectively by a heterogeneous aggregate of individuals and a homogeneous social category. Consistent with this, ethnic in-group faces are represented by a large cloud containing many exemplars whereas ethnic out-group faces are represented in a smaller, more dense area of the space (the multidimensional space hypothesis)[9,10], resulting in better discriminations[9] and memory[11] of ethnic in-group than out-group faces. The asymmetric cognitive representation of in-group and out-group members

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may lead to different emotional responses to ethnic in-group and out-group members such that people show exaggerated affective responses to ethnic in-group members but not to pictures of ethnic out-group members[12].

To investigate whether distinct neurocognitive processes engage in the asymmetric cognitive representation of ethnic in-group and out-group faces, we recorded ERPs from Han[1)] Chinese when they responded to orientations of ethnic in-group (Han Chinese) and out-group (Uygur[2)] Chinese) faces that had been primed with positive or negative affective links using video clips in which the face owners behaved aggressively or amicably towards observers. We examined whether the affective link priming, which induced individuation of target faces in terms of positive or negative attitudes, modulates neural activity underlying the processing of ethnic in-group or out-group faces. Of particular interests is whether the neural activity in association with differentiation of individual faces of ethnic in-group members is stronger than that of ethnic out-group members.

1 Methods

1.1 Subjects

Fourteen healthy college students (7 females, mean age = 20.9±2.17) in Urumchi, the capital of Xinjiang Uygur Autonomous Region of China, participated in this study. All were born and reared by Han Chinese parents. All were right-handed and had normal or corrected-to-normal vision. Informed consent was obtained prior to the study.

1.2 Stimuli and procedure

Visual stimuli consisted of 40 digital pictures obtained from 4 unfamiliar male actors (2 Han Chinese and 2 Uygur Chinese). Ten photos of faces with neutral expression were taken from each actor using a digital camera. The faces were oriented to the left in five images and to the right in the other images between 30 and 90 degrees. The luminance and contrast of each image were calibrated to the means to eliminate the influence of low-level perceptual properties on behavioral and neural responses. Each picture subtended a visual angle of 4.3°×4.6° at a viewing distance of 70 cm on a 17-inch color monitor. Each participant performed 8 blocks of 80 trials in a face orientation identification task. In each block of trials, half of the faces were oriented to the left and half to the right. On each trial a face stimulus was presented for 200 ms followed by a fixation cross with a duration that varied randomly from 800 to 1200 ms. Faces of different actors with different orientations were presented in a random order. Participants had to judge the face orientation of each stimulus by pressing one of the two buttons with the left or right index finger. Instructions emphasized both response speed and accuracy.

Two 30-s video clips were recorded from each actor who performed friendly behaviors (e.g., smile or wave) in one clip but aggressive behaviors (e.g., pointing to the observer using a gun or knife) in another one towards observers. Before every two blocks of trials requiring face-orientation identification, participants were shown with four video clips to induce their temporary affective link with each actor. One Han and one Uygur actor in the video clips behaved amicably whereas another Han and another Uygur actor behaved aggressively. The affective link with each actor was invariant for each participant during the electrophysiological (EEG) recording procedure but was counterbalanced across participants so that identical face stimuli were used in positive and negative affective link conditions.

1.3 Manipulation check

To measure the primed affective link with each actor, after the EEG recording procedure, participants were asked to rate their attitudes towards each actor by answering three questions on an 11-point scale (–5 = extremely negative, 5 = extremely positive): (1) How nice was the actor? (2) How much do you like the actor? (3) How much do you want to make friends with the actor?

1.4 ERP data recording and analysis

EEG was recorded (250-Hz sampling rate, 0.01- to 40-Hz band-pass filter) from 32 scalp electrodes and referenced to the average of the left and right mastoid electrodes. Electrode impedance was kept below 5

1) Han is an ethnic group in China that constitutes about 91.53% of the population of China and 40% of the population of Xinjiang Uygur Autonomous Region of China according to *China Population Statistics Yearbook* 2006 (National Bureau of Statistics of China, Chinese Statistics Press, Beijing).

2) Uygur is an ethnic group in Xinjiang Uygur Autonomous Region of China. Uygur constitutes about 45% of the population of Xinjiang Uygur Autonomous Region of China.

kohms. Eye blinks and vertical eye movements were monitored using electrodes located above and below the left eye, and horizontal electro-oculogram via electrodes placed 1.5 cm lateral to the left and right external canthi. ERPs in each condition were averaged separately off-line with an epoch of 1000 ms, starting 200 ms before stimulus onset. Trials that were contaminated by eye blinks, eye movements, or muscle potentials exceeding ±70 μV at any electrode, and response errors were excluded from the average. The baseline for ERP measurements was the mean voltage of a 200 ms prestimulus interval and the latency was measured relative to the stimulus onset. Statistical analyses were performed on these ERP components at frontal (Fz, FCz, F3-F4, F7-F8, FC3-FC4), central (Cz, CPz, C3-C4, CP3-CP4), and parietal (Pz, P3-P4) electrodes. The mean amplitudes of the N170 were analyzed at temporal sites P7-P8. Behavioral performances and ERPs were analyzed using repeated measures analyses of variance (ANOVAs) with Ethnicity (Han vs. Uygur faces), Affective Link (positive vs. negative) as within-subjects independent variables.

2 Results

2.1 Behavioral performance

The mean rating scores of the three manipulation check questions were calculated, and then were normalized across subjects so that the rating scores varied from −1 (extremely negative) to 1(extremely positive). ANOVAs of the normalized rating scores showed a significant main effect of Affective Link ($F(1,13) = 51.64$, $P < 0.001$), suggesting that the affective link priming manipulation resulted in negative attitudes towards the actors who behaved aggressively but positive attitudes towards the actors who behaved amicably. The effect of Ethnicity and its interaction with Affective Link did not reach significance (*Ps* > 0.05) (Table 1).

Table 1 Results of behavioral performances (mean (SD))

Affective link	In-group		Out-group	
	Positive	Negative	Positive	Negative
RTs of 8 blocks (ms)	465 (64)	468 (65)	476 (61)	469 (61)
RTs of 2 blocks (ms)	464 (66)	483 (76)	498 (74)	483 (71)
Accuracies (%)	94 (5.0)	95 (5.0)	94 (6.0)	93 (5.0)
Normalized rating scores	0.36 (0.53)	−0.28 (0.55)	0.48 (0.44)	−0.43 (0.44)

Response accuracies to the identification of face orientations were high (mean = 94.12%) and did not differ between different stimulus conditions (*Ps*>0.05). Reaction times (RTs) to the face stimuli were first calculated from 8 blocks of trials. ANOVAs of RTs showed a significant main effect of Ethnicity ($F(1,13) = 7.37$, $P = 0.018$), RTs were slightly shorter to the ethnic in-group (466 ms) than to the out-group faces (472 ms). Neither the main effect of Affective Link ($F(1,13) = 1.10$, $P = 0.313$) nor its interaction with Ethnicity ($F(1,13) = 1.96$, $P = 0.185$) was significant. Because exhausting practice may weaken the priming effect on behavioral performances, we also calculated RTs from the first two blocks and found a significant main effect of Ethnicity ($F(1,13) = 14.30$, $P = 0.002$) and a reliable interaction of Ethnicity×Affective Link ($F(1,13) = 7.90$, $P = 0.015$). Post-hoc analyses confirmed that subjects responded faster to ethnic in-group faces primed with positive than negative attitudes (464 vs. 483 ms, $F(1,13) = 12.92$, $P = 0.003$), whereas RTs did not differ between ethnic out-group faces primed with positive and negative attitudes (498 vs. 483 ms, $F(1,13) = 2.02$, $P = 0.179$).

2.2 Electrophysiological data

Grand-averaged ERPs to face stimuli were computed for each condition. The ERPs over the frontal-central electrodes were characterized with a negative component peaking at 110—140 ms (N100), which was followed by a positive deflection at 170—200 ms (VPP), a negative wave at 200—280 ms (N2), and a positive component at 400—600 ms (LPP). Face stimuli also evoked a positivity at 80—140 ms (P1) and a negativity at 140—200 ms (N170) over the occipito-temporal area. Figure 1 illustrates the voltage topographies of each ERP component.

ANOVAs of the mean N100 amplitude showed a significant main effect of Ethnicity (F3-F4: $F(1,13) = 4.86$, $P = 0.046$) and significant interactions of Ethnicity x Affective Link at frontal-central electrodes (FZ: $F(1,13) = 8.248$, $P = 0.013$; F3-4: $F(1,13) = 7.993$, $P = 0.014$; FCZ: $F(1,13) = 5.761$, $P = 0.032$; FC3-4: $F(1,13) = 5.866$, $P = 0.031$; CZ: $F(1,13) = 5.374$, $P = 0.037$; CPZ: $F(1,13) = 6.533$, $P = 0.024$). Post-hoc analysis confirmed that, relative to positive affective link priming, negative affective link priming induced larger N100 to ethnic in-group faces (FZ: $F(1,13) = 5.409$, $P = 0.037$; F3-4: $F(1,13) = 5.036$, $P = 0.043$). However, the N100 amplitude did not differentiate between out-group faces primed with positive and negative attitudes (*Ps*>0.05). No significant effect was observed on the amplitudes of N170 and VPP (*Ps*>0.05).

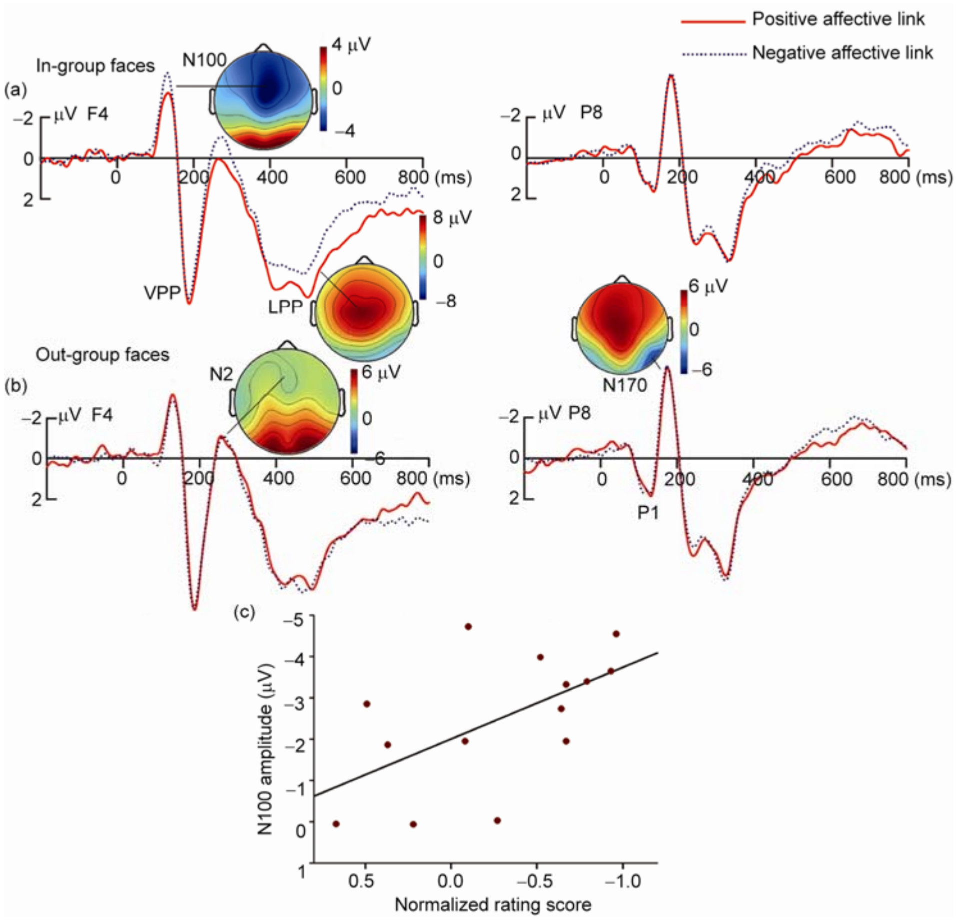

Figure 1 (a) ERPs to ethnic in-group faces primed with positive and negative attitudes at electrodes over the right frontal (F4) and right occipito-temporal (P8) sites. Voltage topographies illustrate a frontal distribution of the N100 and the central-parietal distribution of the LPP. (b) ERPs to ethnic out-group faces primed with positive and negative attitudes at electrodes over the right frontal (F4) and right occipito-temporal (P8) sites. Voltage topographies illustrate a right occipital-temporal distribution of the N170 and a fronto-central distribution of the N2. The voltage topographies of the N100 and N170 were plotted from ERPs to in-group faces in the negative link condition. The voltage topographies of the N2 and LPP were plotted from ERPs to in-group faces in the positive link condition. (c) Correlation between the mean N100 amplitudes and priming induced negative attitudes towards ethnic in-group members. Each point represents the data from a single subject. The mean N100 amplitudes were obtained from the electrodes F3, FZ, F4, C3, CZ and C4.

ANOVAs of the mean N2 amplitudes also showed a significant main effect of Ethnicity (F3-F4: $F(1,13) = 5.15$, $P = 0.041$) and significant interactions of Ethnicity x Affective Link at right frontal electrodes (F4: $F(1,13) = 6.108$, $P = 0.028$; FC4: $F(1,13) = 4.925$, $P = 0.043$; F8: $F(1,13) = 5.119$, $P = 0.041$). Post-hoc analysis indicated that, compared to positive affective link priming, negative affective link priming induced larger N2 to ethnic in-group faces (FZ: $F(1,13) = 6.060$, $P = 0.029$; F4: $F(1,13) = 8.357$, $P = 0.013$). By contrast, the N2 amplitudes did not differ between ethnic out-group faces primed with positive or negative attitudes ($Fs<1$). Similarly, ANOVAs of the mean LPP amplitudes revealed reliable interactions of Ethnicity x Affective Link over the frontal-central-parietal area (FZ: $F(1,13) = 7.182$, $P = 0.019$; F3-4: $F(1,13) = 12.452$, $P = 0.004$; CZ: $F(1,13) = 9.436$, $P = 0.009$; C3-4: $F(1,13) = 14.748$, $P = 0.002$; PZ: $F(1,13) = 6.400$, $P = 0.025$; P3-4: $F(1,13) = 12.545$, $P = 0.004$), as the LPP was of larger amplitude to ethnic in-group faces primed with positive than negative attitudes (FZ: $F(1,13) = 16.636$, $P = 0.001$; F3-4: $F(1,13) = 14.206$, $P = 0.002$; CZ: $F(1,13) = 16.171$, $P = 0.001$; C3-4: $F(1,13) = 21.363$, $P = 0.001$; PZ: $F(1,13) = 14.852$, $P = 0.002$; P3-4: $F(1,13) = 9.476$, $P = 0.009$), whereas affective link priming did not modulate the LPP amplitudes to ethnic out-group faces ($Fs<1$).

Finally, we found a significant correlation between the mean N100 amplitudes and normalized rating scores of negative attitudes towards ethnic in-group actors (F3: $r = 0.633$, $P = 0.015$; FZ: $r = 0.604$, $P = 0.022$; F4: $r =$

0.542, P = 0.045; C3: r = 0.619, P = 0.018; CZ: r = 0.582, P = 0.029; C4: r = 0.600, P = 0.023; Figure 1(c)). The stronger negative attitudes towards the actors, the larger the N100 amplitudes induced by the actor's face. No reliable correlation was observed between ERP amplitudes and induced attitudes towards ethnic out-group actors.

3 Discussion

Subjective ratings indicate that the affective link priming indeed induced positive and negative attitudes towards the actors. Although the attitudes indexed by the rating scores did not differ between ethnic in-group and out-group members, the effects of affective link priming on both behavioral performances and ERPs in association with the face orientation identification task were significantly different between ethnic in-group and out-group faces. RTs of the first two blocks of trials suggest that response speeds differentiated between ethnic in-group faces primed with positive and negative attitudes, whereas no such effect was observed for ethnic out-group faces. This result suggests that the affective link priming easily individuated ethnic in-group faces even when participants identified a perceptual feature of faces (i.e., orientation) that is; irrelevant to face identity. This is in agreement with the multidimensional space hypothesis[9,10] in that ethnic in-group faces rather than ethnic out-group faces are represented as many exemplars.

Our ERP results revealed neural mechanisms underlying the asymmetric cognitive construal of ethnic in-group and out-group faces. The ERPs to ethnic out-group faces primed with positive and negative attitudes did not show any differences. However, the ERPs to ethnic in-group faces were significantly modulated by the affective link priming. The N100 amplitude recorded over the frontal-central electrodes was enlarged by ethnic in-group faces primed with negative than positive attitudes. In addition, the N100 amplitude showed a quantitative relation with the strength of primed negative attitudes towards ethnic in-group faces, being larger to the faces with stronger negative attitudes. This is consistent with the prior observation that the strength of amygdala activation to Black-versus-White faces correlated with the implicit attitude toward a target person[13]. Our ERP results demonstrate that the process of individuation of ethnic in-group faces may take place as early as 110 ms after sensory stimulation. Previous research has shown that the N100 is involved in differentiation between ethnic in-group and out-group faces. Specifically, the N100 was of larger amplitude to Black than White faces in White participants[7], which may reflect that the social knowledge that Blacks are often associated with negative affect[14] and faces of the racial group biased with stereotype of danger induced enhanced attention during the early time window of facial processing[15]. Similarly, the N100 results in our study may arise from enhanced attention to faces of ethnic in-group members with the negative affective link relative to those with the positive affective link. More importantly, our findings indicate that the processing of individuation of ethnic in-group faces may take place as early as the categorization of faces in terms of ethnic in-group and out-group faces.

The long-latency ERP components were also involved in differentiation between ethnic in-group faces primed with negative and positive affective links. The negative affective link priming enlarged the N2 over the right frontal cortex relative to the positive affective link priming. By contrast, the LPP over the frontal-central-parietal area was enlarged by the positive compared to negative affective link priming. As the N2 is larger to one's own face than to others' faces[16] and to famous faces than to unfamiliar ones[17], the N2 has been associated with individuation and deeper processing of faces[18]. Thus our N2 results suggest that observers may carry out extensive processing or individuation of ethnic in-group faces in terms of affective links between the observer and target faces. Similar processes may occur in real-life situations for the sake of perceivers' safety. The LPP over the central-parietal area has been shown to mediate evaluative categorizations of trait adjectives[19] and is enlarged to pictures depicting pleasant than unpleasant events[20]. The ethnic in-group faces primed with positive attitudes in our study were similar to the pleasant pictures used by Schupp et al.[20] in that the stimuli with positive attitudes underwent enhanced evaluative processing. It should be noted that the effects of affective priming on the N2 and LPP were evident with ethnic in-group faces but not with ethnic out-group faces, providing further ERP evidence for the asymmetric cognitive representation of ethnic in-group and out-group faces.

Previous studies observed modulation of the N170 by ethnic in-group/out-group faces. Ito and Urland[7] found enlarged N170 to White compared to Black faces in

White participants, whereas Stahl et al.[21] reported enlarged N170 to Caucasian compared to Asian faces in Caucasian participants. The N170 engages in facial structural encoding[22] and varies as a function of face familiarity[23]. Although the N170 modulation by in-group/out-group faces showed inconsistent patterns in previous research, the observations suggest that long-term visual experience may influence low-level face recognition of racial faces. The current work, however, failed to find evidence for the N170 modulation by affective link priming applied to either ethnic in-group or out-group faces, suggesting that attitude change towards faces induced by short-term affective link priming does not affect low-level face recognition.

In conclusion, our ERP findings indicate that multiple-level neural mechanisms are involved in the asymmetric cognitive representation of ethnic in-group and out-group faces. The neural activity involved in distinguishing individual ethnic in-group faces underpins both early attentional processing and late individuation and evaluative processes. Although we showed that the effect of affective link priming was seemingly irrelevant to the task at hand, consistent with the idea that social categorization of others is an automatic mental process[1], our ERP results indicate that individuation of strangers by affective links is conditional and constrained by ethnic group membership. Finally, as the current work employed in-group/ out-group relations defined by ethnicity, future research should examine whether similar neural mechanisms engage in the process of sub-categories of other social groups such as those defined by gender and age.

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