Physical coldness enhances racial in-group bias in empathy: Electrophysiological evidence

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ABSTRACT

Empathy for others' pain plays a key role in prosocial behavior and is influenced by intergroup relationships. Increasing evidence suggests greater empathy for racial in-group than out-group individuals' pain and the racial in-group bias undergoes sociocultural and biological influences. The present study further investigated whether and how physical environments influence racial in-group bias in empathy by testing the hypothesis that sensory experiences of physical coldness versus warmth enhance differential empathic neural responses to racial in-group vs. out-group individuals' suffering. We recorded event-related brain potentials to painful versus neutral expressions of same-race and other-race faces when participants held a cold or warm pack. We found that brain activity in the N2 (200–340 ms) and P3 (400–600 ms) time windows over the frontal/central region was positively shifted by painful (vs. neutral) expressions. Moreover, the N2/P3 empathic neural responses were significantly larger for same-race than other-race faces in the cold but not in the warm condition. Moreover, subjective ratings of different temperatures in the cold vs. warm conditions predicted larger changes of racial in-group bias in empathic neural responses in the N2 time window. Our findings suggest that sensory experiences of physical coldness can strengthen emotional resonance with same-race individuals.

1. Introduction

Racial in-group favoritism in behavioral tendency (e.g., intention to help members of one's own group more than members of other groups) can be observed in real life situations and has been identified in empirical psychological research. For instance, it was found that individuals reported greater altruistic motivation toward same-race compared to other-race individuals during judicial decisions and clinical pain treatments and the racial in-group favoritism in behavioral tendency was associated with better sharing of racial in-group members' emotional states (Drwecki et al., 2011; Johnson et al., 2002).

The behavioral findings led to increasing interests in brain imaging research to reveal whether and how the brain activity underlying emotional understanding and sharing (i.e., empathy) is modulated by racial intergroup relationships between observers and targets. An early functional magnetic resonance imaging (fMRI) study reported brain imaging evidence of racial in-group bias in empathic neural responses by showing that the anterior cingulate cortex responded more strongly to perceived painful stimulations applied to same-race than other-race

individuals (Xu et al., 2009). Subsequent studies also revealed racial in-group bias in empathic neural responses in the sensorimotor cortex (Avenanti et al., 2010), dorsal medial prefrontal cortex (Mathur et al., 2010; Cheon et al., 2011), anterior insula (Azevedo et al., 2013; Sheng et al., 2014) and temporoparietal junction (Cheon et al., 2011). Event-related potentials (ERPs) research also revealed differential neural responses over the frontal/central regions to same-race and other-race individuals' pain as early as 120 ms after stimulus onset (Sheng and Han, 2012; Sheng et al., 2013, 2016; Han et al., 2016; Contreras-Huerta et al., 2014; Sessa et al., 2014). These brain imaging findings demonstrate that racial in-group bias in empathy occurs during the early stage of neural processes of others' suffering and in multiple brain regions involved in social cognition and emotion.

Because of the novel social significance of the brain imaging findings of racial in-group bias in empathy, recent research has focused on sociocultural and biological mechanisms involved in racial in-group bias in empathy. For example, an ERP study found that changing intergroup relationships by including other-race individuals into one's own team for competition reduced the racial in-group bias in empathy

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by enhancing neural responses to other-race individuals' pain (Sheng and Han, 2012). An fMRI study showed that priming a specific cultural trait (e.g., independence) can decrease racial in-group bias in empathic neural responses in the cingulate and insula (Wang et al., 2015). People with long-term life experiences with other-race individuals during development showed comparable empathic neural responses in the cingulate to perceived pain of same-race and other-race individuals (Zuo and Han, 2013). These findings indicate that social relationship and sociocultural experiences contribute to the differential empathic neural responses to same-race and other-race individuals' pain.

Other studies have revealed biological mechanisms underlying racial in-group bias in empathic neural responses. For instance, by examining repetition suppression of ERP amplitudes to painful expressions, Sheng et al. (2016) showed that neural responses to painful expression of a target face at 120–180 ms (P2) over the central/frontal region was decreased by a preceding face with pain expression when the two faces were of the same race but not different races, suggesting that distinct neuronal populations are engaged in coding painful expressions of same-race and other-race faces. Sheng et al. (2013) also found that intranasal administration of oxytocin selectively increased the P2 amplitudes to same-race but not other-race painful expressions, suggesting engagement of different neural transmitters in the processing of same-race and other-race individuals' pain. A recent fMRI study further revealed greater racial in-group bias in empathic neural responses in the anterior cingulate in G compared with A allele carriers of oxytocin receptor gene polymorphism rs53576 (Luo et al., 2015). Together these findings suggest that racial in-group bias in empathic neural responses is possibly mediated by multiple level biological mechanisms.

While the aforementioned brain imaging findings suggest sociocultural and biological underpinnings of racial in-group bias in empathic neural responses, it remains unclear whether and how physical environments influence the neural correlates of racial in-group bias in empathy. It has been proposed that an inclement environment with scarce resources threatens human survival and demands increased in-group favoritism (Brewer, 1979). In line with this proposal, a cross-culture study of 116 nations that examined inhabitants' cultural adaptations to climate-based demands and wealth-based resources found that inhabitants in lower-income countries reported greater indices of in-group favoritism such as compatriotism, nepotism, and familism when they had to cope with harsher climates (Van de Vliert, 2011). Laboratory studies also reported that physical coldness compared to warmth increased interpersonal distance (Bargh and Shalev, 2012), which was associated with psychological distance (e.g., Wang and Yao, 2016), and diminished prosocial behavior (Williams and Bargh, 2008). Because empathy has been supposed to be a proximate mechanism of prosocial behavior (Batson et al., 1987; De Waal, 2008; Batson, 2011; Decety et al., 2016) and empathic neural responses can predict altruistic behavior (Hein et al., 2010; Ma et al., 2011), one may hypothesize that an inclement environment that demands in-group favoritism for individuals' survival may increase racial in-group bias in empathic neural responses. In consistent with this hypothesis we recently found that reminding one's own death, which may occur in an inclement environment, increased racial in-group bias in empathic neural responses in multiple brain regions (Li et al., 2015). However, this study did not directly test how harsh physical environments influence racial in-group bias in empathic neural responses. It is likely that sensory experiences in a cold environment may enhance racial in-group bias in empathic neural responses relative to sensory experiences in a warm environment.

The present study tested this hypothesis by recording ERPs from Chinese healthy adults while they perceived Asian and Caucasian faces with painful or neutral expressions. Sheng and Han (2012) found that, during judgments of race identity of faces, the amplitude of a frontal positive activity at 128–188 ms (P2) was enlarged by painful compared to neutral expressions and this effect was stronger for same-race than other-race faces. A following negative activity at 200–300 ms (N2) showed similar racial in-group bias in neural responses to painful expression. However, the racial in-group bias in empathic neural responses in the P2/N2 time windows was eliminated (i.e., participants showed similar empathic neural responses to same-race and other-race faces) during judgments on emotional states of each individual's face. Therefore, the pattern of neural responses to painful versus neutral expressions during pain judgments provides a baseline for testing whether cold compared to warm experiences can increase the racial in-group bias in empathic neural responses. We asked participants to hold a cold or warm pack to generate cold and warm experiences while ERPs to painful or neutral expressions of same-race (i.e., Asian) and other-race (i.e., Caucasian) faces were recorded. Because racial bias in implicit attitudes predicted weakened empathic reactivity to racial out-group members' pain (Avenanti et al., 2010), we also measured participants' implicit attitudes toward racial in-group and out-group faces using the Implicit Association Test (Greenwald et al., 1998). This allowed us to assess whether the influences of cold versus warm experiences on racial in-group bias in empathy were constrained by individuals' social attitudes toward same-race and other-race people.

2. Methods

2.1. Participants

Forty Chinese male adults aged 18–28 years (M = 21.55, SD = 2.56) participated in this study as paid volunteers. The exclusion criteria included self-reported medical or psychiatric illness and use of medication. All participants were right-handed, and had normal or corrected-to-normal vision. Informed consent was obtained prior to participation. This study was approved by a local ethics committee. The sample size was determined based on our previous research (Sheng and Han, 2012) that showed robust evidence for racial in-group bias in ERPs results.

2.2. Stimuli and procedure

The stimuli consisted of photos of 32 face photos from 16 Asian models and 32 face photos from 16 Caucasian models and were adopted from our previous work (Sheng and Han, 2012). Each model contributed 2 face images with neural and painful expressions, respectively. Emotional intensity, facial attractiveness, and luminance levels were matched between Asian and Caucasian faces (Sheng and Han, 2012). During electroencephalograph (EEG) recording, each face was displayed for 200 ms in the center of a gray background with a visual angle of $3.8° \times 4.7°$ (width × height: 7.94×9.92 cm) at a viewing distance of 120 cm. The interstimulus intervals consisted of a fixation cross with a duration that randomly varied between 800 and 1400 ms. Participants held a cold pack of 6 °C using the left hand in the cold condition but a warm pack of 39 °C in the warm condition. In the control condition participants put their left hand on a handrail at room temperature (25 °C). There was a 3-min break between the warm, cold and control conditions and the order of the three conditions was counterbalanced across participants. Participants completed 12 EEG blocks during the experiment. There were 4 blocks of 128 trials in the cold, warm and control conditions, respectively. Each photo was presented twice in a random order in each block. Participants made judgments on expression of each face (painful versus neutral) with a button press using the right index and middle fingers.

After the EEG recording, participants rated the intensity of the pain portrayed by each face and their subjective ratings of unpleasantness induced by each face on a 9-point Likert scale. Participants were also asked to rate how warm/cold they felt in the warm/cold conditions on a 11-point Likert scale as manipulation check (with 0 = very cold , 10 = very warm). Differential sensory feelings in the cold and warm conditions were indexed by the difference in rating scores between the cold and warm conditions. After EEG recording, participants completed

a race version of the Implicit Association Test (Greenwald et al., 1998). They categorized Asian faces/positive words with one key and Caucasian faces/negative words with another key in two blocks and Asian faces/negative words with one key and Caucasian faces/positive words with another key in another two blocks. A D score, calculated based on an established algorithm of response latencies (Greenwald et al., 2003), provided an index of participants' implicit attitudes toward racial in-group and out-group faces. A D score larger than zero indicates that in-group faces are associated with a positive rather than negative attitude compared to out-group faces. Participant also completed the Interpersonal Reactivity Index (IRI, Davis, 1983) to measure their empathy traits.

2.3. EEG recording and analysis

The EEG Recordings were taken from 64 scalp electrodes (based on the 10/20 system) and two electrodes placed on the left and right mastoids. Eye blinks and vertical eye movements were monitored with electrodes located above and below the left eye. The horizontal electrooculogram was recorded from electrodes placed 1.5 cm lateral to the left and right external canthi. The EEG was amplified (band pass 0.1–100 Hz) and digitized at a sampling rate of 250 Hz. The ERPs in each condition were averaged separately off-line, with an epoch beginning 200 ms before stimulus onset and continuing for 1200 ms. Trials contaminated by eye movements and muscle potentials exceeding ± 50 µV at any electrode or response errors were excluded from average. This resulted in rejection of 19.2 ± 10.5% of the trials. The baseline for the measurements of ERP amplitudes was the mean voltage of a 200 ms pre-stimulus interval, and the time windows for the measures referred to the stimulus onset. The mean amplitudes of each ERP component were calculated at the frontal (Fz, FCz, F3, F4, FC3, and FC4), central and parietal (Cz, C3, C4, CPz, CP3, CP4) and occipito-temporal (P7, P8, PO7, and PO8) electrodes. The analysis of the P2 and N2 components was conducted over the frontal and central electrodes. The central electrodes were included for the analysis of the long latency component, such as the P3, and the parietal and occipital electrodes were included for the analysis of the early posterior ERP components, such as the N170. Preliminary repeated measures analyses of variance (ANOVAs) of behavior and ERP data included treatment order as a between-subject variable. Neither the main effect of treatment order nor its interaction with other variables was significant (F < 1). Thus we reported the results of the ANOVAs of reaction times (RTs), response accuracies, and the mean ERP amplitudes with Treatment (cold versus warm), Expression (painful versus neutral), and Race (Same-race (Asian) versus Other-race(Caucasian)) as within-subjects variables. The ANOVAs of the mean ERP amplitudes recorded at the bilateral electrodes included Hemisphere (electrode over the left versus right hemispheres) as a within subjects variable. To further quantify the effects of cold/warm manipulations, we calculated the difference waves by subtracting ERPs in the control (25 °C) condition from those in the cold and warm conditions. The amplitudes of the difference waves were also subject to ANOVAs with Treatment (cold versus warm), Expression (painful versus neutral), and Race (Same-race(Asian) versus Other-race (Caucasian)) as within-subjects variables.

Both voltage topography and the standardized Low Resolution Brain Electromagnetic Tomography (sLORETA) (Pascual-Marqui, 2002) were used to estimate potential sources of empathic neural responses. sLORETA is a linear method of computing statistical maps from EEG data that reveal locations of the underlying source processes and do not require a priori hypotheses regarding the field distribution of the active sources. We performed the analysis using sLORETA to assess the potential 3D current sources of neural activity that differentiated between ERPs to painful and neutral expressions. A boundary element model was first created with about 5000 nodes from a realistic head model. Statistical nonparametric mapping was calculated in a specific time window to estimate the source that differentiated ERPs to painful

Table 1
Behavioral performances (mean ± SD) during EEG recording.

	Expression	Warm		Cold	
		Asian	Caucasian	Asian	Caucasian
Reaction time (ms)	Neutral	562 ± 61	574 ± 58	556 ± 66	571 ± 65
	Painful	566 ± 62	567 ± 63	561 ± 58	560 ± 63
Accuracy (%)	Neutral	93 ± 5	91 ± 5	93 ± 6	92 ± 6
	Painful	90 ± 4	91 ± 5	91 ± 5	93 ± 5

and neutral expressions. The log of the F ratio of averages was used and considered with a 0.95 level of significance.

3. Results

3.1. Behavioral results

Behavioral performances are shown in Table 1. Response accuracies were high (> 90%) and did not significantly differ between the cold and warm conditions (p > 0.05). ANOVAs of RTs showed a significant main effect of Race in both the cold and warm conditions (F(1,39) = 15.01 and 6.40, ps < 0.05, η^2 = 0.44 and 0.25) as participants responded faster to Asian than to Caucasian faces. The interaction of Race and Expression was significant in the cold condition (F(1,39) = 12.82, p < 0.005, η^2 = 0.40) and marginally significant in the warm condition (F(1,39) = 4.01, p = 0.06, η^2 = 0.17). Post hoc analyses revealed that RTs were longer to Caucasian than to Asian faces with neutral expressions in both the cold and warm conditions (F(1,39) = 5.61 and 3.67, ps < 0.005, η^2 = 0.62 and 0.42) but did not significantly differ between Caucasian and Asian faces with painful expressions (ps > 0.5).

Painful expressions were rated with higher scores of pain intensity and self-unpleasantness relative to neutral expressions (F(1,39) = 1288.94 and 82.24, ps < 0.001, η^2 = 0.97 and 0.68, Table 2), but these effects did not differ significantly between same-race and other-race faces (ps > 0.4). Participants rated the cold pack with a lower temperature than the warm pack (cold: M = 1.95, SD = 1.01, warm: M = 8.55, SD = 1.16, t(1,39) = 26.06, p < 0.001). However, rating scores of unpleasantness related to the cold and warm pads did not differ significantly (cold: M = 3.94, SD = 1.61, warm: M = 3.60, SD = 1.34, t(1,39) = −1.34, p > 0.1). The D score in the Implicit Association Test was significantly larger than zero (M = 0.24 SD = 0.40, t(1,39) = 3.82, p < 0.001), suggesting greater implicit negative attitudes toward other-face faces.

3.2. Electrophysiological results

Fig. 1 illustrates the ERPs to painful and neutral expressions at a frontocentral electrode in the cold, warm, and neutral conditions. The ERPs were characterized by a negative wave at 92–120 ms (N1) and a positive deflection at 140–188 ms (P2) over the frontal/central areas, which were followed by a negative wave at 200–340 ms (N2) over the frontal/central region and a long-latency positivity at 400–600 ms (P3) over the central area. The face stimuli also elicited a posterior P1 at 116–148 ms and a N170 at 148–188 ms over the occipital and temporal electrodes.

Table 2
Rating scores of pain intensity and self-unpleasantness (mean ± SD).

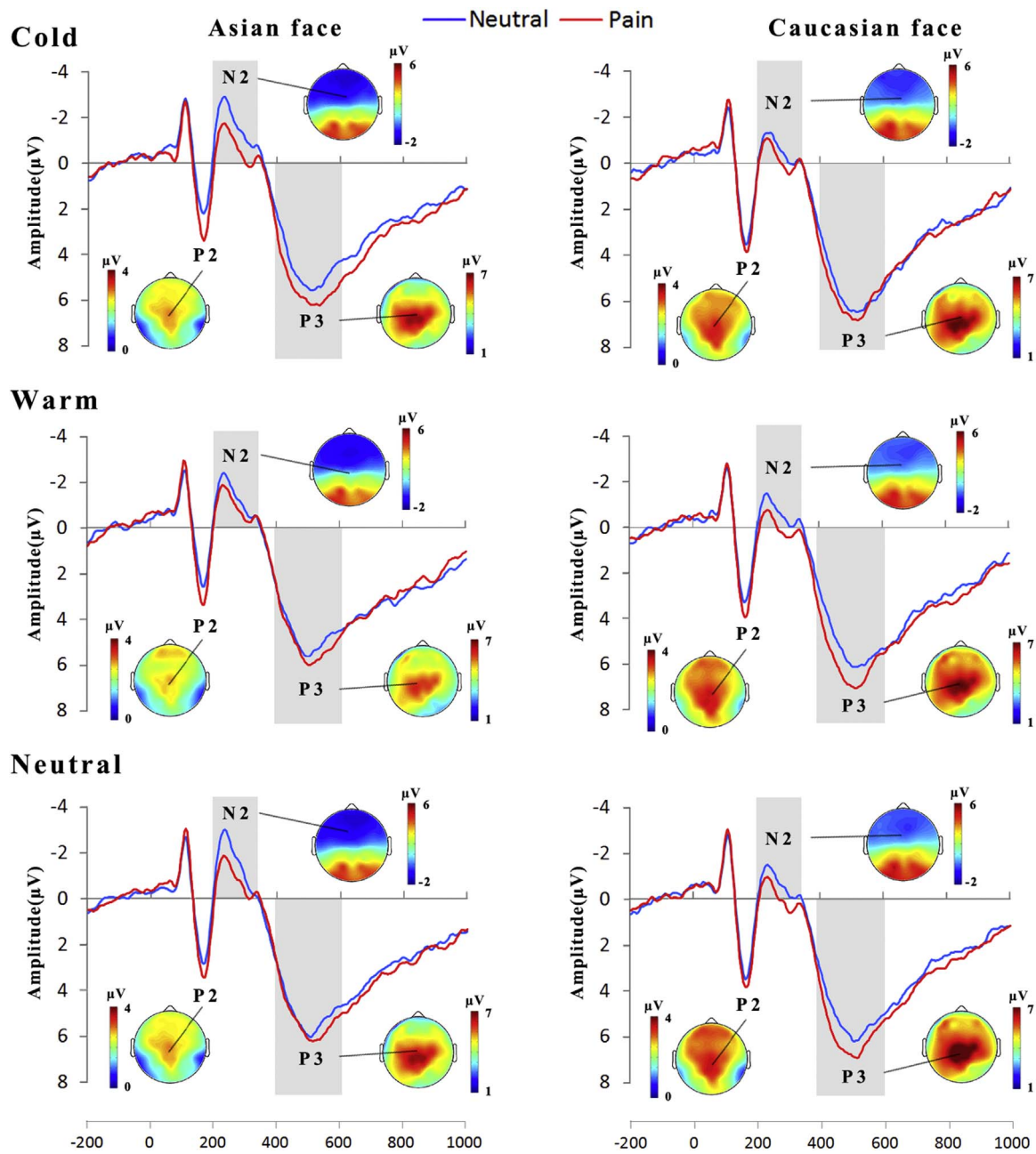|	Pain intensity		Self-unpleasantness	
	Neutral	Painful	Neutral	Painful
Asian face	1.47 ± 0.72	6.83 ± 0.56	2.52 ± 1.34	4.92 ± 1.59
Caucasian face	1.48 ± 0.71	6.88 ± 0.70	2.47 ± 1.49	4.95 ± 1.50

Fig. 1. Illustration of the ERP results in the cold and warm conditions. ERPs recorded at FCz to painful and neutral expressions of Asian and Caucasian faces in the cold, warm, and neutral conditions.

Table 3
Mean amplitudes of FCZ for each component (Mean ± SE).

FCZ		Cold condition		Warm condition		Treatment × Race × Expression		
		Asian	Caucasian	Asian	Caucasian	F	p	η^2
P2	Pain	2.57 ± 0.47	3.03 ± 0.52	2.38 ± 0.51	3.10 ± 0.56	3.89	0.06	0.091
	Neutral	1.57 ± 0.47	2.64 ± 0.50	1.77 ± 0.49	2.52 ± 0.50			
N2	Pain	0.51 ± 0.51	0.49 ± 0.51	0.54 ± 0.50	0.49 ± 0.52	6.80	0.01	0.149
	Neutral	−1.52 ± 0.51	−0.55 ± 0.49	−1.31 ± 0.54	−0.70 ± 0.49			
P3	Pain	5.66 ± 0.64	5.99 ± 0.59	5.17 ± 0.58	6.10 ± 0.61	9.35	0.004	0.193
	Neutral	4.69 ± 0.62	5.61 ± 0.58	4.65 ± 0.61	5.20 ± 0.61			

3.2.1. Treatment effects on empathic neural responses

To test our hypothesis of differential racial in-group bias in empathic neural responses, we conduct ANOVAs of the amplitudes of each ERP component in the cold and warm conditions with Treatment (cold versus warm), Expression (painful versus neutral), and Race (Same-race(Asian) versus Other-race(Caucasian)) as independent with-in-subjects variables. The ANOVAs of the P2 amplitudes at 140–188 ms over the frontal/central electrodes showed significant main effects of

Race (Fz: F(1,39) = 32.72, p < 0.001, η² = 0.46; FCz: F(1,39) = 35.55, p < 0.001, η² = 0.48; Cz: F(1,39) = 39.68, p < 0.001, η² = 0.50; F3-F4: F(1,39) = 27.68, p < 0.001, η² = 0.42; FC3-FC4: F(1,39) = 33.69, p < 0.001, η² = 0.46; C3-C4: F(1,39) = 49.12, p < 0.001, η² = 0.56) and Expression (Fz: F(1,39) = 32.92, p < 0.001, η² = 0.46; FCz: F(1,39) = 33.76, p < 0.001, η² = 0.46; Cz: F(1,39) = 36.81, p < 0.001, η² = 0.49; F3-F4: F(1,39) = 31.88, p < 0.001, η² = 0.45; FC3-FC4: F(1,39) = 32.42, p < 0.001, η² = 0.45; C3-C4: F(1,39) = 28.58, p < 0.001, η² = 0.42). The P2 amplitudes were enlarged by other-race compared to same-race faces and by painful vs. neutral expressions (see Fig. 1 and Table 3). These replicate the previous ERP findings (e.g., Ito and Bartholow, 2009; Sheng and Han, 2012) and suggest that the frontal/central P2 was involved in coding of both racial identity and emotional state (i.e., pain). The interactions of Expression × Race on the P2 amplitude were not significant (Fz: F(1,39) = 1.41, p = 0.24, η² = 0.04; FCz: F(1,39) = 3.42, p = 0.07, η² = 0.08; Cz: F(1,39) = 1.98, p = 0.17, η² = 0.05; F3-F4: F(1,39) = 1.39, p = 0.25, η² = 0.03; FC3-FC4: F(1,39) = 1.65, p = 0.21, η² = 0.04; C3-C4: F(1,39) = 1.64, p = 0.21, η² = 0.04), indicating similar effects of painful expression on the P2 amplitude to same-race and other-race faces. These results replicate the previous ERP results that the task demand of pain judgments lead to similar neural responses to painful (vs. neutral) expression of racial in-group and out-group individuals (Sheng and Han, 2012). However, neither the main effect of Treatment nor its interaction with Race and Expression was significant on the P2 amplitude (ps > 0.05). Thus physical warm/cold treatments failed to modulate the early empathic neural responses to painful (vs. neutral) expression with the current sample size.

The ANOVAs of the N2 amplitudes at 200–340 ms showed significant main effects of Race (Fz: F(1,39) = 63.34, p < 0.001, η² = 0.62; FCz: F(1,39) = 61.22, p < 0.001, η² = 0.61; Cz: F(1,39) = 53.06, p < 0.001, η² = 0.58; F3-F4: F(1,39) = 45.06, p < 0.001, η² = 0.54; FC3-FC4: F(1,39) = 49.52, p < 0.001, η² = 0.56; C3-C4: F(1,39) = 58.90, p < 0.001, η² = 0.60) and Expression (Fz: F(1,39) = 21.59, p < 0.001, η² = 0.36; FCz: F(1,39) = 22.27, p < 0.001, η² = 0.36; Cz: F(1,39) = 23.01, p < 0.001, η² = 0.37; F3-F4: F(1,39) = 19.11, p < 0.001, η² = 0.33; FC3-FC4: F(1,39) = 18.79, p < 0.001, η² = 0.33; C3-C4: F(1,39) = 17.23, p < 0.001, η² = 0.31). The N2 was of larger amplitude to same-race than other-race faces and was of smaller amplitude to painful compared to neutral expressions (Figs. 1 and 2A). Interestingly, these effects were quantified by significant interactions of Treatment × Race × Expression (Fz: F(1,39) = 5.79, p < 0.05, η² = 0.13; FCz: F(1,39) = 6.80, p < 0.05, η² = 0.15; Cz: F(1,39) = 7.36, p < 0.05, η² = 0.16; F3-F4: F(1,39) = 7.32, p < 0.05, η² = 0.16; FC3-FC4: F(1,39) = 7.42, p < 0.05, η² = 0.16; C3-C4: F(1,39) = 3.44, p = 0.07, η² = 0.08). simple effect analyses further revealed significant main effects of Expression on the N2 amplitude in the warm condition (Fz: F(1,39) = 11.89, p = 0.001, η² = 0.23; FCz: F(1,39) = 11.83, p = 0.001, η² = 0.23; Cz: F(1,39) = 11.67, p < 0.005, η² = 0.23; F3-F4: F(1,39) = 11.52, p = 0.002, η² = 0.23; FC3-FC4: F(1,39) = 12.92, p = 0.001, η² = 0.25; C3-C4: F(1,39) = 12.11, p = 0.001, η² = 0.24). However, the interaction of Race × Expression on the N2 amplitude was not significant (ps > 0.05), suggesting comparable empathic neural responses to same-race and other-race faces in the warm condition. ANOVAs of the N2 amplitudes in the cold condition showed significant interactions of Race × Expression on the N2 amplitude (FC3: F(1,39) = 4.64, p < 0.05, η² = 0.11; Cz: F(1,39) = 4.81, p < 0.05, η² = 0.11), due to larger differential N2 responses to painful (vs. neutral) expressions of same-race than other-race faces, although, in the cold condition, the effect of Expression was significant for both same-race faces (Fz: F(1,39) = 18.95, p < 0.001, η² = 0.33; FCz: F(1,39) = 21.18, p < 0.001, η² = 0.35; Cz: F(1,39) = 23.85, p < 0.001, η² = 0.38; F3-F4: F(1,39) = 14.06, p = 0.001, η² = 0.27; FC3-FC4: F(1,39) = 14.89, p < 0.001, η² = 0.28; C3-C4: F(1,39) = 11.30, p < 0.005, η² = 0.23) and other-race faces (Fz: F(1,39) = 8.11, p = 0.01, η² = 0.17; FCz: F(1,39) = 5.42, p = 0.03, η² = 0.12; Cz: F(1,39) = 4.76, p = 0.04, η² = 0.11; F3-F4: F

(1,39) = 5.94, p = 0.02, η² = 0.13; FC3-FC4: F(1,39) = 3.78, p = 0.06, η² = 0.09; C3-C4: F(1,39) = 4.73, p = 0.04, η² = 0.11).

We also conducted similar ANOVAs of the amplitudes of difference waves (ERPs in the warm/cold conditions minus those in the control condition) in the N2 time window. The analyses also confirmed significant interactions of Treatment × Race × Expression (Fz: F(1,39) = 31.85, p < 0.001, η² = 0.45; FCz: F(1,39) = 34.07, p < 0.001, η² = 0.47; Cz: F(1,39) = 35.89, p < 0.001, η² = 0.48; F3-F4: F(1,39) = 19.99, p < 0.001, η² = 0.34; FC3-FC4: F(1,39) = 24.44, p < 0.001, η² = 0.39; C3-C4: F(1,39) = 21.35, p < 0.001, η² = 0.35). Source estimation using sLORETA suggested that the neural activity in the N2 time window that differentiated between painful and neutral expressions had potential sources in left anterior insula and inferior frontal cortex (peak MNI coordinates: −50, 10, −5, Fig. 2B).

The ANOVAs of the P3 amplitudes at 400–600 ms showed significant main effects of Race (FCz: F(1,39) = 25.54, p < 0.001, η² = 0.40; Cz: F(1,39) = 32.28, p < 0.001, η² = 0.45; CPz: F(1,39) = 32.17, p < 0.001, η² = 0.45; FC3-FC4: F(1,39) = 23.49, p < 0.001, η² = 0.38; C3-C4: F(1,39) = 37.04, p < 0.001, η² = 0.49; CP3-CP4: F(1,39) = 24.85, p < 0.001, η² = 0.39) and Expression (FCz: F(1,39) = 8.92, p < 0.01, η² = 0.19; Cz: F(1,39) = 14.51, p < 0.001, η² = 0.27; CPz: F(1,39) = 9.84, p < 0.005, η² = 0.20; FC3-FC4: F(1,39) = 12.53, p < 0.005, η² = 0.24; C3-C4: F(1,39) = 19.38, p < 0.001, η² = 0.33; CP3-CP4: F(1,39) = 21.99, p < 0.001, η² = 0.36). The P3 amplitudes were enlarged by other-race than same-race faces and by painful compared to neutral expressions, consistent with the previous findings (Ito and Bartholow, 2009; Li et al., 2015; Han et al., 2016). Moreover, the ANOVAs of the P3 amplitudes showed significant interactions of Treatment × Race × Expression (FCz: F(1,39) = 9.35, p < 0.005, η² = 0.19; Cz: F(1,39) = 15.92, p < 0.001, η² = 0.29; CPz: F(1,39) = 11.06, p < 0.005, η² = 0.22; FC3-FC4: F(1,39) = 8.35, p < 0.01, η² = 0.18; C3-C4: F(1,39) = 4.35, p < 0.05, η² = 0.10; CP3-CP4: F(1,39) = 9.08, p < 0.01, η² = 0.19), suggesting differential racial in-group bias in the P3 amplitudes to painful (vs. neutral) expression in the cold and warm conditions. Simple effect analyses revealed significant interactions of Race × Expression over the frontocentral electrodes in the cold condition (FCz: F(1,39) = 7.21, p < 0.01, η² = 0.16; Cz: F(1,39) = 9.15, p < 0.005, η² = 0.19; FC3-FC4: F(1,39) = 6.07, p < 0.05, η² = 0.14) due to greater differential P3 amplitudes to painful (vs. neutral) expressions of same-race than other-race faces, although the P3 amplitudes over frontal/central/parietal electrodes were enlarged to painful compared to neutral expressions of both same-race faces (FCz: F(1,39) = 12.52, p = 0.001, η² = 0.24; Cz: F(1,39) = 16.73, p < 0.001, η² = 0.30; CPz: F(1,39) = 14.28, p = 0.001, η² = 0.27; FC3-FC4: F(1,39) = 14.38, p = 0.001, η² = 0.27; C3-C4: F(1,39) = 19.61, p < 0.001, η² = 0.34; CP3-CP4: F(1,39) = 25.26, p < 0.001, η² = 0.39, Figs. 1 and 2A) and other-race faces (CPZ: F(1,39) = 5.67, p = 0.02, η² = 0.13; C3-C4: F(1,39) = 6.84, p = 0.01, η² = 0.15; and CP3-CP4: F(1,39) = 9.47, p < 0.01, η² = 0.19)). There were also significant interactions of Race × Expression on the P3 amplitudes over the centroparietal electrodes in the warm condition (CPz: F(1,39) = 6.97, p = 0.01, η² = 0.15; CP3-CP4: F(1,39) = 5.06, p = 0.03, η² = 0.12), suggesting greater effects of Expression on the P3 amplitudes to other-race than same-race faces, though separate analyses confirmed larger P3 amplitudes to painful compared to neutral expression of both same-race faces (Cz: F(1,39) = 4.87, p = 0.03, η² = 0.11; FC3-FC4: F(1,39) = 4.51, p = 0.04, η² = 0.10; C3-C4: F(1,39) = 6.91, p = 0.01, η² = 0.15; CP3-CP4: F(1,39) = 6.08, p = 0.02, η² = 0.14) and other-race faces (FCz: F(1,39) = 11.92, p = 0.001, η² = 0.23; Cz: F(1,39) = 16.99, p < 0.001, η² = 0.30; CPz: F(1,39) = 14.49, p < 0.001, η² = 0.27; FC3-FC4: F(1,39) = 19.50, p < 0.001, η² = 0.33; C3-C4: F(1,39) = 23.48, p < 0.001, η² = 0.38; CP3-CP4: F(1,39) = 25.48, p < 0.001, η² = 0.40).

Similar ANOVAs of the amplitudes of difference waves in the P3 time window also confirmed significant interactions of Treatment × Race × Expression (FCz: F(1,39) = 27.19, p < 0.001, η² = 0.41; Cz: F(1,39) = 29.82, p < 0.001, η² = 0.43; CPz: F(1,39)
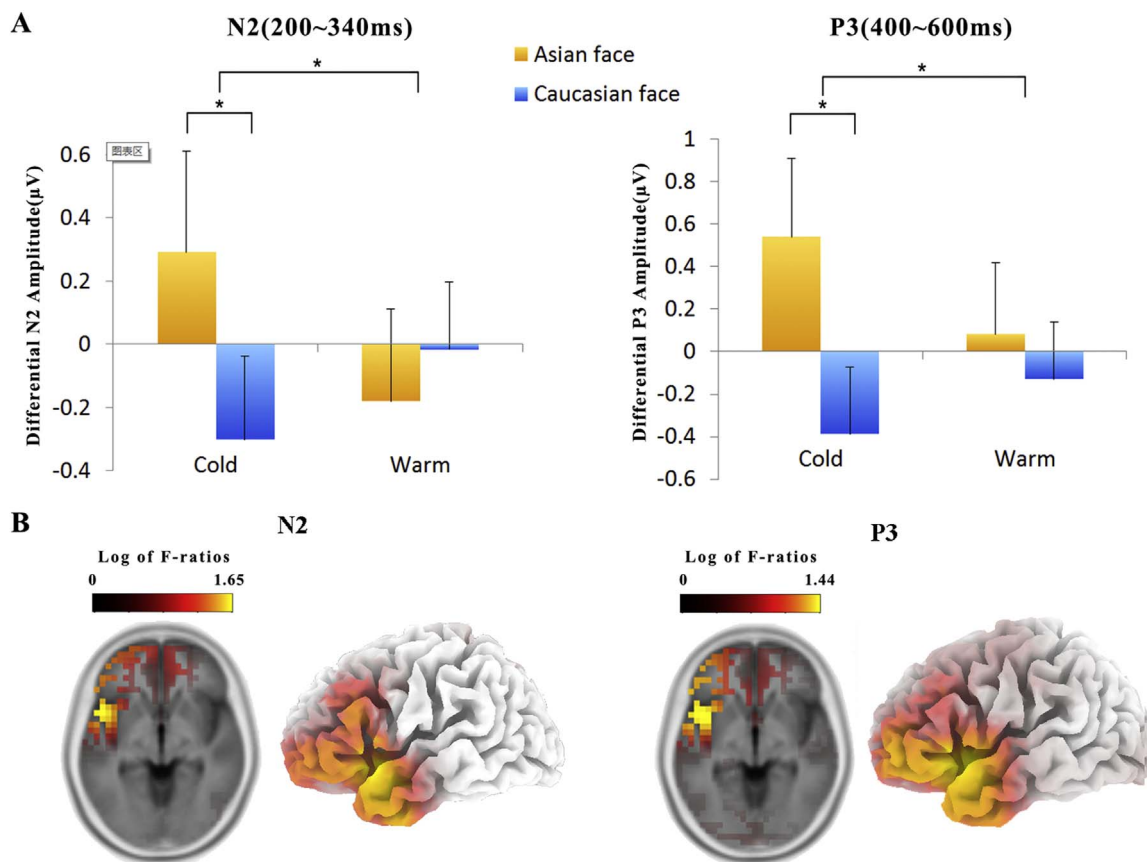
Fig. 2. (A) The mean amplitudes of the difference wave at 200–340 ms (N2) and at 400–600 (P3) were obtained by Cold(FCz_{pain}-$FCz_{Neutral}$)-Neutral(FCz_{pain}-$FCz_{Neutral}$) and Warm(FCz_{pain}-$FCz_{Neutral}$)-Neutral(FCz_{pain}-$FCz_{Neutral}$), respectively. (B) Illustration of the results of source estimation. Increased activities to painful vs. neutral expressions in the N2 and P3 time windows were identified in the left insula and inferior frontal cortex.

$= 20.56$, $p < 0.001$, $\eta^2 = 0.35$; FC3-FC4: $F(1,39) = 23.45$, $p < 0.001$, $\eta^2 = 0.38$; C3-C4: $F(1,39) = 21.70$, $p < 0.001$, $\eta^2 = 0.36$; CP3-CP4: F $(1,39) = 14.88$, $p < 0.001$, $\eta^2 = 0.28$). Source estimation using sLORETA suggested that the neural activity in the P3 time window that differentiated between painful and neutral expressions of Asian faces also had potential sources in left anterior insular and inferior frontal cortex (peak MNI coordinates: -45, 10, -5, Fig. 2B).

Finally, we assessed whether treatment, facial expression and race identity influence the amplitude of N170 related to perceptual processing of faces. The ANOVAs of the N170 amplitudes showed significant main effects of Race (P7-P8: $F(1,39) = 44.93$, $p < 0.001$, $\eta^2 = 0.54$; PO7-PO8: $F(1,39) = 49.71$, $p < 0.001$, $\eta^2 = 0.56$) and Expression (P7-P8: F $(1,39) = 6.54$, $p < 0.05$, $\eta^2 = 0.14$), suggesting larger N170 amplitudes in response to same-race than other-race faces and to neutral than painful expressions. However, neither the main effect of treatment nor its interaction with race and expression was significant on the N170 amplitude (ps > 0.05). There was no significant correlation between the N170 amplitudes and the D score (ps > 0.1).

3.2.2. Relationships between subjective ratings, implicit racial attitudes and treatment effects

To test whether differential subjective ratings of sensory feelings in the cold vs. warm conditions could predict the differences in racial in-group bias in the empathic neural response between the two conditions, we calculated the correlations between the differential rating scores and the differential racial in-group bias in empathic neural responses in the N2 or P3 time windows in the cold and warm condition. These analyses revealed significant correlations in the N2 time window (F4: r $(40) = 0.36$, $p < 0.05$; FCz: $r(40) = 0.40$, $p < 0.01$; FC4: $r(40) = 0.37$, $p < 0.05$; Cz: $r(40) = 0.38$, $p < 0.05$; C4: $r(40) = 0.47$, $p < 0.05$) and in the P3 time window (Fz: $r(40) = 0.36$, $p < 0.05$; FCz: $r(40) = 0.39$,

$p = 0.01$; Cz: $r(40) = 0.40$, $p < 0.01$; C4: $r(40) = 0.34$, $p < 0.05$, Fig. 3A), suggesting that larger differences in subjective ratings of sensory feelings between cold and warm treatments positively predicted larger changes of racial in-group bias in N2/P3 empathic neural responses in these two conditions.

Next we assessed whether the differential racial in-group bias in the empathic neural responses between the cold and warm conditions was associated with the racial in-group bias in the implicit attitude indexed by the D score in the Implicit Association Test. We found that the D score was positively correlated with the differential racial in-group bias in the empathic neural response between the cold and warm conditions in the N2 time window (C4: $r(40) = 0.35$, $p < 0.05$; CPz: $r(40) = 0.36$, $p < 0.05$; CP4: $r(40) = 0.36$, $p < 0.05$; Pz: $r(40) = 0.40$, $p < 0.01$) and in the P3 time window (CPz: $r(40) = 0.35$, $p < 0.05$; Pz: $r(40) = 0.38$, $p < 0.05$, Fig. 3B), suggesting that racial in-group bias in empathic neural response in participants with greater negative implicit attitudes toward other-race faces were more sensitive to the cold/warm manipulations. We also examined whether individuals' empathy traits were associated with the effect of treatment on the racial in-group bias in the N2 and P3 amplitudes but failed to find significant correlations between the IRI score and the effect of treatment on the racial in-group bias in the empathic neural response in the N2 and P3 time windows (ps > 0.05).

4. Discussion

The present study examined the influences of sensory (cold vs. warm) experiences on racial in-group bias in empathic neural responses. We predicted that sensory experiences in a cold environment enhance racial in-group bias in empathic neural responses relative to sensory experiences in a warm environment. Our ERP results support
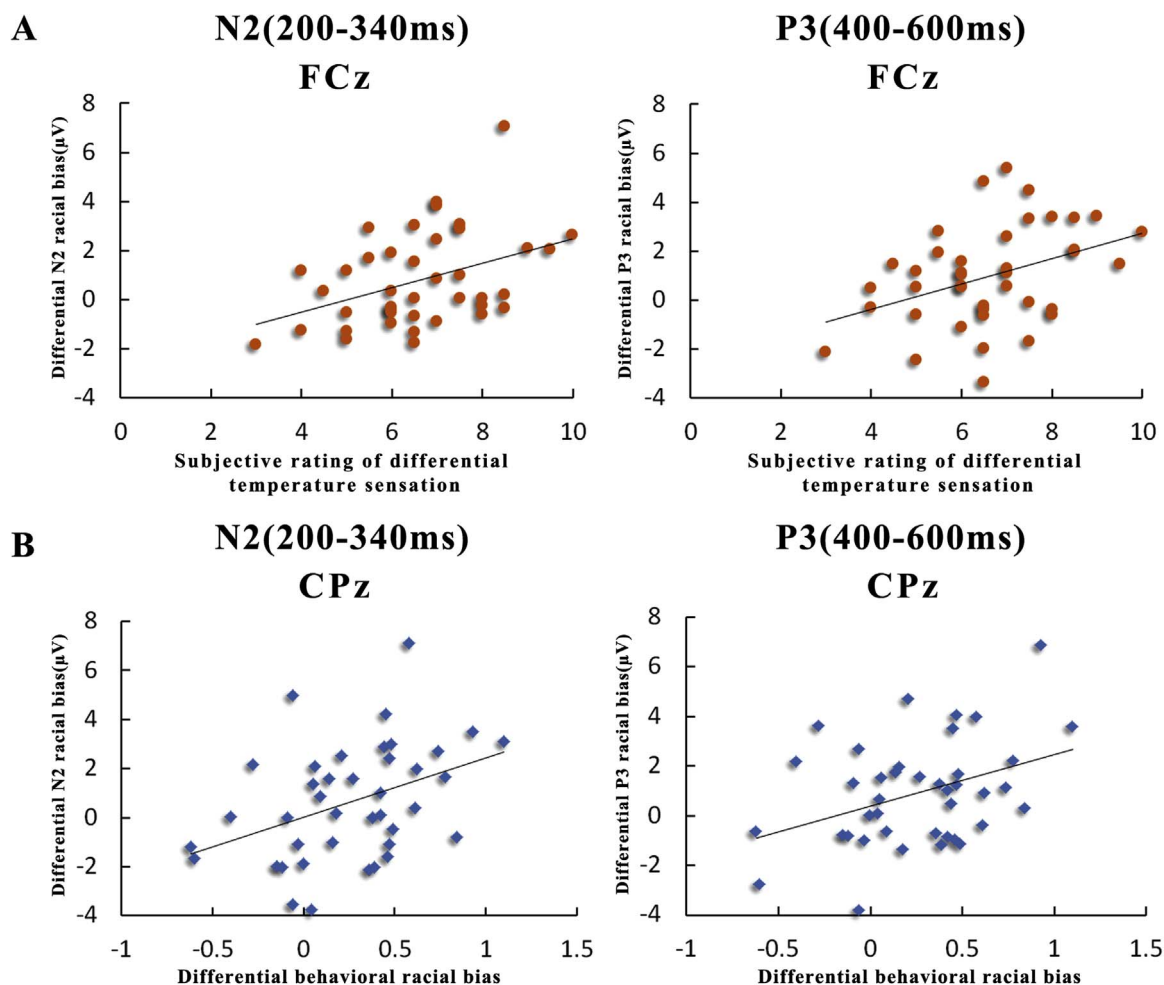
Fig. 3. (A) The correlation between the differential racial bias in the N2 and P3 amplitudes and differential subjective rating scores of temperature sensation to cold vs. warm treatment. (B) The correlation between the racial bias in the implicit racial attitudes and the differential racial bias in the N2 and P3 amplitudes between cold and warm conditions.

this hypothesis by showing evidence that cold experiences during holding a cold pack in hand, which simulated an inclement environment, enhanced racial in-group bias in empathic neural responses to others' pain relative to warm experiences during holding a warm pack in hand.

The ERP results supporting our hypothesis came from the analyses of the N2 and P3 amplitudes to same-race and other-race faces which were positively shifted by painful than neutral expressions. The modulations of the N2/P3 amplitudes by painful vs. neutral expressions are consistent with the previous ERP findings (Sheng et al., 2012, 2013; Han et al., 2016; Contreras-Huerta et al., 2014; Sessa et al., 2014). Moreover, we showed evidence that racial in-group bias in empathic responses in the N2 and P3 time windows was increased in the cold vs. warm conditions. Specifically, we found that, after taking into account of the N2/P3 amplitudes in the control condition, the differential N2/P3 amplitudes to painful (vs. neutral) expressions did not differ significantly between same-race and other-face faces (Fig. 2A) in the warm condition. However, when holding a cold pack, empathic neural responses in the N2/P3 time windows were significantly greater to same-race than other-race faces. Consistent with the effect of cold/warm manipulations on racial in-group bias in empathic neural responses, we found that individuals' subjective ratings of cold vs. warm feelings positively predicted the differential racial bias in the empathic neural response in the N2/P3 time window between cold and warm conditions. These results together suggest a causal link between cold experiences and increased racial in-group bias in empathic neural responses.

In addition, we found that the effect of physical coldness on racial in-group bias in empathic neural responses varied depending on participants' negative implicit attitudes toward other-race faces. The racial in-group bias in empathic neural responses in both the N2 and P3 time windows were more easily influenced by the cold/warm manipulations in those with greater negative attitudes toward other-race faces. It has been shown that experiencing warm or cold significantly affected attitudes (e.g., social trust) toward others (Williams and Bargh, 2008; Kang et al., 2011). Our study employed a within-subject design and the IAT was conducted after both warm and cold treatments. Thus it is unlikely that participants' implicit attitudes toward same-race and other-race faces were changed specifically by warm or cold treatments. Our results suggest possible interactions between sensory experiences and attitudes toward same-race and other-race individuals on the racial in-group bias in empathic neural responses and leave an open question for future research to clarify, i.e., where and how such interactions occur in the brain.

The early P2 amplitude that was sensitive to painful and neutral expressions did not show racial in-group bias in the task that required pain judgments. This is consistent with our previous findings that a task demand of focusing on each individual's painful feeling prompted empathic neural responses to both racial in-group and out-group members' suffering (Sheng and Han, 2012; Sheng et al., 2014, 2016). However, the P2 empathic responses did not vary in accordance with the cold vs. warm manipulations. Thus sensory experiences were unable to differentially modulate the empathic neural responses to same-race and other-race faces in the early P2 time window in the current sample

size.

The pervious ERP research revealed that the early empathic neural responses in the P2 and N2 time windows to hands and same-race faces were associated with emotional sharing (Fan and Han, 2008; Sheng and Han, 2012) and, to a certain degree, occurred independently of task demands that emphasized top-down attention to emotional cues in visual stimuli. The P3 amplitude to others' pain, however, was increased by top-down attention to others' emotional states (Fan and Han, 2008). There was also evidence that the positive activity over the frontal/parietal region in a similar time window was sensitive to cognitive evaluation of others' mental states (e.g., Sabbagh and Taylor, 2000; Wang et al., 2010). The current ERP results suggest that cold experiences seemed to mainly affect the late differential neural processes to same-race and other-race individuals' pain. Our source estimation suggested that the empathic neural responses in the N2/P3 time windows possibly originated from the left anterior insular and inferior frontal cortex—a brain region that is engaged in coding cold vs. warm temperatures (Kang et al., 2011) and in which empathic neural responses show racial in-group bias (Azevedo et al., 2013; Sheng et al., 2014). A meta-analysis suggested that the left insula is involved in both the cognitive–evaluative and affective–perceptual forms of empathy (Fan et al., 2011). Together with these findings, our ERP results suggest that racial in-group bias in both affective and cognitive components of empathy can be augmented by cold vs. warm experiences.

The current ERP findings expand our understanding of the underpinnings of racial in-group bias in empathic neural responses. From an evolutionary perspective, to survive in an inclement environment with scarce resources demands social support from members of a social group, which in turn may facilitate emotional understanding and sharing among in-group members. An inclement environment with scarce resources can also increase the salience of distinctions between in-group and out-group and promote in-group favoritism in behavior (Brewer,1979), and thus gave rise to in-group bias in empathy, as suggested by the ERP results of the current work. The demand of in-group bias in empathy due to long-term environmental pressure and life experiences such as frequent interactions between in-group members may then drive evolvement of biological mechanisms mediating the in-group bias in empathy. In consistent with this proposition, the previous research suggested that the encoding of same-race and other-race painful expressions engaged different neural populations (Sheng et al., 2016) and responded to intranasal administration of oxytocin in different fashions (Sheng et al., 2013). There was even evidence suggesting that racial in-group bias in empathic neural responses in the cingulate was associated with a specific gene (e.g., the oxytocin receptor gene polymorphism, Luo et al., 2015). Taken together, the current and previous findings suggest complex interactions between environment, sociocultural, and biological influences on empathy in humans.

Previous behavioral research has suggested that physical warmth enhances emotional link and prosocial behavioral. For example, holding a cup of hot (vs. iced) coffee enhanced belief of others' "warmer" personality such as generous and caring and led to choosing a gift for a friend instead of for oneself (Williams and Bargh, 2008). Handing participants warm vs. cold beverages or placing them in comfortable warm vs. cold ambient conditions gave rise to greater feelings of close to others and a greater relational perspective during perceptual judgments (IJzerman and Semin, 2009). These studies reported unidirectional influences of sensory experiences of physical warmth (vs. cold) on social proximity. Our ERP results complement the previous studies by showing that cold experiences can also enhance emotional link between in-group members. Thus it seems that both warm and cold experiences can facilitate social proximity but such influences can be moderated by intergroup relationships between an observer and a target. Our findings illustrate interactions between physical environments and intergroup relationship on empathy and open a new avenue toward the understanding of the influences of physical environments on social cognition.

One may notice the larger P3 amplitudes to other-race than same-race faces and the greater differential P3 amplitudes to painful vs. neutral expressions of other-race than same-race faces in the warm condition. The larger P3 amplitudes to other-race than same-race faces were also observed in the previous studies (Ito and Bartholow, 2009; Li et al., 2015; Han et al., 2016) and have been interpreted as reflecting responses to motivationally significant events (Ito and Bartholow, 2009). In a warm and comfortable condition one may not expect to see painful expressions and thus the appearance of other-race (relative to same-race) faces with painful expressions might imply events with greater significance (e.g., regressive behavior for revenge) and require further processing of mental states of other-race individuals. This is a possible account of the observed greater differential P3 amplitudes to painful vs. neutral expressions of other-race than same-race faces in the warm condition, though needs to be testified in future work.

The current work also found that the N170 amplitude was larger to same-race than other-race faces and this result is consistent with the idea that the N170 reflects a more general expertise mechanism that is sensitive to faces (Ito and Bartholow, 2009) particularly of same-race individuals (Vizioli et al., 2010). In addition, we found that the N170 amplitude was larger to neutral than painful expressions and this result replicated our previous findings (e.g., Sheng and Han, 2012). The previous literatures reported mixed results regarding the modulation of the N170 amplitudes by facial expression. Early research reported that the face-specific N170 amplitude was not affected by facial expression (e.g., Eimer and Holmes, 2002) whereas later studies found that neutral expression elicited reduced N170 amplitudes than emotional expression including both negative (fear and angry) and positive (happy) facial expressions (e.g., Blau et al., 2007; Almeida et al., 2016; Itier and Neath-Tavares, 2017; see Rellecke et al., 2013 for review). The N170 amplitudes to faces were positively correlated with the blood oxygen level dependent signals recorded from both the fusiform face area and the superior temporal sulcus and thus possibly underwent top-down influences (Sadeh et al., 2010). Thus our ERP results suggest that the N170 amplitudes in response to painful (vs. neutral) expressions might be inhibited by top-down influences and the processing of painful expression in the N170 time window was possibly different from the processing of other facial expressions.

In sum, our ERP results highlight the interaction between physical environment and differential emotional link to racial in-group and out-group members. Our findings indicate that physical coldness vs. warmth can enhance empathy for racial in-group members' pain. Potential behavioral consequences of the modulation of empathy by physical environments should be examined in future research. It should be acknowledged that our ERP findings were limited to male participants because the current work did not recruit female participants. Previous studies have shown evidence for gender differences in both brain structure and functional organization (e.g., Grön et al., 2000; Baron-Cohen et al., 2005). Future studies should test female participants to clarify whether sensory experiences produce similar influences on racial in-group bias in empathic neural responses in both sexes.

Acknowledgement

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