Embodied neural responses to others' suffering

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attentional demand (Fan & Han, 2008; Gu & Han, 2007; Sheng & Han, 2012), affective link (Singer et al., 2006), personal experiences (Cheng et al., 2007), and intergroup relationships (Hein, Silani, Preuschoff, Batson, & Singer, 2010; Huang & Han, 2014; Riečanský, Paul, Kölble, Stieger, & Lamm, in press; Sessa, Meconi, Castelli, & Dell'Acqua, 2014; Sheng & Han, 2012; Xu, Zuo, Wang, & Han, 2009). For example, enhanced attention to painful cues in stimuli or others' painful emotional states significantly increased empathic neural responses (Fan & Han, 2008; Gu & Han, 2007; Sheng & Han, 2012). Ingroup membership determined by shared ethnicity or shared belief also augmented the neural activity to perceived pain in others (Azevedo et al., 2013; Huang & Han, 2014; Mathur, Harada, Lipke, & Chiao, 2010; Sheng & Han, 2012; Sheng, Liu, Li, Fang, & Han, 2014; Xu et al., 2009). While these findings indicate that empathy for others' pain endures cognitive, affective, and social influences, to date, it is unknown whether and how an onlooker's bodily states affect his/her empathy for others' suffering. It is unclear to what degree facial mimicry can improve empathic neural responses to perceived pain expression. Addressing this issue helps to clarify the fundamental mechanisms of empathy related to the theories of embodying emotion.

The basic idea of embodying emotion is that the process of others' emotional states involves perceptual, somatovisceral, and motoric reexperiencing (or embodiment) of one's own relevant emotion (Niedenthal, 2007). The embodiment of emotion influences how emotional information is processed and congruence between an onlooker's bodily expression of emotion and others' emotional states facilitates the processing of others' emotion. In contrast, incongruence between an onlooker's bodily state and perceived emotion impairs comprehension of others' emotion. In support of the theory of embodying emotion, it has been shown that people automatically mimic smiles expressed by virtual characters in dynamic animations (Mojzisch et al., 2006) or in an interactive live setting (Bourgeois & Hess, 2008). Electromyographic (EMG) research also revealed that, when viewing a smile, one's own zygomaticus major muscle contracts within 500 ms after stimulus onset (Dimberg & Thunberg, 1998). Other studies provided evidence for a causal relationship between facial mimicry and the processing of emotion. For example, relative to keeping participants from moving their shoulders, asking participants to avoid facial movements and to clench their teeth slowed responses to categorize positive or negative expressions (Stel & van

Knippenberg, 2008). In addition, blocking the movement of expression-relevant facial muscles by asking participants to hold a pen using teeth and lips significantly impaired the detection of facial expressions (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001; Oberman, Winkielman, & Ramachandran, 2007). An ERP study (Wiswede, Münte, Krämer, & Rüsseler, 2009) reported that manipulation of facial muscles related to smile by asking participants to bite a pen modulated the amplitude of error related negativity (ERN) that is increased in participants scoring high versus low on scales for anxiety and worry (Hajcak, McDonald, & Simons, 2003, 2004). Finally, it has been shown that, during imitation of angry faces, blocking facial mimicry using botulinum toxin attenuated the activation of the left amygdala and its functional coupling with brainstem regions implicated in autonomic manifestations of emotional states (Hennenlotter et al., 2009). Taken together, these findings indicate that facial mimicry plays a critical role in recognition of others' emotional states.

An EMG study has shown evidence for an association between empathy ability and facial mimicry (Sonnby-Borgström, 2002). It was found that when exposed to angry and happy faces, the high-empathy subjects exhibited a higher degree of mimicking behavior than the low-empathy subjects, and this difference emerged at short exposure times (17–40 ms) that represented automatic reactions. In addition, the high-empathy group showed a significantly higher correspondence between facial expressions and self-reported feelings. These findings suggest a link between facial mimicry and empathy. However, there remain several questions regarding the relationship between facial mimicry and empathy. First, does facial mimicry play a causal role in empathic neural responses to others' pain? If facial mimicry is important in constructing embodied simulations for others' pain, then blocking facial muscles engaged in facial mimicry should weaken neural responses to perceived pain expression. Second, the previous ERP research uncovered both early automatic empathic neural responses within 380 ms after stimulus onset that were not influenced by task demands and late empathic neural responses after 380 ms that were). It was found

(Sonnby-Borgström, 2002), it is possible that facial mimicry produces greater effects on the early automatic than the late empathic neural responses. Third, as people showed enhanced empathic neural activity to perceived pain in ingroup compared to outgroup members (Azevedo et al., 2013; Huang & Han, 2014; Mathur et al., 2010; Sheng & Han, 2012; Sheng et al., 2014; Xu et al., 2009), it would be interesting to investigate whether the effect of facial mimicry on empathic neural responses depends on the intergroup relationship between observers and targets. As EMG recordings revealed that participants showed increased frowns in reaction to ingroup compared to outgroup members' angry faces (Bourgeois & Hess, 2008), facial mimicry may produce stronger effects on empathic neural responses to pain expressions of ingroup compared to outgroup members.

The present study tested these hypotheses by recording ERPs from healthy Chinese adults during perception of pain versus neutral expressions of racial ingroup (i.e., Asian) and outgroup (i.e., Caucasian) faces. The stimuli and paradigm were similar to those

Table 1, were subjected to a repeated measure analysis (ANOVA) with Gender (male vs. female faces), Race (Asian vs. Caucasian faces), and Expression (pain vs. neutral faces) as independent variables. This analysis did not show any significant effect (Fs < 1), indicating comparable luminance levels of the face stimuli in different conditions.

The current study adopted a within-subject design with Blocking (Blocked vs. Relaxed), Racial Group (Asian vs. Caucasian), and Expression (pain vs. neutral) as independent variables. During EEG recordings, each photograph was presented in the center of a gray background on a 21-inch color monitor, subtending a visual angle of 3.8° × 4.7° (width × height: 7.94 × 9.92 cm) at a viewing distance of 120 cm. Each trial consisted of a face stimulus with a duration of 200 ms, which was followed by a

continuing for 1200 ms. Trials contaminated by eye blinks, eye movements, muscle potentials exceeding ±50 μV at any electrode, or response errors were

responded slower to pain compared to neutral expressions of Asian faces but faster to pain compared to neutral expressions of Caucasian faces. Neither the main effect of Blocking nor its interaction with other factors was significant (p

(F(1, 23) = 31.50–52.60, ps < .001) and Expression (F(1, 23) = 15.58–42.89, ps < .005), being larger to Asian than Caucasian faces and smaller to pain than neural expressions. Similarly, ANOVAs of the P3 amplitudes at 400–680 ms showed significant main effect of Racial Group (F
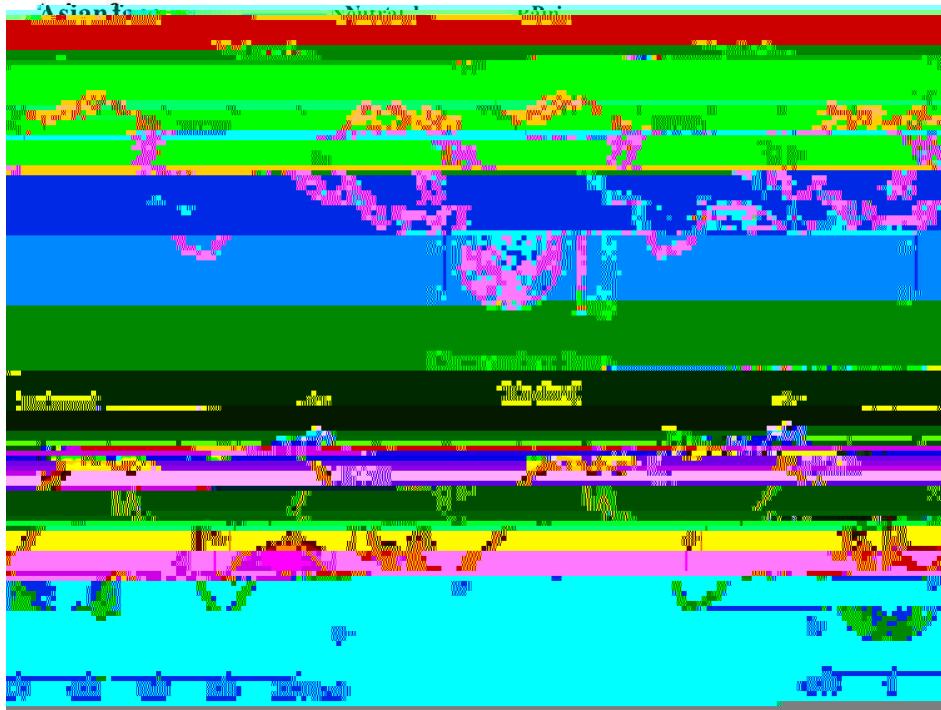
Figure 3. Grand-averaged ERPs to Asian and Caucasian faces recorded at electrode P8.
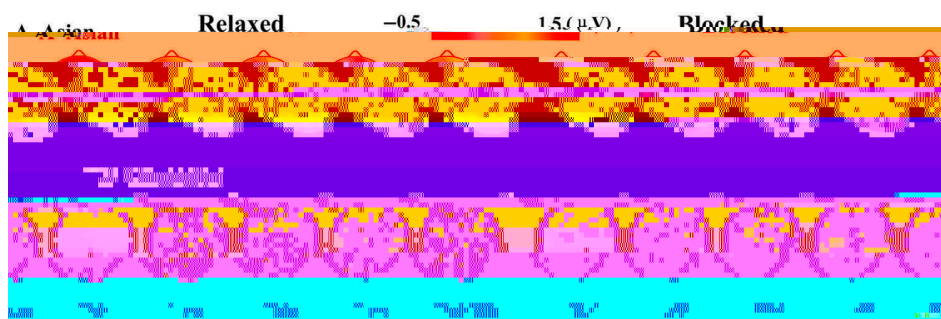
Figure 4. Voltage topographies of the difference waves to pain (vs. neutral) expression in the time windows corresponding to each ERP component.

P2, N2, P3, and N170 amplitude was significant (ps > .05).

To examine whether empathic neural responses were associated with subjective feelings of perceived pain and participants' empathy traits, we calculated correlations between the differential ERP amplitudes to pain versus neutral expressions and differential rating scores of pain intensity and self-unpleasantness. The empathic neural responses to Asian faces in the N1 time window were negatively correlated with subjective rating of pain intensity

(r = −.55~−.44, ps < .05, see Figure 5A) and self-unpleasantness (r = −.57~−0.46, ps < .05, see Figure 5B) in the Relaxed condition. The larger the N1 amplitude increased by pain versus neutral expressions of Asian faces in the Relaxed condition, the stronger feelings of others' pain and one's own unpleasantness. To further assess whether the mimicry effect on empathic neural responses was related to participants' empathy traits, we calculated the mimicry effect by subtracting empathic neural responses of Asian faces (i.e., N1 amplitude to pain

vs. neutral expressions) in the Blocked condition from those in the Relaxed condition. We then calculated the correlation between IRI scores and the mimicry effect on the empathic neural response in the N1 time window. This revealed a significantly negative correlation between the N1 mimicry effect and the subscale of personal distress in IRI ($r = -.56 \sim -.41$, $ps < 0.05$, see Figure 5C), the larger the personal distress score, the greater mimicry effect on the N1 amplitude.

EMG results

ANOVAs of the EMG activity revealed a significant main effect of Block (masseter: $F(1, 19) = 30.28$, $p < .001$; risorius: $F(1, 19) = 24.85$, $p < .001$) and Sequence (masseter: $F(3, 57) = 8.78$, $p < .001$; risorius: $F(3, 57) = 5.11$, $p < .005$). The interaction of Block and Sequence did not reach significance ($ps > .05$). These results suggest that EMG activity was stronger in the Blocked than Relaxed conditions and tended to increase as EEG recording preceded (Figure 6).

DISCUSSION

emotion (Niedenthal, 2007), we can assume a similar relationship between bodily states of emotion and encoding/representation of others' emotional states regardless of what emotion (e.g., pain, fear) is processed. This may then allow us to predict that blocking facial mimicry should also modulate the neural activity underlying the processing other types of emotion. This can be tested in future research.

Our ERP results also suggest a new mechanism underlying the racial ingroup bias in empathy. Previous ERP and fMRI studies unveiled multiple factors that contribute to the racial ingroup bias in empathic neural responses. For example, the lack of individuated process and perspective-taking characterizes the perception of perceived pain in racial outgroup members (Drwecki, Moore, Ward, & Prkachin, 2011; Sheng & Han, 2012; Sheng et al., 2014). Perception of pain expressions of racial ingroup and outgroup individuals recruits distinct neuronal populations at a specific stage of the processing stream (Sheng, Han, & Han, 2015). Oxytocin, a neuropeptide that functions as both hormone and neurotransmitter and plays a key role in social attachment and affiliation, facilitates empathic neural responses in the P2 time window to racial ingroup but not outgroup members' suffering (De Dreu et al., 2010, 2011; Domes, Heinrichs, Michel, Berger, & Herpertz, 2007; Sheng et al., 2013). The racial ingroup bias in empathy for pain is also associated with the oxytocin receptor gene (OXTR) because G/G compared to A/A homozygous of OXTR rs53576 showed stronger ACC/SMA activity in response to racial ingroup members' pain (Luo et al., 2015). Life experiences also influence racial ingroup bias in empathic neural responses as Chinese adults who were brought up in Western countries, where Caucasians consist of the majority of population, did not show racial ingroup favoritism in the ACC and insular activity in response to perceived pain in others (Zuo & Han, 2013). The current findings complement the previous work by illustrating that, besides the distinct cognitive strategy and biological function of hormone/ neurotransmitter associated with perceived pain in racial ingroup and outgroup members, an observer's bodily state may also contribute to the racial ingroup bias in empathy due to the greater sensitivity of facial muscles to perceived pain expression in racial ingroup than outgroup members. This may be attributed to more social experiences and greater similarity in physical appearance with racial ingroup versus outgroup members, which may lead to a stronger sense of familiarity with racial ingroup members. Together with the finding of increased frowns in response to ingroup member's compared to the outgroup member's angry faces (Bourgeois & Hess, 2008), our ERP results support the proposition that

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