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Task modulations of racial bias in neural responses to others' suffering

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ABSTRACT

Recent event related brain potential research observed a greater frontal activity to pain expressions of racial in-group than out-group members and such racial bias in neural responses to others' suffering was modulated by task demands that emphasize race identity or painful feeling. However, as pain expressions activate multiple brain regions in the pain matrix, it remains unclear which part of the neural circuit in response to others' suffering undergoes modulations by task demands. We scanned Chinese adults, using functional MRI, while they categorized Asian and Caucasian faces with pain or neutral expressions in terms of race or identified painful feelings of each individual face. We found that pain vs. neutral expressions of Asian but not Caucasian faces activated the anterior cingulate (ACC) and anterior insular (AI) activity during race judgments. However, pain compared to race judgments increased ACC and AI activity to pain expressions of Caucasian but not Asian faces. Moreover, race judgments induced increased activity in the dorsal medial prefrontal cortex whereas pain judgments increased activity in the bilateral temporoparietal junction. The results suggest that task demands emphasizing an individual's painful feeling increase ACC/AI activities to pain expressions of racial out-group members and reduce the racial bias in empathic neural responses.

Introduction

Empathy, especially that for other's suffering, has been suggested to serve as a proximate mechanism of altruistic behavior (De Waal, 2008; Decety and Jackson, 2004). The neural correlates of empathy for pain have been investigated extensively in recent functional magnetic resonance imaging (fMRI) studies. It has been shown that a neural circuit consisting of the anterior cingulate cortex (ACC), bilateral anterior insula (AI), and sensorimotor cortex is activated when perceiving painful stimulation applied to others (Avenanti et al., 2005; Gu and Han, 2007a; Lamm et al., 2010; Singer et al., 2004) or perceiving others' painful facial expressions (Botvinick et al., 2005; Han et al., 2009; Lamm et al., 2007; Saarela et al., 2007; see Fan et al., 2011; Lamm et al., 2011; for review). Event related potential (ERP) studies revealed that empathic neural responses to perceived pain in others occur as early as 140 ms after stimulus presentation over the frontal/central regions (Decety et al., 2010; Fan and Han, 2008; Han et al., 2008; Li and Han, 2010; Mu et al., 2008; Sheng and Han, 2012; Sheng et al., 2013). The neural responses to others' suffering are associated with subjective feelings of others' pain (e.g., Jackson et al., 2005) and observers' traits of empathy (e.g., Sheng and Han, 2012; Singer et al., 2004). The magnitude of neural responses to others' suffering predicts altruistic behavior such as donation (Ma et al., 2011) and costly help (Hein et al., 2010), suggesting that neural responses to others' suffering may mediate altruistic behavior.

Interestingly, recent brain imaging studies have shown that, rather than showing equal neural responses to perceived suffering in others, human adults exhibit different empathic neural responses to others' suffering depending on the intergroup relationship between a perceiver and a target. Xu et al. (2009) reported the first fMRI evidence that both Chinese and Caucasian participants exhibited stronger ACC activity to painful stimulations applied to racial in-group compared to racial out-group individuals. Other researchers reported racial in-group bias in neural responses to others' suffering in Black and White participants. Using transcranial magnetic stimulation, Avenanti et al. (2010) showed that observing painful stimulation applied to racial in-group but not out-group models inhibited the onlookers' sensorimotor activity. Mathur et al. (2010) showed fMRI evidence for greater activity in the dorsal medial prefrontal cortex (MPFC) when African-American individuals observed the suffering of racial in-group relative to out-group individuals. Azevedo et al. (in press) also reported that the left AI activity was more strongly activated by perceived pain experienced by own-race models compared to that of other-race models and that greater racial bias in implicit attitudes predicted increased activity within the left AI in response to own-race pain relative to other-race pain. The racial bias in empathy exhibits cultural difference as, compared to Caucasian-American participants, Korean participants reported experiencing greater empathy and showed stronger activity

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in the left temporoparietal junction (TPJ) for racial in-group compared to out-group members (Cheon et al., 2011, 2013). A recent ERP research further showed that a neural peptide, i.e., oxytocin that serves as both hormone and neurotransmitter, may be engaged in racial in-group bias in empathic neural responses because oxytocin vs. placebo treatments increased the racial in-group bias in neural responses to others' suffering (Sheng et al., 2013). These findings uncover neural, sociocultural and molecular basis of racial in-group bias in empathy.

Although humans exhibit racial bias in empathic neural responses and the racial bias in empathy may affect prosical behavior (Drwecki et al., 2011; Johnson et al., 2002), our recent research has shown evidence that the racial bias in neural responses to others' suffering is not inevitable. Zuo and Han (2013) found that Chinese individuals with long-term experiences of living in American and European countries showed comparable neural responses to perceived painful stimulations applied to Asian and Caucasian individuals. By recording ERPs from Chinese adults during perceiving pain and neutral facial expressions of Asian and Caucasian models, Sheng and Han (2012) found that, relative to neutral expressions, pain expressions increased neural responses at 128–188 ms after stimulus onset over the frontal/central brain regions when participants categorized faces in terms of race (race judgments). However, this effect was evident for racial in-group (i.e., Asian) faces but not for racial out-group (i.e., Caucasian) faces. More interestingly, they showed that the racial bias in neural responses to others' suffering can be reduced by enhancing attention to painful feelings of racial out-group individuals. Sheng and Han compared neural responses to pain vs. neutral expressions when participants performed race judgments or pain judgments (i.e., identifying each observed individual's feelings of pain) on face stimuli. They found that paying attention to each individual's painful feeling significantly eliminated the racial bias in empathic neural responses by increasing the neural activity to pain expressions of other-race faces. These findings indicate that the racial bias in empathic neural responses can be reduced when participants adopt a specific cognitive strategy.

The ERP findings of variable racial bias in empathic neural responses leave two open questions. First, due to the low spatial resolution of ERP signals, the exact brain regions in which neural responses to the suffering of racial out-group members were enhanced by task demands remain unknown. It is likely that empathic neural responses in the ACC and AI that are less activated to racial out-group compared to in-group individuals (Azevedo et al., in press; Xu et al., 2009) may be specifically enhanced by task instructions that promote attention to each individual's painful feeling. Second, although the ERP research has shown that pain judgments compared to race judgments increased empathic neural responses to racial out-group members (Sheng and Han, 2012), it is still unclear which brain regions are specifically engaged during pain vs. race judgments. As individuated processing of racial in-group and out-group faces, which encourage perceiving another person as a unique social entity rather than merely a member of a social group, engaged brain regions implicated in mentalizing and theory of mind (e.g., TPJ, Freeman et al., 2010), it is possible that performing pain judgments on facial expressions may induce greater TPJ activity relative to race judgments.

To test these hypotheses, we scanned Chinese adults using fMRI while they were presented with pain and neutral expressions of Asian and Caucasian faces that were used in our previous ERP study (Sheng and Han, 2012). Previous fMRI (de Greck et al., 2012; Gu and Han, 2007a; Lamm et al., 2010; Xu et al., 2009) and ERP (Fan and Han, 2008; Li and Han, 2010; Sheng and Han, 2012; Sheng et al., 2013) studies asked participants to either evaluate/empathize/perceive the pain of others on an individual level or categorize faces into different social groups (e.g., race). Similarly, the present study asked participants to perform race judgments or pain judgments on face stimuli in separate blocks of trials, respectively. We predicted that empathic neural responses in brain regions such as the ACC and AI would be stronger to racial in-group than out-group individuals during race judgments. However, such racial bias in empathic neural responses would be reduced during pain judgments that emphasize attention to each individual's painful feelings. Finally, we predicted that, relative to race judgments, pain judgments may engage theory-of-mind related brain regions such as the TPJ.

Materials and methods

Participants

Twenty one Chinese college students (11 females; 19–26 years, mean ± SD = 22.0 ± 1.8 years) participated in the study as pain volunteers. All participants were right-handed, reported no history of neurological or psychiatric diagnoses, and had normal or corrected-to-normal vision. Informed consent approved by a local ethics committee was obtained prior to the study.

Stimuli and procedure

The stimuli consisted of 64 color photos of 16 Asian (8 females) and 16 Caucasian faces (8 females) with pain or neutral expressions, which were adopted from our previous study (Sheng and Han, 2012). Emotional intensity, attractiveness and luminance of Asian and Caucasian faces were matched (see Sheng and Han, 2012).

Stimuli were presented through an LCD projector onto a rear projection screen, which were viewed with an angled mirror positioned on the head-coil. Each photo was presented at the center of a gray background, subtending a visual angle of 4.0° × 5.0° at a viewing distance of 100 cm. A mixed design was used. Each participant completed eight functional scans. Each scan consisted of 4 blocks of trials and participants conducted race judgments (Asian or Caucasian) in 2 blocks of trials but pain judgments (pain or neutral expression) in another 2 blocks of trials. During race judgments participants were asked to identify race of each face (Asian vs. Caucasian) while ignoring facial expressions. During pain judgments participants were asked to identify facial expression of each face (pain vs. neutral) while ignoring its race. Instructions emphasized both speed and accuracy. Each block started with a 4 s prompt screen with an instruction to define a judgment task, followed by 8 trials. On each trial an Asian or Caucasian face with pain or neutral expressions was presented with a duration of 2 s, which was followed by a cross fixation with a duration of 2, 4, 6 or 8 s. Participants responded to each stimulus by a button press using the left and right index fingers. The stimuli in each block and 4 blocks in each scan were presented in a random order. The association between response buttons and stimulus categories (Asian vs. Caucasian or pain vs. neutral expression) was counterbalanced across participants.

After scanning, participants were asked to rate pain intensity of each face and subjective feeling of self-unpleasantness induced by each face on an 11 point Likert scale (0 = not at all painful or unpleasant, 10 = extremely painful or unpleasant). Participants completed the Interpersonal Reactivity Index (IRI) that includes two cognitive subscales (Perspective Taking and Fantasy) and two affective subscales (Empathic Concern and Personal Distress) (Davis, 1996) to assess their trait empathy. Participants were also asked to rate the likability of each face (0 = not at all, 10 = very strong) in order to assess their explicit attitude toward racial in-group/out-group faces. In addition, participants were required to perform a race version of the Implicit Association Test (IAT; Greenwald et al., 1998) using another set of Asian and Caucasian faces with neutral expressions. The participants 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. The difference of response latencies between the two types of blocks were calculated as an index of racial bias in attitude, namely D score (Greenwald et al., 2003). A D score

above zero indicates that relative to out-group members, in-group members are associated with positive rather than negative attitude, whereas a D score below zero indicates negative rather than positive attitude toward in-group members relative to out-group members.

fMRI data acquisition

Imaging data were acquired using a 3-T Siemens Trio system with a standard head coil. Head motion was minimized using foam padding. Thirty-two transversal slices of functional images that covered the whole brain were acquired using a gradient-echo echoplanar pulse sequence ($64 \times 64 \times 32$ matrix with $3.75 \times 3.75 \times 4$ mm^3 spatial resolution, repetition time (TR) = 2000 ms, echo time (TE) = 30 ms, flip angle = 90°, field of view (FOV) = 24 × 24 cm). Anatomical images were subsequently obtained using a standard 3D T1-weighted sequence ($256 \times 256 \times 144$ matrix with $1.0 \times 1.0 \times 1.3$ mm^3 spatial resolution, TR = 2530 ms, TE = 3.37 ms, flip angle = 7°).

fMRI data analysis

The fMRI data were analyzed using SPM8 (the Wellcome Trust Centre for Neuroimaging, London, United Kingdom). The functional images were corrected for differences in acquisition time between slices for each whole-brain volume and realigned within and across runs to correct for head movement. Six movement parameters (translation: x, y, z and rotation: pitch, roll, yaw) were included in the statistical model. The anatomical image was co-registered with the mean functional image produced during the process of realignment. All images were normalized to a $2 \times 2 \times 2$ mm^3 Montreal Neurological Institute (MNI) template. Functional images were spatially smoothed using a Gaussian filter with the full-width/half-maximum parameter (FWHM) set to 8 mm.

Region-of-interest (ROI) analyses were first conducted to test our hypothesis. The ROIs were defined as a sphere with a radius of 10 mm centered at the ACC (x/y/z = 6/26/44) and the left AI (x/y/z = −36/24/2) that were observed in the contrast of pain vs. neutral expression in Chinese participants in our previous work (Han et al., 2009). Parameter estimates of signal intensity in these brain regions were calculated using MarsBaR 0.38 (http://marsbar.sourceforge.net) and then subjected to a repeated analysis of variance (ANOVA) with Expression (pain vs. neutral), Race (Asian vs. Caucasian) and Task (race vs. pain judgments) as independent within-subjects variables.

Whole brain analyses were also conducted to further confirm the results of ROI analyses. In the first level of the whole brain analysis, the onsets and durations of each stimulus were modeled for each subject using a general linear model. The fixed effect model was used to estimate a canonical hemodynamic response function and its time derivatives. Given that the response accuracy across all conditions was near ceiling (mean accuracy > 92%) and did not differ significantly between different conditions, all trials were included in the SPM model to ensure equal number of trials per condition. The conditions [2 (Expression: Pain or Neutral) × 2 (Race: Asian or Caucasian) × 2 (Task: Race judgment or Expression judgment)] were modeled for each subject. Random-effect analyses at the group level were then conducted using the individual contrast estimates. The contrast of pain vs. neutral expressions was calculated to identify the neural circuit engaged in perceiving others' pain expression. The contrast of $(\text{Pain} - \text{Neutral})_{\text{Asian faces}}$ vs. $(\text{Pain} - \text{Neutral})_{\text{Caucasian faces}}$ were calculated for both race-judgment and pain-judgment tasks to examine the racial bias in neural responses to others' suffering. The contrast of $(\text{Pain} - \text{Neutral})_{\text{Pain judgment}}$ vs. $(\text{Pain} - \text{Neutral})_{\text{Race judgment}}$ were calculated respectively for Asian and Caucasian faces to assess the task effect on neural responses to pain expression of racial in-group and out-group individuals. The contrast of pain vs. race judgments and the reverse contrast were calculated to examine brain regions that were specifically related to each task. Significant activations in the whole-brain analysis were identified using a threshold of $p < 0.05$ (false discovery rate (FDR) corrected for multiple comparisons).

Results

Behavioral results

Table 1 shows mean reaction times (RT) and responses accuracies during race and pain judgments. ANOVAs of RTs with Expression (pain vs. neutral), Race (Asian vs. Caucasian) and Task (race vs. pain judgments) as independent within-subjects variables showed a significant interaction of Task × Expression ($F(1,20) = 13.83$, $P = 0.001$). Post hoc analyses revealed that RTs were longer to pain than neutral expressions during race judgments ($F(1,20) = 21.10$, $P < 0.001$) whereas a reverse pattern was evident during pain judgments ($F(1,20) = 4.45$, $P < 0.05$). ANOVAs of response accuracies did not show any significant effect ($Ps > 0.1$).

Participants rated pain expressions being more painful ($F(1,20) = 444.63$, $P < 0.001$), inducing more self-unpleasantness ($F(1,20) = 57.44$, $P < 0.001$), and being less likable ($F(1,20) = 14.29$, $P < 0.001$) compared to neutral expressions (Table 1). However, these rating scores did not differ significantly between Asian and Caucasian faces ($Ps > 0.1$), similar to the previous findings (Azevedo et al., in press; Sheng and Han, 2012; Xu et al., 2009). The D score of IAT tended to be larger than zero but the difference did not reach significance ($M \pm SD = 0.11 \pm 0.40$, $P > 0.1$). This is similar to our pervious observations (Sheng and Han, 2012) and suggests comparable implicit attitudes toward Asian and Caucasian faces in our participants.

fMRI results

ROI analysis

ANOVAs of parameter estimates of signal intensity in the ACC and left AI showed significant main effects of Expression (ACC: $F(1,20) = 7.19$, $P < 0.05$; left AI: $F(1,20) = 7.06$, $P < 0.05$) and significant interactions of Expression × Task (ACC: $F(1,20) = 4.90$, $P < 0.05$; left AI: $F(1,20) = 9.81$, $P < 0.01$), suggesting that race vs. pain judgments significantly modulated the ACC and AI activity to others' suffering. Moreover, there was a significant three-way interaction of Expression × Race × Task for the ACC activity ($F(1,20) = 6.17$, $P < 0.05$), marginally significant for the left AI activity ($F(1,20) = 3.54$, $P = 0.075$) (Fig. 1), suggesting that, relative to race judgments, pain judgments significantly reduced the racial bias in neural responses to others' suffering.

To further assess the racial bias in neural responses to pain vs. neutral expressions during race and pain judgments, we conducted ANOVAs of signal intensity with Expression (pain vs. neutral) and Race (Asian vs. Caucasian) as independent within-subjects variables for the two tasks, respectively. We found significant interactions of Expression × Race in the ACC ($F(1,20) = 15.02$, $P < 0.001$) and left AI activity ($F(1,20) = 6.01$, $P < 0.05$) during race judgments. Post-hoc analyses indicated that the contrast of pain vs. neutral expressions revealed significantly greater ACC and left AI activity for Asian faces ($F(1,20) = 4.41$ and 4.81, $Ps < 0.05$) but not for Caucasian faces ($F(1,20) = 2.56$ and 1.30, $Ps > 0.1$). During pain judgments, however, the interaction of Expression × Race was not significant ($Ps > 0.5$). The contrast of pain vs. neutral expressions showed significantly greater ACC and left AI activity for both Asian faces ($F(1,20) = 4.71$ and 6.02, both $Ps < 0.05$) and Caucasian faces ($F(1,20) = 7.30$ and 7.73, both $Ps < 0.05$), suggesting that participants showed increased ACC and AI activity to pain expressions of both racial in-group and out-group individuals.

We also estimated the effect of task modulations of racial bias in neural responses to others' suffering by conducting ANOVAs with Expression (pain vs. neutral) and Task (race vs. pain judgments) as independent within-subjects variables for Asian and Caucasian faces,

Table 1
Results of behavioral performances during scanning and post-scanning ratings (mean ± SD).

		Asian face		Caucasian face	
		Neutral	Pain	Neutral	Pain
Accuracy (%)	Race judgment	93 ± 8	92 ± 8	93 ± 11	94 ± 8
	Pain judgment	94 ± 11	95 ± 6	94 ± 5	92 ± 7
Reaction Time (ms)	Race judgment	987 ± 196	1030 ± 166	980 ± 182	1011 ± 199
	Pain judgment	1056 ± 204	1003 ± 157	1047 ± 203	1011 ± 143
Pain intensity		0.31 ± 0.47	5.99 ± 1.39	0.28 ± 0.35	6.09 ± 1.23
Unpleasantness		0.66 ± 0.62	3.82 ± 2.13	0.54 ± 0.49	3.73 ± 1.94
Likability		4.04 ± 2.28	2.62 ± 1.69	4.18 ± 2.07	2.82 ± 1.79

Note: RTs were longer to pain than neutral expressions during race judgments ($P < 0.001$) but slower to pain than neutral expressions during pain judgments ($P < 0.05$). Pain expressions were rated being more painful, inducing more self-unpleasantness, and being less likable compared to neutral expressions ($Ps < 0.001$).

respectively. ANOVAs of the ACC and left AI activity to Caucasian faces showed significant interactions of Task × Pain ($F(1,20) = 13.25$ and 15.34, $Ps < 0.005$ and 0.001) because pain vs. neutral expressions induced stronger ACC activity and stronger left AI activity for Caucasian faces during pain judgments ($F(1,20) = 7.30$ and 7.73, $Ps < 0.05$) but not during race judgments ($F(1,20) = 2.56$ and 1.30, $Ps > 0.1$). However, ANOVAs of the ACC and left AI activity to Asian faces did not show significant interactions of Task × Pain ($F(1,20) = 0.01$ and 0.44, $Ps > 0.1$), suggesting comparable neural responses to pain vs. neutral expressions of Asian faces during race and pain judgments. Taken together, these results indicate that pain- vs. race-judgment tasks mainly modulated the ACC and AI activity to the suffering of racial out-group members.

We also calculated contrast values in the ACC and AI defined in a meta-analysis (Fan et al., 2011). ANOVAs of the ACC and AI activity based on the meta-analysis are similar to those based on the ROIs from our previous study of Chinese participants (Han et al., 2009), and the corresponding results are reported in Supplementary data.

Whole brain analysis

We first conducted the whole brain analysis to examine brain regions involved in perceiving pain vs. neutral expressions by collapsing the fMRI data associated with Asian and Caucasian faces. During pain judgments the contrast of pain vs. neutral expressions revealed significant activations in the ACC (extending into the supplementary motor area (SMA), left AI, bilateral inferior frontal cortex and AI, bilateral thalamus and caudate, right middle temporal cortex and superior temporal sulcus, left posterior temporal middle cortex, right posterior middle temporal cortex, and left cerebellum) (Table 2 and Fig. 2A). During race judgments, however, the contrast of pain vs. neutral expressions failed to show any significant activation, presumably due to the weakened neural response to pain expressions of racial out-group faces.

Whole brain regression analyses were then conducted to assess the association between trait empathy and neural responses to others' suffering. Participants' IRI rating scores were entered as a regressor into the SPM simple regression analysis along with each participant's contrast image of pain vs. neutral expressions during pain judgments. This revealed significant activations in the ACC and left AI at the threshold of $p < 0.05$ (FDR corrected, Table 3). Fig. 2B illustrates the positive correlation between the rating scores of empathy concern subscale and ACC/AI activity across all participants. The regression analyses using rating scores of other subscales of IRI did not show any significant activation. We also conducted regression analyses using the post-scan rating scores (pain intensity, self-unpleasantness, likability) as regressors but did not find significant results.

To further examine racial in-group bias in neural responses to others' pain, we conducted whole-brain interaction analyses of the contrast of $(\text{Pain} - \text{Neutral})_{\text{Asian faces}}$ vs. $(\text{Pain} - \text{Neutral})_{\text{Caucasian faces}}$ during race and pain judgments, respectively. This analysis revealed significant activation in the ACC/SMA ($x/y/z = 4/30/52$, $K = 388$, Fig. 3A) during race judgments, suggesting stronger neural activity to pain expressions of racial in-group compared to out-group faces. The same contrast, however, did now show any significant activation during pain judgments. The reverse contrast of $(\text{Pain} - \text{Neutral})_{\text{Caucasian faces}}$ vs. $(\text{Pain} - \text{Neutral})_{\text{Asian faces}}$ did not show any significant activation during either race or pain judgments. A whole brain regression analysis was also conducted to examine the association between racial bias in neural activity and implicit attitudes toward other-race faces using IAT scores

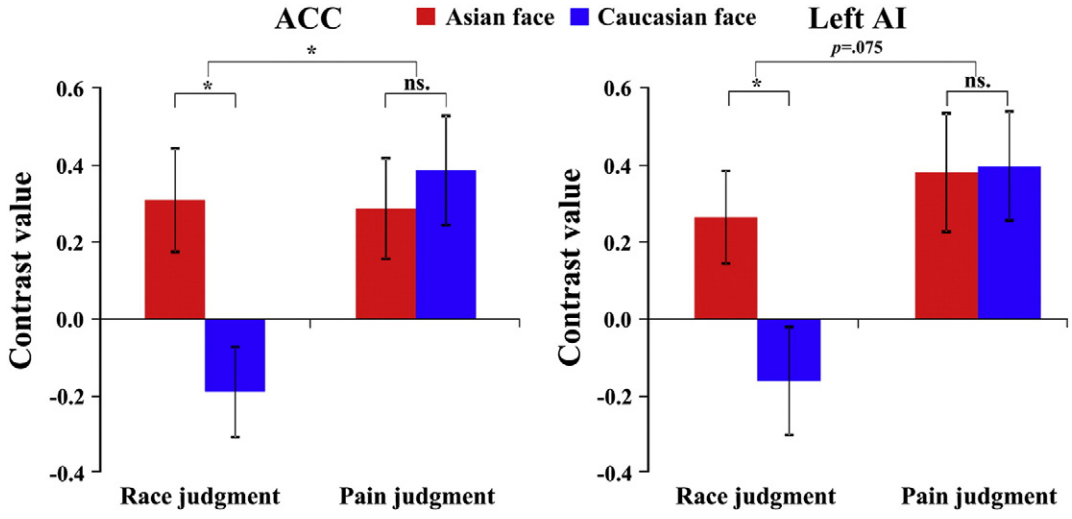

Fig. 1. Contrast values of the parameter estimates of signal intensity in the ACC and left AI that differentiated pain and neutral expressions. *$P < 0.05$.

Table 2
The results of whole-brain analyses.

Cortical region	Cluster size	x	y	z	t
Pain effect during pain judgments					
Pain > Neutral					
Anterior cingulated cortex/Supplementary motor area	1984	8	36	2	5.48
Left anterior insula	852	−40	30	−16	5.64
Left inferior frontal cortex	169	−54	16	6	4.39
Right anterior insula/inferior frontal cortex	205	54	38	0	6.89
Left thalamus	286	−12	−10	10	5.69
Right thalamus/Caudate	627	24	20	4	6.40
Right Superior temporal sulcus	1439	46	−58	−6	5.67
Left posterior middle temporal cortex	317	−28	−92	2	5.20
Right posterior middle temporal cortex	392	40	−78	18	5.40
Left cerebellum	1081	−40	−72	−20	6.97
Empathic bias during race judgments					
Asian face (Pain − Neutral) > Caucasian face(Pain − Neutral)					
Anterior cingulated cortex/Supplementary motor area	388	4	30	52	4.96
Task effect on Caucasian face					
$(Pain - Neutral)_{pain\ judgment} > (Pain - Neutral)_{ace\ judgment}$					
Anterior cingulated cortex/Supplementary motor area	2659	2	46	12	6.80
Right insular cortex	496	38	22	−10	5.52
Left insular cortex	509	−40	6	−12	5.45
Task effect					
Pain judgment > Race judgment					
Right temporoparietal cortex	544	68	−36	26	5.70
Left temporoparietal cortex	721	−66	−36	28	5.67
Right Parietal cortex	315	20	−50	60	4.89
Race judgment > Pain judgment					
Medial prefrontal cortex	513	0	50	22	5.16

Note: MNI coordinates are given. A threshold of ($P < 0.05$, FDR-corrected) was used.

as regressors. This analysis, however, did not show any significant result possibly due to the lack of implicit negative attitudes toward Caucasian faces in our participants.

Table 3
The results of whole-brain regression analyses.

Cortical region	Cluster size	x	y	z	t
Anterior cingulated cortex	3472	6	40	18	5.56
Left anterior insula	1100	−44	30	−14	7.07
Right anterior insula/inferior frontal cortex	275	38	24	−16	6.16
Left thalamus	1055	−10	−8	10	5.59
Right thalamus		12	−6	8	5.91

Note: MNI coordinates are given. A threshold of ($P < 0.05$, FDR-corrected) was used.

To further assess the effect of task modulations on neural responses to others' suffering, we conducted the interaction analyses of contrast of $(Pain - Neutral)_{Pain\ judgment}$ vs. $(Pain - Neutral)_{Race\ judgment}$ for Asian and Caucasian faces, respectively. This contrast revealed significant activations in the ACC/SMA (x/y/z = 2/46/12, K = 2659) and bilateral AI (left: x/y/z = −40/6/−12, K = 509; right: x/y/z = 38/22/−10, K = 496, Fig. 3B) for Caucasian faces but not for Asian faces. The reversed contrast of $(Pain - Neutral)_{Race\ judgment}$ vs. $(Pain - Neutral)_{Pain\ judgment}$ did not show any significant activations during either race or pain judgments.

Finally, we examined neural correlates of task effects by contrasting pain vs. race judgments regardless of facial expressions. The contrast of pain vs. race judgments showed significant activations in the left and right TPJ (left: x/y/z = −66/−36/28, k = 721; right: x/y/z = 68/−36/26, k = 544, Fig. 4A) as well as the right lateral parietal cortex (x/y/z = 20/−50/60, k = 315). The contrast of race vs. pain judgments, however, significantly activated in dorsal MPFC (x/y/z = 0/50/22, k = 513, Fig. 4B).

Discussion

The current study aimed to identify the brain regions in the neural network involved in empathy for pain that are modulated by task demands emphasizing either race identity or painful feeling of each face. Our behavioral measurements showed that response speeds to pain and neutral expressions were sensitive to task demands as RTs were longer to pain than neutral expressions during

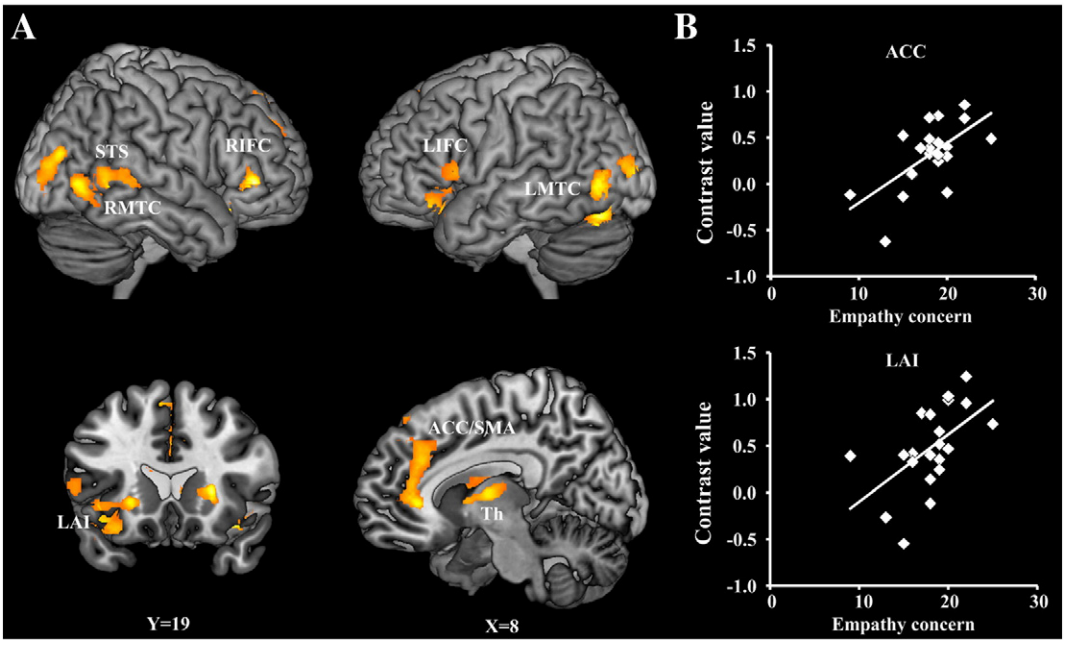

Fig. 2. Empathic neural response during pain judgments. (A) The contrast of pain vs. neutral expressions across racial in-group and out-group members during pain judgments showed activations in the ACC/SMA, bilateral inferior frontal cortex (IFC) and AI, bilateral middle temporal cortex (MTC) and superior temporal sulcus (STS), and thalamus (Th). (B) Correlation between rating scores of empathy concern and the contrast value of pain vs. neutral expressions in the ROIs (a sphere with radius of 10 mm) centered at x/y/z = 6/40/18 (ACC, $r = 0.63$, $p < 0.005$) and x/y/z = −44/30/−14 (left AI, $r = 0.55$, $p < 0.01$).

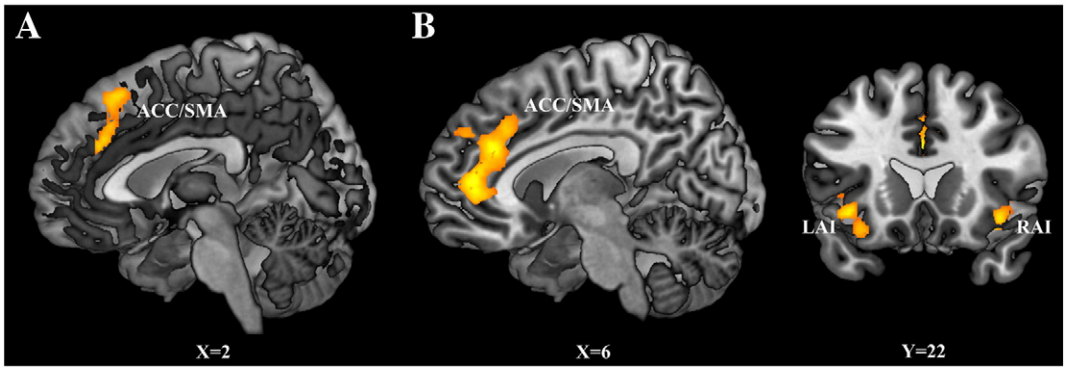

Fig. 3. Modulations of empathic neural responses. (A) Racial in-group bias in empathic neural responses (defined by the contrast of (Pain − Neutral)$_{\text{Asian faces}}$ vs. (Pain − Neutral)$_{\text{Caucasian faces}}$) during race judgments was evident in the ACC/SMA. (B) Task modulations of empathic neural response to Caucasian faces (defined by the contrast of (Pain − Neutral)$_{\text{Pain judgment}}$ vs. (Pain − Neutral)$_{\text{Race judgment}}$) were evident in the ACC/SMA and the bilateral AIs.

race judgments but were shorter to pain than neutral expressions during pain judgments. The RT results suggest that race judgments that required processing of racial identity independent of facial expressions were disrupted by pain expressions. In contrast, the task demand of pain judgments may guide top-down attention toward painful feelings and thus facilitated response speeds to pain expressions. Our fMRI results showed that perceiving others' pain vs. neutral expressions activated the key nodes of the pain matrix involved in first-hand pain experience. These included the ACC, AI, inferior frontal cortex, thalamus, posterior superior temporal sulcus, etc., similar to the previous observations (Botvinick et al., 2005; Gu and Han, 2007a, 2007b; Han et al., 2009; Jackson et al., 2005; Lamm et al., 2007, 2010; Saarela et al., 2007; Singer et al., 2004). In addition, our regression analyses showed evidence that the signal intensity in the ACC and AI activity was predicted by individuals' self-reported personal trait of empathy. These findings together indicate that multiple brain regions in the pain matrix are engaged in perceiving others' suffering and the ACC/AI activity is associated with participants' empathy traits.

Our fMRI results replicated the racial bias in empathic neural responses to pain expressions that were observed in our previous ERP

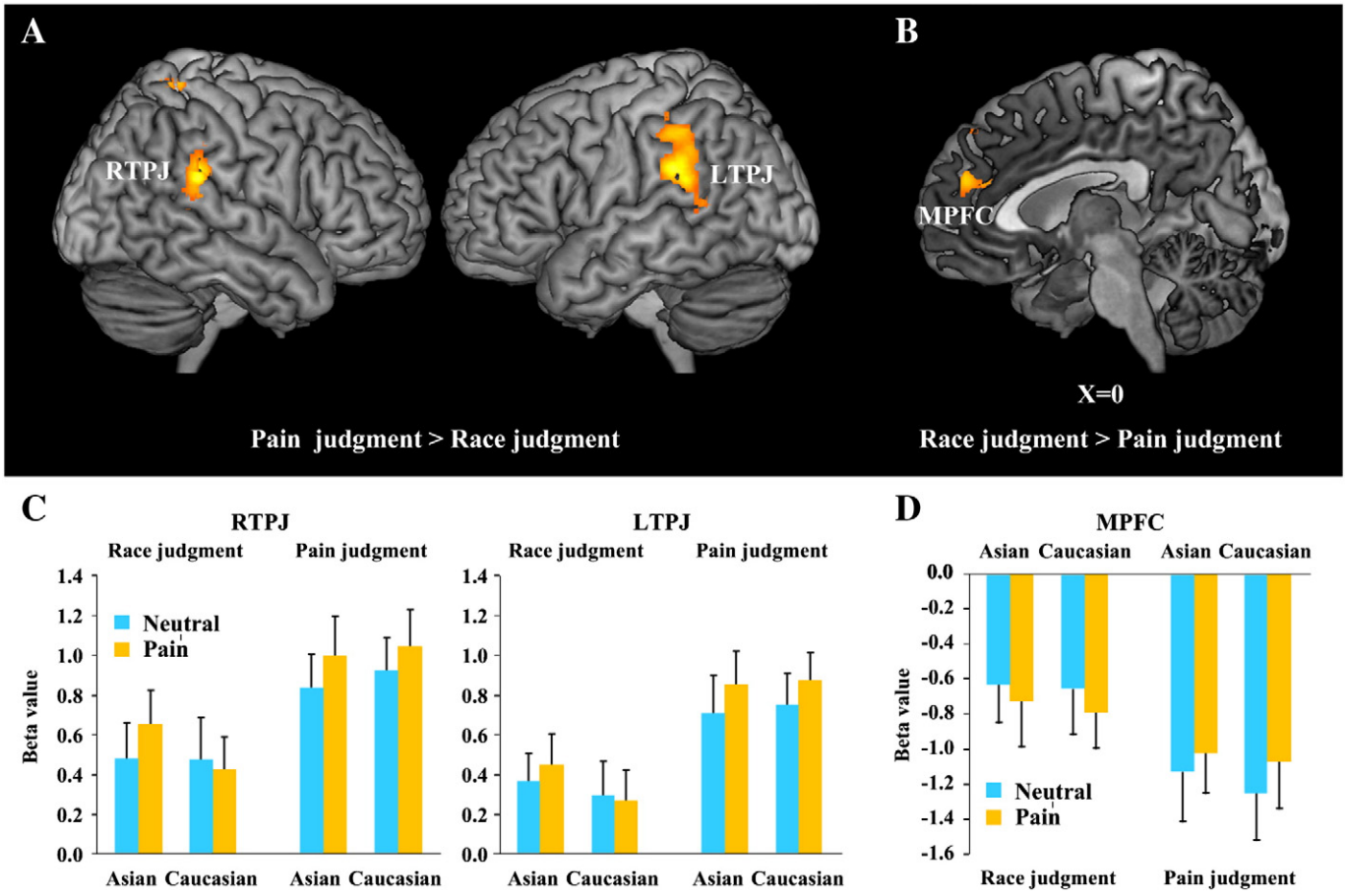

Fig. 4. The main effects of race and pain judgment tasks. (A) Stronger activations in bilateral TPJ and right parietal cortex were evident when contrasting pain judgments with race judgments. (B) The stronger activation in the MPFC was evident when contrasting race judgments with pain judgments. (C) Illustration of beta values that were extracted from the left and right TPJ (spheres with radius of 10 mm centered at x/y/z = 68/−36/26 and x/y/z = −66/−36/28). (D) Illustration of beta values that were extracted from the MPFC (a sphere with radius of 10 mm centered at x/y/z = 0/50/22).

studies (Sheng and Han, 2012; Sheng et al., 2013) and identified the brain regions in which the activity showed racial bias during race judgments. Specifically, participants showed stronger ACC and AI activity in response to racial in-group than out-group individuals' pain expressions when categorizing faces into racial groups. These findings complement the previous ERP results by localizing the racial bias in empathic neural responses to pain expression in specific brain regions. The previous studies found that the activity in the ACC (Xu et al., 2009) and AI (Azevedo et al., in press) was stronger when perceiving painful stimulations applied to faces or hands of racial in-group than out-group members when participants were instructed to perform pain judgments on the stimuli (Xu et al., 2009) or to pay maximum attention to the stimuli in order to answer some questions about the stimuli afterwards (Azevedo et al., in press). Thus the ACC and AI activity showed similar racial bias in responses to others' painful facial expressions and stimulations applied to others. The ACC and AI are the key nodes of the neural circuit involved in empathy for pain (Lamm et al., 2011) and may play different functional roles in empathy (Fan et al., 2011; Gu et al., 2012). Specifically, the ACC is recruited more frequently in the cognitive–evaluative form of empathy whereas the AI (particularly the right AI) is involved more frequently in the affective-perceptual form of empathy only. Thus the previous (Azevedo et al., in press; Xu et al., 2009) and current fMRI findings indicate that the racial intergroup relationship modulates the activity in the key nodes of the neural network that mediate both the cognitive and affective components of empathy for pain.

Most importantly, we showed evidence that the racial bias shown in the ACC and AI activity in response to others' suffering can be reduced significantly by task demands that emphasize attention to others' emotional states. Relative to the race judgment task that emphasized race identity, the pain judgment task instructed participants to focus on others' personal feeling and significantly increased the ACC and AI activity to pain expressions of racial out-group individuals. Consequently, the racial bias in ACC and AI activity in responses to others' suffering that was observed during race judgments was reduced during pain judgments. These fMRI results reinforce our ERP findings (Sheng and Han, 2012) and demonstrate that paying attention to each individual's emotional states can significantly improve understanding and sharing of others' painful feelings. The effect of task modulations of empathic neural responses to racial out-group members' suffering were not observed in subcortical structures (e.g., thalamus and caudate) and the posterior temporal cortex that play important roles in the processing of facial expressions (see Calder and Young, 2005 for review). Therefore, it appears that task demands for processing each individual's painful feelings may specifically influence the empathic neural responses to others' suffering in the ACC and AI.

Moreover, the effects of task modulations of empathic neural responses to pain expressions seemed to be specific to racial out-group members as instructions for pain judgments did not influence the empathic neural responses to the suffering of racial in-group members. Similarly, early research showed that racial group categorization caused de-individuation of out-group members but not of in-group members (Fiske and Neuberg, 1990; Ostrom et al., 1993). Our previous ERP research found that minimal group manipulations that assigned same-race and other-race faces into fellow or opponent teams for a competitive game only increase neural responses to pain expressions of other-race faces. The neural responses to pain expressions of same-race faces, however, were not influenced by the minimal group manipulations (Sheng and Han, 2012). These results suggest that long-term life experiences with racial in-group members may result in automatic individuated processing of in-group members that is less affected by task demands. The racial in-group bias in empathic neural responses to painful feelings in the ACC and AI may be different from the in-group bias in other brain regions produced by minimal group manipulations in terms of susceptibility to task modulations. For example, Van Bavel et al. (2008) found that perceiving novel in-group vs. out-group faces produced by minimal group manipulations induced greater activity in the amygdala, fusiform gyri, orbitofrontal cortex, and dorsal striatum, and that the in-group biases in neural activity in these brain regions were not moderated by race or by whether participants explicitly attended to team membership or race. Therefore, whether the in-group bias in brain activity is susceptible to top-down task demands depends on both the neural structures involved in in-group bias and how the intergroup relationship is defined.

Supporting our hypothesis, we found that, relative to race judgments, pain judgments significantly increased the activity in the bilateral TPJ that have been shown to play a key role in taking others' perspective in order to understand others' mind (Samson et al., 2004; Saxe and Kanwisher, 2003; Saxe and Wexler, 2005). The greater TPJ activity during pain vs. race judgments suggests that the task demand of focusing on each individual's emotional states may lead to increased reference to each individual's personal situation and thus weakened the processing of racial out-group faces in terms of social category defined by race. Similarly, recent behavioral studies have shown that task demands emphasizing actively contemplating others' psychological experiences facilitate co-representation of out-group members' actions (Müller et al., 2011) and attenuate automatic expressions of racial bias (Todd et al., 2011). Together, these findings indicate that racial bias in emotion and action understanding may be attributed at least partially to the lack of perspective taking and can be attenuated by task demands that emphasize taking others' perspective. In contrast, relative to pain judgments, race judgments induced stronger activity in the MPFC. This is consistent with the proposal that the MPFC plays a key role in processing general social information (Amodio and Frith, 2006) and person knowledge (Mitchell et al., 2002) as race judgments require processing of the social information about each individual face (e.g., race) and categorizing people into social groups.

There may be alternative accounts of the racial bias in neural responses to others' suffering. For example, it is likely that Chinese participants are more familiar with Asian faces compared to Caucasian faces and thus lead to the racial bias in empathic neural responses to the suffering of Caucasian faces. However, previous fMRI studies have shown that face familiarity is encoded in the fusiform region (Eger et al., 2005) and face familiarity modulates the frontal and temporal activity underlying view-independent coding of face identity (Pourtois et al., 2005). There has been no evidence that face familiarity modulates the activity in the key nodes of the pain matrix (e.g., ACC and AI). Moreover, the face familiarity account cannot explain the effect of task demands on neural responses to the suffering of racial out-group individuals because the same face stimuli were used during race and pain judgments. However, future research should explore to what degree perceptual familiarity of faces may influence neural responses to others' emotional states.

Finally, one may notice that a similar pain judgment task was used in the previous fMRI research (Xu et al., 2009) that found racial bias in ACC activity, whereas studies using static images (e.g., Mathur et al., 2010; Sheng and Han, 2012; and the current work) did not show racial bias in ACC activity during pain judgments. One possible account is that Xu et al. (2009) used videos clips with long durations (3-s video clips) and painful stimulations were applied to neutral faces after the neutral faces had been shown for about 1 s. Thus categorization of faces based on race, which may start as early as 150 ms after stimulus onset (Sheng and Han, 2012), might have occurred prior to pain judgments in Xu et al. (2009). Thus pain judgments were actually conducted after an early categorization of faces based on race and thus resulted in racial bias in ACC activity in response to others' suffering even in a pain judgment task in Xu et al. (2009). However, this interpretation needs to be clarified in future research.

In conclusion, our fMRI results suggest that task demands that emphasize individuated processing of others may reduce racial bias in empathic neural responses in the ACC and AI. The effects of task

demands on empathic neural responses were more salient on racial out-group than in-group members and may help to promote the understanding and sharing of racial out-group members' painful feelings. Our brain imaging findings extend our knowledge about how task demands reduce racial bias in empathy and provide further evidence that racial in-group bias in empathy for others' pain is malleable rather than inevitable.

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Conflict of interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.neuroimage.2013.10.017.

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