Journal of Neurolinguistics 51 (2019) 111–120

Contents lists available at ScienceDirect

Journal of Neurolinguistics

journal homepage: www.elsevier.com/locate/jneuroling

Neural correlates of processing emotions in words across cultures

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ARTICLE INFO

Keywords:
Cultural difference
Positive emotion
Negative emotion
Neural mechanisms

ABSTRACT

Culture influences its individuals' behaviors in a subtle yet effective way. While the physical experience of emotions is largely biologically determined, emotion perception and processing can still be culturally specific. The present study investigates the neural mechanisms that underlie emotion processing and experience in two cultures. Participants from Eastern and Western cultures performed a lexical decision task on positive and negative words, along with pseudowords. While the two groups' behavioral response to emotional words did not differ, Eastern participants showed greater activation in the left cerebellum and thalamus when processing positive words, and in the right precuneus and the left superior parietal lobe when processing negative words as compared to Western participants. These neural activation patterns suggest that Eastern participants use more emotion regulation and control than Western participants. In contrast, Western participants showed increased activation in the right amygdala and the medial frontal gyrus, suggesting enhanced emotional experience and evaluation. These findings suggest that emotion experience and processing are influenced by cultural norms and values.

1. Introduction

Do people from different cultural backgrounds process emotions in a similar way? Early studies show that facial expressions of basic emotions can be recognized by people from different cultures (Ekman, 1973; Ekman & Friesen, 1971), supporting the universality of emotion (see Ekman et al., 1992 for a review). However, recent studies using a wider range of methodology and emotional material have challenged this universal view of emotion processing, suggesting that some aspects of emotion processing vary across cultures (Elfenbein & Ambady, 2002; Jack, Garrod, Yu, Caldara, & Schyns, 2012; Kitayama & Markus, 1994; Stephan, Stephan, Saito, & Barnett, 1998, see Gendron, 2017 and Russell, 1994 for reviews). On the one hand, behavioral studies have found that Easterners and Westerners not only perceive the intensity of emotional stimuli to different extents (Bond, 1993; Ekman et al., 1987; Matsumoto, 1989; Matsumoto & Ekman, 1989; Tsai & Levenson, 1997), but also judge emotional valence of the same daily events differently (Mesquita & Karasawa, 2002). On the other hand, neuroimaging studies have identified different neural activation patterns between people from Eastern and Western cultures during emotion processing (de Greck et al., 2012; Moriguchi et al., 2005). Nevertheless, our knowledge of cross-cultural differences on emotion processing is only based on negative emotions and facial expressions. The present study aims to identify neural mechanisms that underlie both positive and negative emotion processing across different cultures.

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https://doi.org/10.1016/j.jneuroling.2019.01.004
Received 8 November 2017; Received in revised form 23 January 2019; Accepted 24 January 2019
Available online 07 February 2019

A wide range of neural correlates have been associated with processing emotions, largely due to the use of different types of emotion and materials. In the first meta-analysis, no single brain area was found to activate consistently (Phan, Wager, Taylor, & Liberzon, 2002), confirming a great variance in neural responses to emotions. Nevertheless, the medial prefrontal cortex was identified as a common area involved in emotion processing (Phan et al., 2002). The prefrontal area has also been associated with emotion regulation and appraisal (Kohn et al., 2014; Ochsner, Bunge, Gross, & Gabrieli, 2002; Wager, Davidson, Hughes, Lindquist, & Ochsner, 2008). Meanwhile, the amygdala plays a crucial role in processing negative emotions, especially fear (Garrett & Maddock, 2006; Murphy, Nimmo-Smith, & Lawrence, 2003; Vuilleumier, Armony, Driver, & Dolan, 2001), as well as in processing positive emotions (Garavan, Pendergrass, Ross, Stein, & Risinger, 2001; Hamann, Ely, Hoffman, & Kilts, 2002). Some frontal regions (Kesler-West et al., 2001) and temporal areas (Garrett & Maddock, 2006), the orbitofrontal cortex (Garrett & Maddock, 2006; Vuilleumier et al., 2001), and the insular and globus pallidus (Murphy et al., 2003) have also been found to relate to negative emotion processing. Positive emotions activate some frontal and temporal regions (Canli, Desmond, Zhao, Glover, & Gabrieli, 1998), the medial frontal/cingulate sulcus (Kesler-West et al., 2001), and the cerebellum and occipital cortex (Hamann et al., 2002).

A few cross-cultural studies have compared the neural correlates of emotion processing across Eastern and Western cultures, but with a focus on negative emotions (de Greck et al., 2012; Moriguchi et al., 2005). For example, when perceiving fearful faces of their own race, Eastern people have been found to activate areas such as the right inferior frontal gyrus and the left insula more than Western people. In contrast, Western people showed greater activation in the posterior cingulate cortex and the amygdala than Eastern people, suggesting that Western people perceived fearful emotion in a more direct way than Eastern people (Moriguchi et al., 2005). Similarly, when asked to show empathy with angry faces, the left dorsolateral prefrontal cortex showed stronger activation in Eastern people than in Western people, indicating enhanced emotion regulation. On the contrary, stronger activation was found in the right temporal lobe, the temporo-parietal junction, and the left middle insula in Western people, suggesting increased tolerance to anger (de Greck et al., 2012). In a meta-analysis, Han and Ma (2014) found that Easterners showed greater activity in the dorsolateral prefrontal cortex while Westerners showed more activation in the insula, the dorsal anterior cingulate cortex, the ventromedial prefrontal cortex, and the temporal pole. The author concluded that Easterners aim to keep the emotion state low while Westerners have a more intense activation in the social brain network (Han & Ma, 2014).

While these results reveal cross-cultural differences in emotion experience and perception, these differences were restricted to negative facial expressions. The neural mechanism of processing positive emotions has not been compared. Furthermore, using facial expressions might not be ideal for examining the cultural effect on emotion processing because the exact emotions elicited by these facial expressions can sometimes be ambiguous and people from different cultures might interpret or categorize facial expressions differently (Chen et al., 2018; Moriguchi et al., 2005; Russell, 1994). In addition, the observed neural differences in processing facial expressions could have partly been attributed to different visual gaze patterns in face processing across cultures. Blais, Jack, Scheepers, Fiset, and Caldara (2008) have found that Westerners tend to place the fixations around the eye region and partially the mouth, whereas Easterners extract facial information from the central region (Blais et al., 2008). This finding also concords with the cross-cultural difference in visual scene processing (Chua, Boland, & Nisbett, 2005; Kelly, Miellet, & Caldara, 2010; see Nisbett & Miyamoto, 2005 for a review). To avoid the ambiguity and potential visual gaze pattern differences caused by processing facial expressions, emotional words were chosen in the present study to further expand the understanding of cross-cultural emotion processing. Examining cross-cultural differences in emotional words is important not only because words play a crucial role in expressing feelings, but also because words and languages serve as an engine of cultural transmission systems (Gelman & Roberts, 2017). Emotional words, compared to facial expressions and emotional pictures, therefore, might carry additional cultural weight. While most languages have translation equivalents for the same emotional concept, the core meaning, or the connotation of the word might sometimes differ across cultures (Mesquita, Frijda, & Scherer, 1997). We also included both positive and negative emotional words to further examine whether emotional valence modulates the cross-cultural difference in emotion processing.

Because of the unique role of language in expressing emotions, previous studies have investigated the neural correlates in emotional words processing. Similar to facial expression and affective picture processing, the amygdala has been associated with both negative word and positive word processing (e.g., Hamann & Mao, 2002; Kensinger & Schacter, 2006; Straube, Sauer, & Miltner, 2011), suggesting its general role in responding to intense stimuli. In addition, positive words have also been shown to activate the globus palidus/putamen and caudate (Hamann & Mao, 2002), the orbitoryfrontal gyrus (Kuchinke et al., 2005; Maddock, Garrett, & Buonocore, 2003), the superior and middle temporal gyrus, as well as the superior frontal gyrus (Kuchinke et al., 2005) while negative words activate the inferior frontal gyrus (Kuchinke et al., 2005), the cingulate cortex (Cato et al., 2004; George et al., 1994; Maddock & Buonocore, 1997; Nakic, Smith, Busis, Vythilingam, & Blair, 2006; Whalen et al., 1998).

In the present study, Eastern participants from China, representing the collective culture, and Western participants from Canada, the United Kingdom, and the United States, representing the individualistic culture were compared. Both groups of participants performed a lexical decision task on words with positive or negative valence (i.e., Chinese words for Eastern participants, and English words for Western participants) while being scanned with fMRI. Since the present study was the first to explore emotional word processing across Eastern and Western cultures, we relied on the whole brain analysis to identify potential neural differences. In general, we expected that Western participants from a culture placing a greater emphasis on individualism would engage more in processing both positive and negative emotions while Chinese participants from a collective culture would tend to neutralize their experience with both positive and negative emotions. Specifically, we predicted that Western participants would have greater activation in areas related to emotional processing than Chinese participants.

Table 1
Characteristics of positive and negative words in each language. Standard deviations are in parentheses.

Word type	Frequency (per million)	Number of letters or strokes	Concreteness	Valence rating	Arousal rating
Chinese					
Positive	39.9 (48.5)	17.7 (4.7)	–	6.1 (0.3)	5.4 (0.6)
Negative	39.1 (51.1)	17.0 (4.7)	–	1.9 (0.5)	5.5 (0.6)
English					
Positive	38.5 (31.8)	6.9 (2.1)	2.7 (1.1)	7.3 (0.4)	4.5 (0.9)
Negative	39.6 (46.0)	6.5 (1.7)	2.9 (0.8)	2.7 (0.8)	5.2 (0.8)

The frequency information for Chinese words was obtained from Modern Chinese Frequency Dictionary (Wang, 1986) and the frequency of English words was obtained from the English Lexicon Project (Balota et al., 2007). Concreteness ratings (on a scale from 1 = abstract to 5 = concrete) were obtained from Brysbaert et al. (2014). Valence and Arousal ratings (on a scale from 1 = extremely negative/low intensity to 7 = extremely positive/high intensity) for Chinese words were gathered from a norming study before the formal experiment. Valence and Arousal ratings (on a scale from 1 = sad/in control to 9 = happy/excited) for English words were from Warriner et al., (2013).

2. Methods

2.1. Participants

Twenty-three Chinese and twenty-four Western young adults participated in the experiment. They were all right-handed with normal or correct-to-normal vision. None of them had any history of neurological or mood disorders. This study was approved by the Institutional Review Board of the Imaging Center for Brain Research of Beijing Normal University. All participants gave informed written consent prior to the experiment, and were paid for their participation. The participants were all undergraduates or graduate students. One Chinese participant was excluded because the range of head movement exceeded 1 voxel. The remaining 22 Chinese (mean age = 22.41, SD = 1.56, 16 females) were all native Mandarin speakers. The 24 Westerners (mean age = 22.71, SD = 2.84, 8 females) were all native speakers of English, among whom 15 were from the United States, 6 were from the United Kingdom, and 3 were from Canada. Most of the Western participants were undergraduate students in their home countries (15 out of 24) and were participating in various summer exchange programs in Beijing at the time of testing. Of the 20 Western participants who reported their experience of living in Asian countries, 12 had spent less than six months in China or any other Asian countries. Three of them had spent 9–10 months in China, and another three had lived in China for 15–22 months. Two of them had spent 3–4 years in China.

2.2. Materials

The materials were same as those used in Chen, Lin, Chen, Lu, and Guo (2015). The critical stimuli consisted of 60 positive and 60 negative words in Chinese and English, respectively. Lexical and affective characteristics of the critical stimuli are summarized in Table 1. Another 60 neutral words were also included as fillers. Words of different valances in each language were matched for stroke numbers/length and word frequency ($Fs < 1$, $ps > 0.1$). Emotional valence and arousal ratings were obtained in each language to ensure that emotional words were different from neutral words. Concreteness of positive and negative words did not differ from each other ($p > 0.1$; Brysbaert, Warriner, & Kuperman, 2014). In addition, 180 orthographically correct but meaningless words (i.e., pseudowords) were selected in each language. All English pseudowords were from the English Lexicon Project (Balota et al., 2007) whereas Chinese pseudowords were created by combining only real characters. Words and pseudowords in each language were matched in stroke numbers or word length. Additionally, there were 90 baseline stimuli (i.e., + + + +) in the experiment.

2.3. Procedure

An event-related design was employed. Words, pseudowords, and the baseline stimuli were presented in a pseudorandomized order. In each trial, a stimulus (i.e., word, pseudowords, or a baseline stimulus) was presented for 1 s followed by a blank screen of 1 s. Participants were instructed to judge whether the stimulus was a real word or not by pressing the left or right button with their thumbs. If a baseline stimulus was presented, no response was required. Each group of participants received one run that contained 90 words (30 positive, 30 negative, and 30 neutral words), 90 pseudowords, and 90 baseline stimuli in their native language. In addition to performing the lexical decision task in their native language, Chinese participants completed another run of the task in English, which did not contain the translation equivalents in the Chinses run. A more detailed procedure can be found in Chen et al. (2015). Behavioral and fMRI data from Chinese participants have been reported in Chen et al. (2015), which examined the neural difference between processing emotional information in the native and the second language. For the purpose of the present study, we only reported the Chinese portion from Chinese participants to compare with the English portion from English speakers.

2.4. Data acquisition and analysis

Whole-brain images were acquired using a Siemens 3.0 T Sonata whole-body MRI scanner. During the whole scanning process, the participant's head was secured to minimize movements. Every functional image comprised 33 transversal slices. 274 functional images of each participant were acquired using a T2-weighted echo planar sequence (TR = 2000 ms, TE = 30 ms, flip angle = 90°, FOV = 200 × 200 mm^2, Matrix = 64 × 64) with a voxel resolution of 3.1 mm × 3.1 mm x 4 mm. Every structural image comprised 144 sagittal slices. A T1-weighted (TR = 2,530 ms, TE = 3.39 ms, flip angle = 7°, FOV = 256 × 256 mm^2, matrix = 256 × 256) image with a voxel resolution of 1.0 mm × 1.0 mm x 1.0 mm of each participant was acquired as a structural image. Both functional and structural images were acquired by interlaced scanning.

Imaging data were preprocessed and analyzed using SPM8 (Welcome Department of Imaging Neuroscience, London, UK: http://www.fil.ion.ucl.ac.uk/spm) in MATLAB 2010a (MathWorks, Inc.). After excluding the first and last two functional images, the remaining images were slice-timing corrected, motion corrected and co-registered to the structural image. The structural image was normalized to T1 template provided by SPM. The functional images applied the same normalization transformation and were then smoothed by using a 6-mm full-width at half maximum Gaussian filter.

General linear modeling was then conducted for the functional images from each participant to estimate the condition effect. It implemented a high pass filter with 128 s cutoff. The movement parameters derived from the realignment stage were incorporated as nuisance variables. The contrasts of interest at the individual level were negative or positive emotional words relative to the pseudowords. Four contrasts for group comparison were obtained: (1) negative emotional words versus pseudowords in Chinese participants; (2) negative emotional words versus pseudowords in Western participants; (3) positive emotional words versus pseudowords in Chinese participants; (4) positive emotional words versus pseudowords in Western participants. Two-sample t-tests in SPM8 were then performed to examine the neural difference in positive or negative emotion processing between the two groups. Significant voxels were defined as those exceeding a statistical threshold of $p < 0.05$ (AlphaSim corrected, with 10 contiguous voxels).

3. Results

3.1. Behavioral results

The average accuracy rates for positive and negative words in each group were all higher than 96%, suggesting that participants were able to perform the lexical decision task easily. Trials with incorrect responses were excluded from the analysis. The averaged response times for each word type were within the range between 605 and 627 ms. A series of 2 (trial type: positive/negative) *2 (group: Chinese/Western) ANOVAs were performed to detect behavioral differences between the two groups of participants. In the analysis for the reaction times, the main effect of trial type was significant, $F(1, 44) = 8.82, p < 0.01$, indicating that positive words were responded faster than negative words. The main effect of group was not significant, $p > 0.9$. The interaction between trial type and group was marginally significant, $F(1, 44) = 3.74, p = 0.06$. However, further t-tests did not reveal any group difference in processing either positive or negative words. No significant behavioral difference was found between groups in the analysis for accuracy rates ($ps > 0.2$).

3.2. fMRI results

When processing negative emotional words, Chinese participants showed increased activity in the left superior parietal lobule and the right precuneus compared to Western participants. In contrast, Western participants had no significantly activated regions when compared to Chinese participants. The results of negative words are shown in Table 2 and Fig. 1.

Significant differences between groups were also observed in processing positive emotional words. Chinese participants showed greater activation in the left thalamus and left cerebellum, while Western participants demonstrated greater activation in the right amygdala and right medial frontal gyrus. These results are shown in Table 3 and Fig. 2.

4. Discussion

The present study is the first to investigate the effect of culture on the processing of emotions carried by positive and negative words using fMRI. Behavioral results revealed no significant differences between Chinese and Western participants in processing emotional words in their own languages. fMRI results showed that different brain regions were enhanced when Chinese and Western participants processed negative and positive words, providing neural evidence for culturally specific emotion processing.

When processing negative emotional words, Chinese participants showed increased activity in the left superior parietal lobule and

Table 2
Results from the whole brain analysis showing activation during processing negative emotional words in Chinese and Western participants.

Brain Regions	Cluster size	BA	MNI coordinates			T value
			x	y	z	
Chinese > Westerners						
R_Precuneus	115	7	20	−66	48	4.94
L_Superior Parietal Lobe	114	7	−24	−68	58	4.12

BA = Brodmann area; L = left; MNI = Montreal Neurological Institute; R = right.

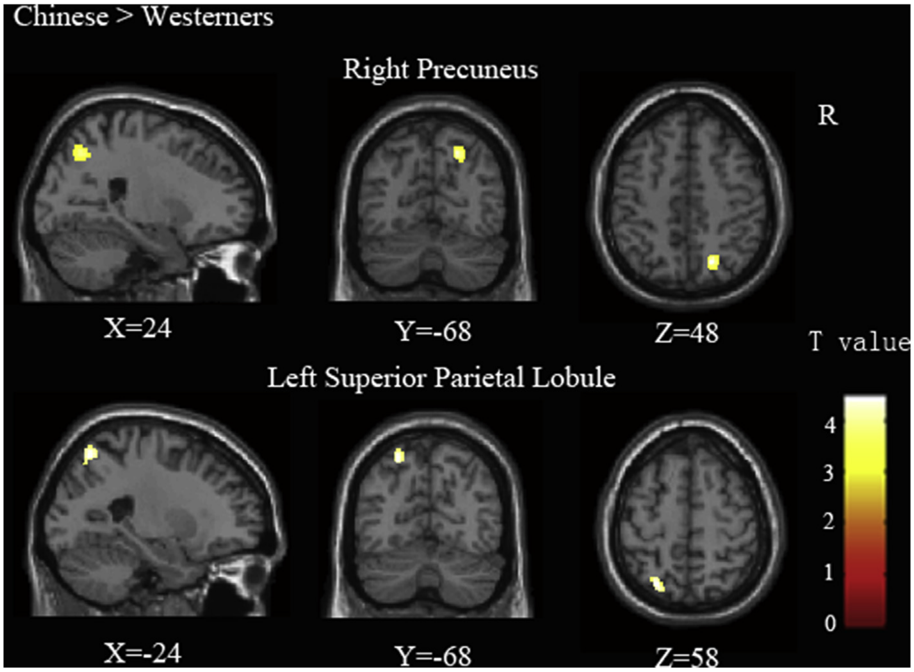

Fig. 1. Results of processing negative emotional words vs. pseudowords. Regions showing significant stronger BOLD response among Chinese participants compared to Westerners. The statistical threshold is $p < 0.05$ (AlphaSim corrected). R = right.

Table 3
Results from the whole brain analysis showing activation during processing positive emotional words in Chinese and Western participants.

Brain Regions	Cluster size	BA	MNI coordinates			T value
			x	y	z	
Chinese > Westerners						
L_Thalamus	57		−2	−10	14	4.47
L_Cerebellum	28		−20	−72	−38	4.43
Westerners > Chinese						
R_Amygdala	97		24	−8	−14	4.36
R_Medial Frontal Gyrus	76	32	14	58	2	3.86

BA = Brodmann area; L = left; MNI = Montreal Neurological Institute; R = right.

the right precuneus when compared to Western participants. Both the superior parietal lobule and precuneus belong to the parietal cortex, a brain region that has been suggested to play an important role in emotion regulation in patients with emotion disorders (Canli et al., 2004; Goldin, McRae, Ramel, & Gross, 2009). Several cognitive training studies have also found that the superior parietal lobule increased its activity after cognitive therapy was administered for social emotion disorders (Bölte et al., 2006; Goldin & Gross, 2014; Paquette et al., 2003). Therefore, increased activity in these regions might indicate that Chinese participants enlisted emotion-regulation mechanisms to a greater extent than Western participants when encountering negative emotional words. This explanation is consistent with the previous finding that Chinese participants have been shown to use inhibition and regulation systems to protect themselves from emotional over-arousal (de Greck et al., 2012), as suppressing negative emotions might be crucial for individuals in a collective culture where group harmonies and interpersonal social structure are emphasized (Matsumoto, 1989).

In the processing of positive emotional words, Western participants demonstrated increased activity in the right amygdala and right medial frontal gyrus relative to Chinese participants, whereas Chinese participants showed enhanced activity in the left thalamus and cerebellum when compared to Western participants. These differences might suggest that positive emotion is processed differently by the two cultures. First, the two areas in which Western participants showed stronger activation than Chinese participants are two typical emotional brain areas. Amygdala, as part of the limbic system, plays a key role in the detection and evaluation of emotion (Cunningham, Van Bavel, & Johnsen, 2008; Hamann & Mao, 2002; Morris et al., 1996; Sergerie, Chochol, & Armony, 2008; Straube et al., 2011; for a review, see; Armony, 2013). While early studies found that the amygdala plays a dominant role in detecting fearful as well as other negative emotions, several recent studies demonstrated that the amygdala also engages in perceiving positive emotions (e.g., Fusar-Poli et al., 2009; Pohl, Anders, Schulte-Rüther, Mathiak, & Kircher, 2013). Of particular interest to the current study, Herbert et al. (2009) found that positive emotional content in words received enhanced perceptual processing with the assistance of the amygdala (Herbert et al., 2009). This suggests that the involvement of the amygdala in processing words is related to

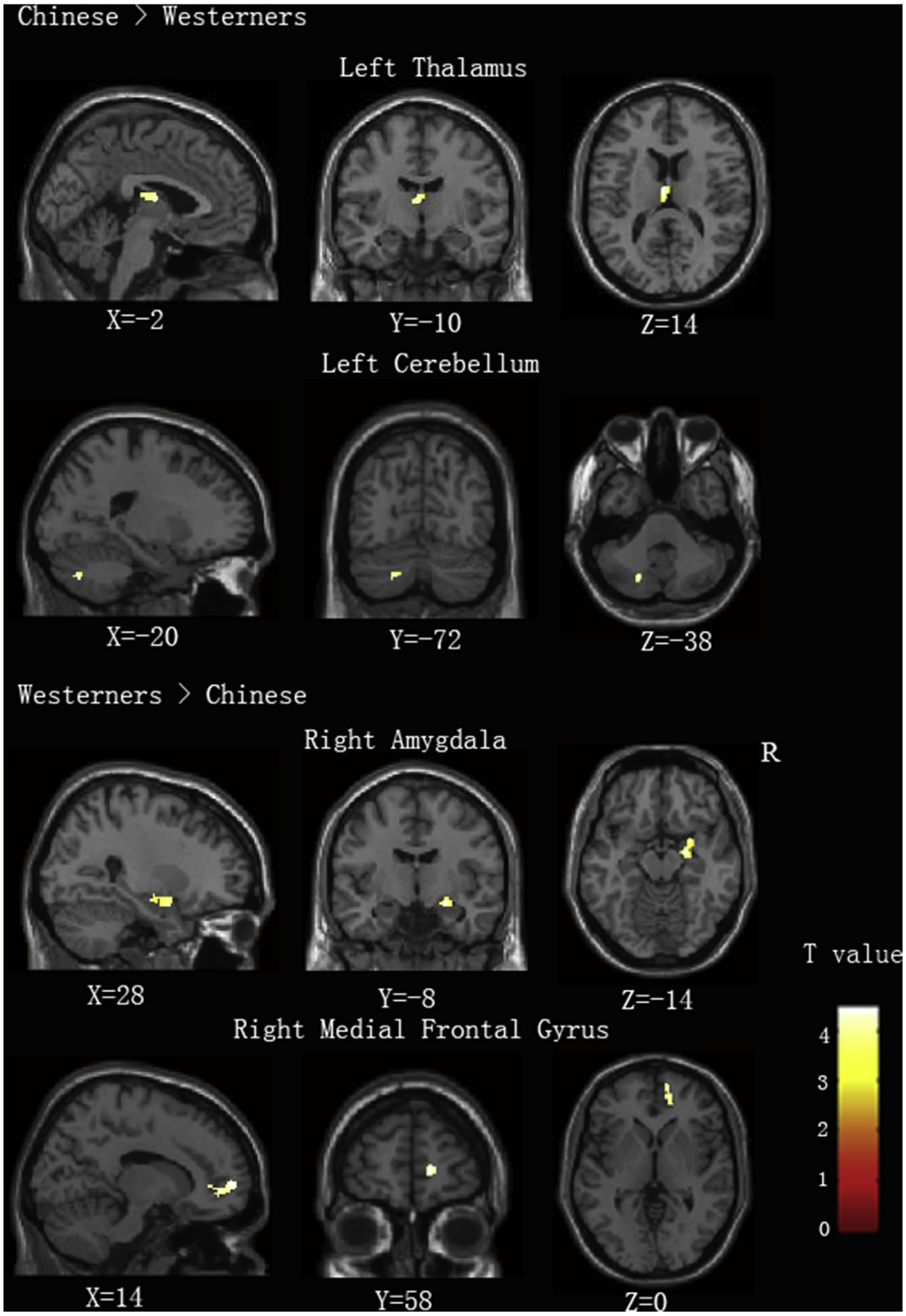

Fig. 2. Results of processing positive emotional words vs. pseudowords. Upper panel: Regions showing significant stronger BOLD response among Chinese participants compared to Westerners. Lower panel: Regions showing significant stronger BOLD response among Westerners compared to Chinese. The statistical threshold is $p < 0.05$ (AlphaSim corrected). R = right.

perceiving emotional content directly. The other brain area in which Westerners showed stronger activation than Chinese participants is the right medial frontal gyrus. As part of the prefrontal cortex, the medial prefrontal gyrus plays an important role in evaluating emotion (Gusnard, Akbudak, Shulman, & Raichle, 2001; Phan et al., 2002; Taylor, Phan, Decker, & Liberzon, 2003). Posner et al. (2009) observed that the bilateral medial PFC was directly involved in response to emotional valence. Since both the amygdala and the prefrontal cortex are related to perceiving and evaluating emotional aspects in words directly, stronger activation in these two areas in the present study indicates that the emotional information was evaluated and perceived by Western participants more intensely than Chinese participants (Posner et al., 2009).

In contrast, the two areas in which Chinese participants showed stronger activation for positive words than Western participants seem to have a regulatory role in processing emotions. One of these two areas was the left cerebellum. While the traditional view of cerebellum function is motor control, more recent research has revealed that the cerebellum also is involved in emotion regulation and processing (Canli et al., 2004; Turner et al., 2007; see Schutter & Van Honk, 2005; Stoodley & Schmahmann, 2009 for reviews). Specifically, the cerebellum has been associated with emotion processing (Baumann & Mattingley, 2012), emotion learning (Sacchetti, Scelfo, & Strata, 2009), as well as coordination and adjustment of emotional responses in a social setting (Damasio et al., 2000). Interestingly, when the cerebellum was slowly and repeatedly stimulated with transcranial magnetic stimulation (TMS), participants' mood states were modulated, resulting in reduced positive emotion (Schutter & van Honk, 2009). Taken together, the enhanced activation in the cerebellum in Chinese compared to Westerners might reflect that Chinese had more regulation of perceived positive emotion than Westerners. The other brain area where increased activation was found for Chinese participants relative to Western participants was the left thalamus. The thalamus is part of the fronto-striato-thalamic loops which regulate and control behaviors (Alexander, DeLong, & Strick, 1986). For example, the activity in the thalamus (as well as frontro-striato-thalamic loops) was reduced in participants with impaired cognitive-behavioral flexibility (Zastrow et al., 2009). Meanwhile, the structure abnormality and functional deficiency in the thalamus have been suggested to be the bases of impaired cognitive performance in children with attention deficits (Xia et al., 2012). Therefore, it is possible that the enhanced activation we observed in the thalamus reflects the additional effort that Chinese participants made in order to regulate and control positive emotion, as compared to Western participants.

In the processing of both positive and negative emotions, we observed that brain areas that are related to regulation and control were more activated in Chinese participants than Western participants. Meanwhile, Western participants, compared to Chinese participants, showed increased activation in brain areas that are directly associated with emotion evaluation and experience. These findings are consistent with the predictions of display rules (Ekman, Sorenson, & Friesen, 1969; Engelmann & Pogosyan, 2013; Matsumoto, 1990). Display rules are culturally-specific norms that determine the appropriateness of when, how, and to whom a certain kind of emotions can be expressed (Engelmann & Pogosyan, 2013). In the Eastern collective culture individuals are discouraged from expressing personal feelings in order to maintain a harmonic relationship within the group (Markus & Kitayama, 1991; Matsumoto, Yoo, & Fontaine, 2008). Therefore, Chinese participants might use increased effort to regulate emotions, preventing themselves from showing emotions that are too positive or negative. In fact, a recent fMRI study compared emotion preferences across cultures and found that Eastern participants preferred peaceful emotions and avoided overwhelming emotions (Park, Tsai, Chim, Blevins, & Knutson, 2015). In contrast, in Western culture where individuals' needs and desires are emphasized, expressing personal feelings is encouraged and considered as a pursuit of self (Chiao et al., 2009). Therefore, Western participants enjoy the freedom of fully evaluating and appreciating positive emotion.

While fMRI results in the present study revealed some neural differences for processing positive and negative words across two cultures, the two cultural groups showed comparable behavioral results. This discrepancy could be contributed by the relatively reduced sensitivity of behavioral measures compared to neural measures (McLaughlin, Osterhout, & Kim, 2004) and the simplicity of the experimental task. A lexical decision task in one's native language might be at the ceiling level for revealing any behavioral differences. Furthermore, some brain regions that showed differentiated activation between Eastern and Western participants in the current study, including the right precuneus and left superior parietal lobe, and the left thalamus and cerebellum, are not among those classic regions associated with emotion regulation. While we offered some explanations earlier, it is also possible that differentiated activation in these areas are not entirely due to the differences in emotion processing or regulation per se, but also attributed to differences in attention or language processing. Additionally, no brain area has shown greater activation for Westerners than Chinese participants for processing negative words. This null result might suggest a positive bias of emotion expression in Westerners, which is consistent with the previous finding where Westerners tend to evaluate the same daily event as more pleasant than Japanese people (Mesquita & Karasawa, 2002).

Although this is the first study to compare both positive and negative emotion processing cross-culturally, there are several limitations in the current study. First, we did not use any measures to confirm participants' interdependent and independent self-construals (or individualism vs. collectivism), but only relied on race and country origin information. Future studies should consider using some objective measures such as the Self-Construal Scale (de Greck et al., 2012) to confirm participants' cultural identity. Another potential caveat of the current study is that the gender ratio in each cultural group was not perfectly matched. While some studies failed to find gender difference in emotion processing (Derntl et al., 2012; Sergerie et al., 2008), others have revealed that gender affects emotion regulation (Domes et al., 2009; Koch et al., 2007; McRae, Ochsner, Mauss, Gabrieli, & Gross, 2008; Wager, Phan, Liberzon, & Taylor, 2003). Future studies that focus on emotion regulation should make efforts in balancing gender ratio. However, the neural differences across the two cultural groups observed in the current study are not among those typical areas for gender difference, which include the prefrontal cortex (Domes et al., 2009), the cingulate gyrus and the frontal areas (McRae et al., 2008), and the orbitofrontal cortex (Koch et al., 2007). In fact, the activation pattern in the amygdala, if anything, is opposite to the prediction of gender effects (Domes et al., 2009; McRae et al., 2008). Lastly, we used pseudowords, instead of neutral words, as the baseline condition to compare the emotion effect cross-culturally because neutral words in the current study consisted more nouns than adjectives as compared to the two types of emotional words. Therefore, it is possible that the cross-cultural difference observed in the current study might be associated with both emotion and lexical processing. This potential issue can be addressed by using neutral words as the baseline condition in future studies.

To summarize, the present study investigated the neural mechanism of processing positive and negative emotions in Chinese participants and Western participants who were from two different cultures. Our results suggest that Chinese participants might devote additional effort to regulate both positive and negative emotions when compared to Western participants whereas Western participants enjoy enhanced positive emotional experience relative to Chinese participants. The neural activation patterns in Chinese and Western participants might reflect the differences of desired norms and social expectations in each culture, indicating that emotion processing and its neural mechanism receive influence from culture.

Acknowledgments

The study was supported by the National Natural Science Foundation of China (31871097), the National Key Basic Research Program of China (2014CB846102), the Interdiscipline Research Funds of Beijing Normal University, and the Fundamental Research Funds for the Central Universities (2017XTCX04). The authors would like to thank Jie Lin, and Haoyun Zhang for data collection, as well as Jennifer Callaghan, Krysten Jackson, and Kevin Loughran for proofreading.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jneuroling.2019.01.004.

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