Neural correlates of cultural differences in moral decision making: a combined ERP and sLORETA study

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Cultures affect human social behaviors including moral decision making. However, the brain mechanism underlying cross-cultural moral decision making is still unclear. In the current study, the neural correlates of cultural differences in moral decision making between Chinese and westerners were investigated by combining the event-related potential technique with standardized Low-Resolution brain Electromagnetic Tomography (sLORETA) analyses. Behavioral results showed that participants made a smaller proportion of utilitarian judgments and had longer reaction times in response to personal than impersonal dilemmas, with no obvious differences between westerners and Chinese. However, the event-related potential components were significantly different between the two cultural groups. Smaller P3 amplitudes were evoked by personal than impersonal dilemmas for westerners, while for Chinese, smaller P260 deflections were elicited by personal compared with impersonal dilemmas. The current source density analysis with sLORETA revealed significantly different brain activities for P2, P3, and P260 components elicited by personal and impersonal dilemmas. Different from the sources of P2 and P3 components, which mainly localized in cingulate gyrus and medial frontal areas, the P260 component mainly activated areas in the posterior cingulate, parahippocampal gyrus, and cuneus and precuneus cortices. These findings suggest a relatively earlier initiation of the moral decision-making process for westerners and a relatively integrated processing during the solution of moral decision making for Chinese. *NeuroReport* **25:110–116 © 2014 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

A growing literature has tried to uncover the cognitive and neural mechanisms underlying decision making with a family of ethical dilemmas [1–3]. Generally, an ethical dilemma is a complex situation that involves a conflict in choosing between two undesirable alternatives, which would evoke the competition between deontological (nonutilitarian) choice and utilitarian response. For example, in a personal moral dilemma (the footbridge dilemma), the only way to save five workers from a runaway trolley is to push a large man off an overpass bridge onto the tracks below. He will die, but his body will stop the trolley from reaching the other five people. A corresponding impersonal moral dilemma is the trolley dilemma, in which the only way to save the five workers is to pull a lever redirecting the trolley onto another set of tracks, where it will kill a single worker instead of five workers [1,4]. The deontological response is an aversive emotional response to the harmful act, which would lead to the rejection of utilitarian response. In contrast, the utilitarian response is to take part in the harmful act since doing so will maximize good consequences, which would require overcoming the prepotent emotional response.

Although the proposed actions in both personal and impersonal dilemmas would produce similar outcomes, moral judgment in the two dilemma types might be driven by different principles. Previous studies have indicated that most people show agreement with pulling the lever in the trolley dilemma and disagreement with pushing the man in the footbridge dilemma [1]. Neuroimaging results revealed that personal moral dilemmas elicit greater activation in brain regions associated with emotions, whereas impersonal moral dilemmas elicit greater activation in areas associated with problem solving and working memory, suggesting that both cognitive and emotional processes contribute to moral decision making [1,2].

For both personal and impersonal ethical dilemmas, each act may lead to certain consequences and both sides may be right in different senses. If we adopt the utilitarian way of thinking, we would conclude that it is right to kill one instead of five, but it is also right to develop an intuitive rule against participation in killing others. However, people's moral decisions might be influenced by cultural factors, since people's morals and virtuousness are shaped by culture [5]. Therefore, culture should be taken into consideration when investigating moral decision making. As Kohlberg and Candee [6] have suggested, culture has an impact on an individual's cognitive judgment and decision-making ability regarding

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ethical issues, since sociocultural context guides people's moral evaluation and moral decision making.

Although moral decision making and cultural differences are both major themes in social psychology, the brain mechanism underlying cross-cultural moral decision making is still far from being well understood. In the present study, by combining the event-related potential (ERP) technique with standardized low-resolution brain electromagnetic tomography (sLORETA) [7], we investigated the time course of neural processes and the underlying neural activations associated with moral decision making in both Chinese and westerners. Since there are extensive differences between eastern and western cultures, we hypothesized that Chinese and westerners would show different patterns during the resolution of moral dilemmas, and that the differences, if any, would be reflected in spatiotemporal cortical activation underlying moral decision making.

Methods

Participants

Twenty Chinese (15 males, mean age 24.8 years, range 20–28 years) and 19 western healthy college students (11 males, mean age 22.2 years, range 19–32 years, from USA) were paid for participation in this study. All participants were right-handed, had no history of psychiatric or neurological disorders, and had normal or corrected-to-normal vision. The study was approved by the Institutional Review Board at Dalian University of Technology and informed consent was obtained from each participant.

Stimuli and procedure

The experimental materials consisted of 40 dilemmas, including both personal and impersonal ones [1,2]. Each dilemma was presented as black text against a gray background on the computer monitor through a series of three screens. The first two described the scenario of a dilemma, and the third one posed a question asking whether or not the hypothetical action was morally appropriate. Choosing appropriate options was considered to be utilitarian, whereas choosing inappropriate options was considered to be nonutilitarian.

Both Chinese and westerners were tested individually, and they were instructed to minimize eye blinks to avoid excessive artifacts. The scenarios were written in their native languages (Chinese and English) for each participant. Each trial begins with two slides of texts that describe a scenario. The participants were able to read at their own pace, pressing a button to advance from the current to the next screen. After the second scenario slide was shown, a blank screen appeared for 2 s, followed by the decision slide asking about the appropriateness of the action described in the scenario. Each participant was instructed to respond by pressing a bimanual button using their right hand ('appropriate' or 'inappropriate'). The next trial followed an 8-s interval of blank screen. To familiarize the participants with the task, three practice trials were presented before the start of the experimental trials.

Electrophysiological recordings and analysis

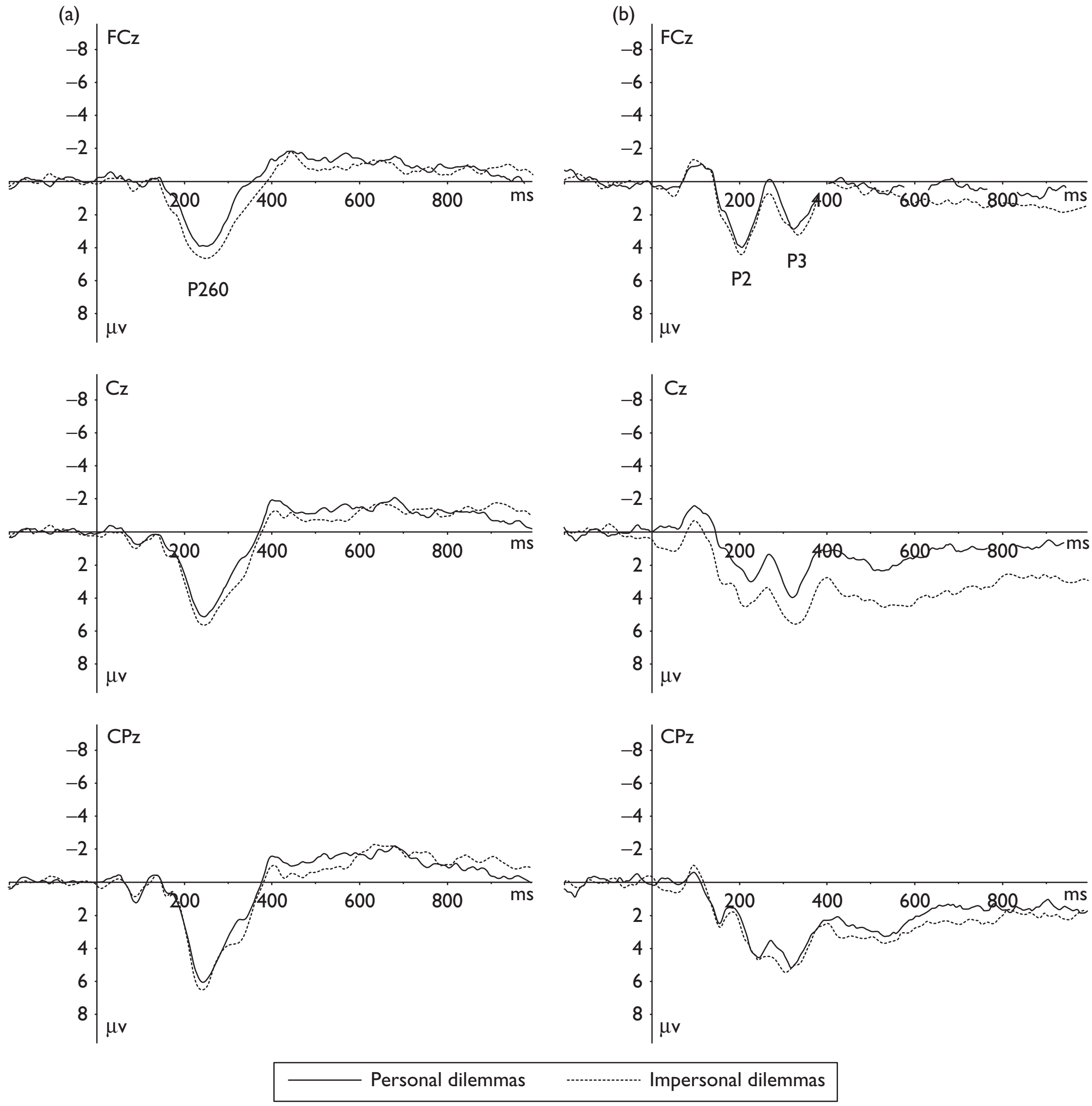
All electroencephalographic (EEG) data were continuously recorded from 64 electrodes mounted in an elastic cap (2Brain Product; HRB München, Munich, Germany), at a sampling rate of 500 Hz. The locations of electrodes were according to International 10-20 System nomenclature. A reference electrode was placed at the center between Fz and Cz. The vertical electrooculogram was recorded with electrodes placed above and below the left eye. All electrode impedances were kept below 10 kΩ. Band pass and notch filtering (0.05–80 Hz, 50 Hz) were applied and the EEG data were rereferenced to left and right ear lobes (average signals of Tp9 and Tp10) before further analysis.

The EEG data were segmented offline with an epoch starting from 200 ms before the decision slide and continuing for 1200 ms. All epochs were refiltered offline with a low-pass filter set at 30 Hz. Trials with electrooculogram artifacts and those contaminated with artifacts were excluded from averaging if amplitudes exceeded $\pm 80\,\mu V$. The averaged ERPs were obtained over trials for each individual in each dilemma type. The ERP trials were then baseline corrected relative to the 200 ms before the question slide. Grand averaged ERPs were obtained over participants.

On the basis of the literature and observations from the grand averaged ERP waveforms (Fig. 1), the P2 and P3 components for westerners were measured separately as the most positive deflections in 180–260 and 280–380 ms time windows. The P260 component for Chinese was identified as the maximum positive voltage peak between 200 and 300 ms time-locked to the onset of the decision slide. The following 25 electrode points were chosen for statistical analysis: F3, F1, Fz, F2, F4, FC3, FC1, FCz, FC2, FC4, C3, C1, Cz, C2, C4, CP3, CP1, CPz, CP2, CP4, P3, P1, Pz, P2, and P4 [8]. The P2, P3, and P260 peak amplitudes were subjected to a repeated measures analysis of variance (ANOVA) with dilemma type (personal, impersonal) and electrode site (25 levels) as the within-subject factors.

sLORETA [7] was used to compute the cortical three-dimensional distribution of the potential sources of ERP reactions to moral dilemmas for both cultural groups. The sLORETA is a method that computes images of electric activity from EEG in a realistic head model [9] using the MNI152 template [10] and estimates the three-dimensional distribution of current density in 6239 voxels with a spatial resolution of 5 mm. In the present study, the voxel-based data were created from the ERP data in each timeframe that corresponded to the peak value of each ERP component. These timeframes corresponded to the latency ranges of P2, P3, and P260 components as

Fig. 1



(a) Grand average event-related potentials (ERPs) for personal and impersonal dilemmas in Chinese. (b) Grand average ERPs for personal and impersonal dilemmas in westerners.

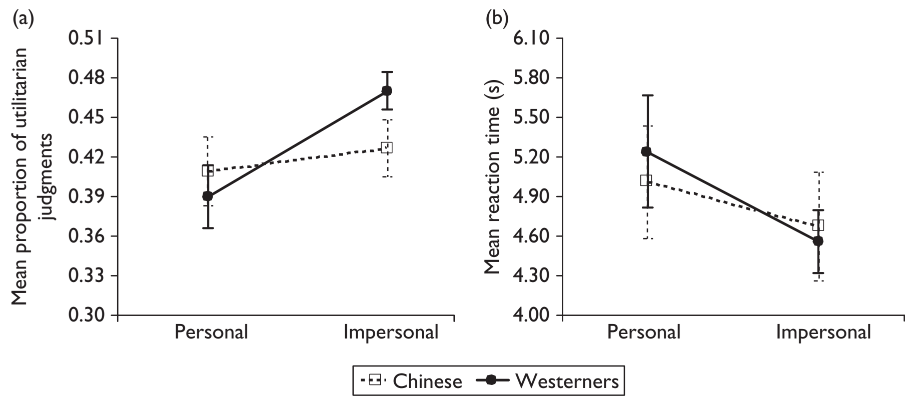
mentioned above. Activation within each timeframe was compared with time 0 for each dilemma type (dependent *t*-tests) [11,12]. For westerners, the density values at the P2 and P3 peak time points were compared with density values at the onset of the decision slide, respectively. Similarly, for Chinese, the comparisons were conducted between the density values at the P260 peak time point and density values at the onset of the decision slide.

Results

Behavioral data

The mean proportion of utilitarian choices and reaction times was subjected to a repeated measures ANOVA with cultural group (Chinese vs. westerners) as the between-subjects factor, and dilemma type (personal vs. impersonal) as the within-subjects factor. The results of the proportion of utilitarian choices revealed a significant main effect of dilemma type [$F(1,37) = 6.531$, $P = 0.015$], indicating that the proportion of utilitarian choices was higher for impersonal than personal dilemmas (Fig. 2a). The main effect of group was not significant. The interaction between dilemma type and racial group was not significant. The mean reaction times (from the onset of the decision slide to the onset of the behavioral response) to the moral dilemmas were 5.127 s (SD: 1.862 s) and 4.621 s (SD: 1.485 s), for personal and impersonal types, respectively. The results of the ANOVAs for reaction times showed a significant dilemma type effect [$F(1,37) = 6.178$, $P = 0.018$], as

Fig. 2



(a) Mean proportion of utilitarian judgments by dilemma type for Chinese and westerners. (b) Mean reaction time by dilemma type for Chinese and westerners. Error bars indicate SEM.

indicated by longer reaction times for personal than impersonal dilemmas (Fig. 2b). The main effect of group and the interaction between dilemma type and group for reaction times were not significant.

ERP result

P2–P3

The results of the ANOVAs for P2 amplitudes showed a marginally significant effect of dilemma type [$F(1,18) = 3.481$, $P = 0.078$], with somewhat smaller amplitudes for personal than impersonal dilemmas. Interaction between dilemma type and electrode site was not significant for P2 amplitudes. For P3 amplitudes, there was a significant effect of dilemma type [$F(1,18) = 6.526$, $P = 0.020$], and personal dilemmas evoked smaller P3 deflections than impersonal dilemmas. Interaction between dilemma type and electrode site was also not significant for P3 amplitudes.

P260

For Chinese, the analysis of P260 amplitudes yielded a significant main effect of dilemma type [$F(1,19) = 6.297$, $P = 0.021$]. The P260 amplitudes were smaller for personal than impersonal dilemmas. The interaction between dilemma type and electrode site was not significant.

sLORETA results

sLORETA brain activity patterns at P2 and P3 latencies

The first four rows of Fig. 3 display the sLORETA brain maps of current source density distributions for westerners corresponding to the maximum sLORETA values within P2 and P3 latencies (vs. baseline) in both dilemma types. Personal dilemmas mainly activated the cingulate gyrus (Brodmann areas BA 24/32) at both P2 and P3 latencies. At P2 latency, impersonal dilemmas activated several widely distributed brain areas including frontal (BA 10/11/47), limbic (BA 24/32), temporal (BA 20/21/38), and sublobar (BA 13) areas. Similarly, at P3 latency, impersonal dilemmas activated sublobar (BA 13), temporal (BA 20/21/22), limbic (BA 32), and frontal (BA 6/8/10/11) areas.

sLORETA brain activity patterns at P260 latency

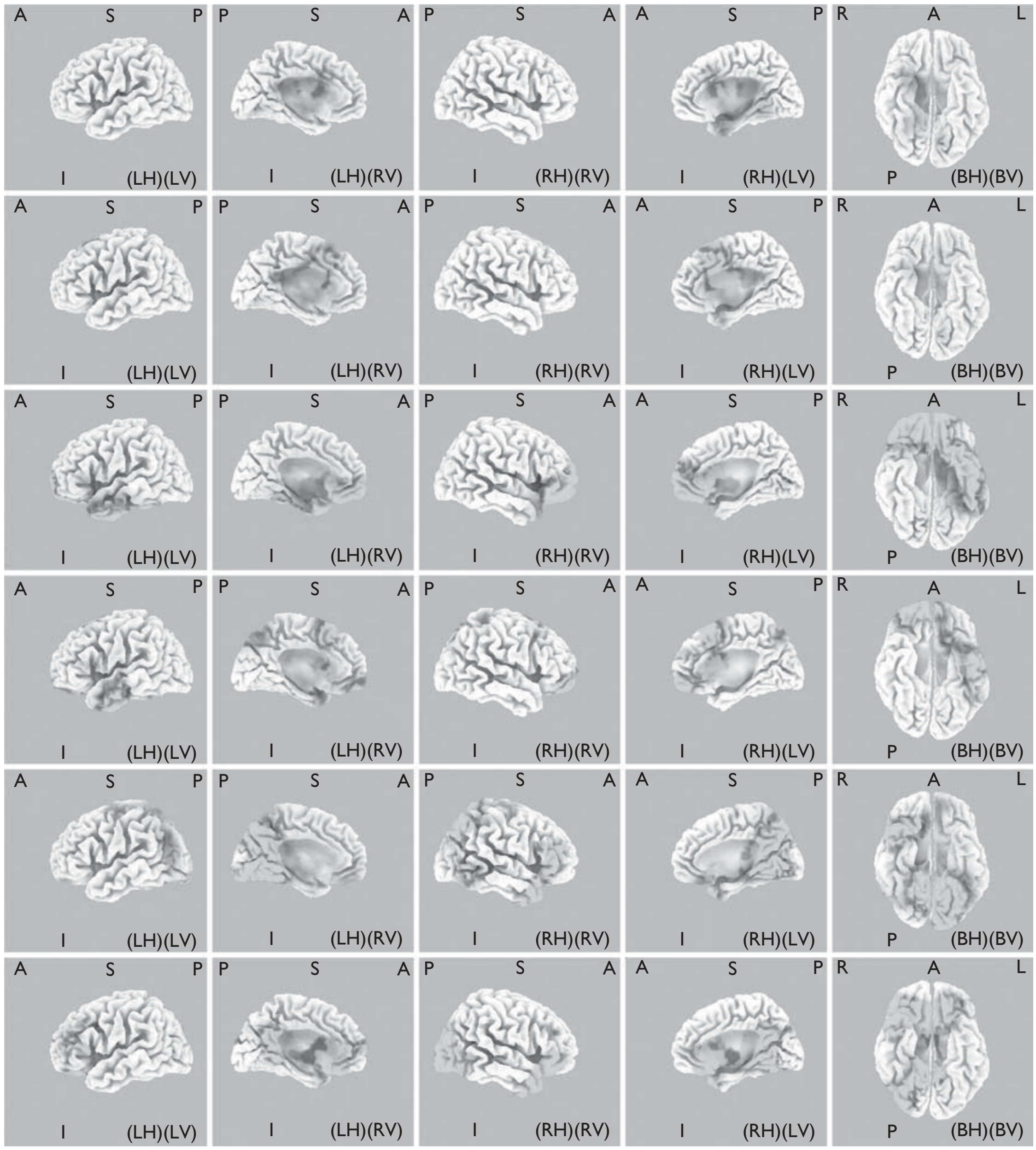
The last two rows of Fig. 3 display the sLORETA brain maps representing cortical regions where Chinese showed activations at the time points corresponding to the maximum sLORETA values within the P260 latency (vs. baseline) in both personal and impersonal dilemmas. Personal dilemmas activated several widely distributed brain areas, including limbic (BA 23/30/31), frontal (BA 45/46/47), occipital (BA 17/18/19), parietal (BA 7/31/40), temporal (BA 21/38), and sublobar (BA 13) areas, while impersonal dilemmas activated similar brain areas to personal dilemmas, including limbic (BA 23/24/30/31/32), occipital (BA 17/18/19), parietal (BA 7/31), frontal (BA 11/45/47), temporal (BA 21/38/39), and sublobar (BA 13) areas.

Discussion

The present study investigated the neural correlates of cultural differences in Chinese and westerners performing a set of moral dilemmas. Participants showed less moral approval and longer reaction times for personal compared with impersonal dilemmas, with no obvious differences between the two cultural groups. This finding is consistent with previous research suggesting that the personal/impersonal distinction represents something fundamental about human moral cognition [13]. By examining participants' reactions to moral dilemmas using ERPs and sLORETA, we gained insight into the cultural differences in moral decision-making processes.

In ERP waveforms time-locked to the onset of the decision slide, prominent P2 and P3 components were exhibited for westerners, while the P260 component was evoked for Chinese. The different ERP components

Fig. 3



Grand average sLORETA images, derived from voxel-by-voxel *t*-test ($P<0.05$). First row: grand average P2 for personal dilemmas. Second row: grand average P3 for personal dilemmas. Third row: grand average P2 for impersonal dilemmas. Forth row: grand average P3 for impersonal dilemmas. Fifth row: grand average P260 for personal dilemmas. Sixth row: grand average P260 for impersonal dilemmas. A, anterior; BH, both hemispheres; BV, bottom view; I, inferior; LH, left hemisphere; LV, left view; P, posterior; RH, right hemisphere; RV, right view; S, superior; sLORETA, standardized low-resolution brain electromagnetic tomography. The dark areas indicate the activated areas ($P<0.05$).

elicited by moral dilemmas might be due to cultural differences. It has been widely demonstrated that East Asians and westerners differ in experience, expertise, and socialization, which might influence their self-representation, cognition, emotion, and motivation, as well as the allocation of attention [14]. Previous research has indicated that Chinese fixated more on the backgrounds than did North Americans, whereas North Americans looked at the object earlier and made more saccadic eye movements toward the object than did the Chinese [15]. This is consistent with the P2 component elicited for westerners, since P2 has previously been suggested as an attentional-related component [16], which might indicate a relatively earlier initiation of decision making in westerners.

Interestingly, for P260 in Chinese and P3 in westerners, personal dilemmas elicited less positive ERP deflections than impersonal dilemmas. In contrast with impersonal dilemmas, many of the proposed actions in personal dilemmas involve death or serious bodily harm, which would evoke social negative emotions during contemplation of such dilemmas. Previous research has indicated that P3 is an index of an inhibition of task-irrelevant emotional information, with less positive amplitudes for negative stimuli than neutral stimuli in the implicit emotional task [17]. This is consistent with current P3 results suggesting that more social negative emotions were required to be inhibited in response to personal than impersonal dilemmas. This inhibition process may be similar for both cultural groups, since smaller P260 deflections were induced by personal than impersonal dilemmas, which might suggest a similar pattern to P3 deflections for personal–impersonal distinction. Moreover, the P260 component has been suggested as a combination of a P2 and a P3-like process [18], and this component has been reported to reflect immediate affective reaction toward options that integrate attention, working memory, and emotional processing [3]. Thus, the P260 component may suggest an integrated process during the solution of moral dilemmas in Chinese.

As noted, sLORETA results suggested a different set of activated brain structures for westerners and Chinese. In fact, the main source of both P2 and P3 components for personal dilemmas was the cingulate gyrus, similar to the other studies suggesting the cingulate gyrus as the source of P2 and P3 components [19,20]. In contrast, the main activities of P2 and P3 components in impersonal dilemmas were localized in the medial frontal area and cingulate gyrus, with contributions of several other brain regions, including temporal and insula areas. These findings are in accord with brain imaging research demonstrating a complex network of brain regions involved in moral decision making [21]. Different from the sources of P2 and P3 components, the P260 component of both dilemma types mainly activated areas in the posterior cingulate, parahippocampal gyrus, and cuneus and precuneus cortices, and these areas have been considered to be related to emotional processing and evaluation [22], retrieving episodic memory representations [23], and attention, as well as the detection of salient stimulus, and higher-order cognitive functions [24]. It seems that brain areas associated with attention, memory retrieval, and emotional processing were involved in the process of moral decision making for Chinese. Consistently, Zhang and Yang [25] proposed that sometimes Chinese might follow the reasonableness (both sensible and reasonable) norm and integrate the considerations of both affective and rational factors when making a decision. Those activated brain areas might contribute to this integration processing.

Conclusion

This study investigated the underlying neural mechanisms of Chinese and westerners' responses to moral dilemmas that involve the competition between utilitarian and nonutilitarian choices. With the help of analysis of spatiotemporal cortical activation, the present research may indicate different methods of information processing with regard to moral dilemmas for westerners and Chinese: westerners tended to initiate the process of moral decision making earlier, whereas Chinese tended to adopt a relatively integrated way of information processing. The present findings may provide new insights into the neural mechanism of cultural differences during decision making under moral dilemmas.

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Conflicts of interest

There are no conflicts of interest.

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