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Research article

Emotional conflict processing induce boosted theta oscillation

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HIGHLIGHTS

- Oscillation activity underlying emotional conflict processing was explored by emotional body-word Stroop task.
- Behavioral data show an interference effect in response time and accuracy.
- Incongruent condition induce pronounced theta oscillation than congruent condition over frontal midline areas.
- Theta activity difference is negatively correlated with corresponding response time difference.

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ABSTRACT

Although previous studies have reported the neural correlates and dynamics of emotional conflict processing, the neural oscillatory features of such processing remain unclear. The present study uses time–frequency analysis to determine the event-related spectral perturbation (ERSP) characteristics underlying emotional conflict processing. Our behavioral results replicate previous findings of shorter response times and fewer response errors under the congruent condition relative to the incongruent condition, indicating a robust interference effect. Theta oscillatory activity was larger for the incongruent than for the congruent condition over frontal and frontal–central midline areas, reflecting a greater need for control under conditions of conflict. Moreover, the theta power difference was negatively associated with the RT difference, indicating that greater theta power leads to better behavioral performance. The present findings provide evidence that the theta oscillation is necessary for the control of emotional conflict.

1. Introduction

Conflict detection and resolution is the core of cognitive control, regarded as a key human function serving to maintain normal life and allow adaptation to a changing environment [1]. Significant emotional stimuli might have the opportunity to gain priority access to cognitive processing in numerous situations [19] and consequently to interfere with human goal-directed behavior. Thus, to adapt to a changing environment, humans must resolve conflicts stemming from emotion-laden stimuli. In laboratory settings, this type of conflict has been investigated using several emotional Stroop paradigms. For example, in the emotional face-word [10,12] and body-word tasks [14], participants are asked to judge the emotion expressed by a face or body while inhibiting influences from an emotion-laden word. Both tasks demonstrate longer response latencies and greater error rates under incongruent than under congruent conditions.

Functional magnetic resonance imaging (fMRI) studies [10,12] have found that resolution of emotional conflict is associated with activity in the rostral anterior cingulate cortex and that resolving emotional conflict occurs via the top-down inhibition of the amygdala by the rostral cingulate cortex. Similarly to the classic Stroop task, ERP studies of emotional conflict found a conflict-related N450 component with a frontal to central topographical distribution [14,26], which might be associated with conflict resolution. Moreover, a later stage consisting of a slow potential developing in both areas was also observed in both tasks. It was suggested that the latter effect represents post-response monitoring.

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Although many studies have explored the neural dynamics and brain structures associated with the resolution of emotional conflict, the neural correlates of the conflict resolution process are still unclear. The above studies are limited to fMRI and ERP techniques, and few studies have investigated the neural oscillatory activity changes associated with processing emotional conflict. Compared to ERP activity, which features time-locking and phase-locking, event-related oscillatory activity has received increasing attention in recent years [9]. Note that onset of a particular type of stimulus not only evokes ERP activity but also time-locked event-related spectral perturbation (ERSP) activity, but not phase-locked ERSP activity [21]. This kind of activity would be cancelled out by traditional trial-averaging techniques aimed at obtaining ERP activity [15]. However, some researchers claim that oscillatory activity has the potential to provide more complex information than ERP can provide, revealing interactions between different brain areas to a specific task. Thus, oscillatory activity analysis is an appealing and promising method of investigating the neural oscillatory mechanism underlying emotion conflict processing.

Previous studies have found that specific bands of ERSP activity can be involved in typical control tasks. Specifically, enhanced theta activity was found for the incongruent rather than the congruent condition in the color-word Stroop task, indicating that enhanced theta oscillatory activity might be associated with a greater need for executive control under conflict conditions [11,13,22,25]. Since the evidence shows a similarity between emotional and cognitive Stroop processing, enhanced theta oscillatory activity could emerge when processing conflict in the affective Stroop domain. Thus, the aim of current study was to explore whether theta oscillation is also present when emotional conflict is being processed. Based on previous studies, we expected that a larger theta signal would be present under conflict conditions.

2. Methods

2.1. Participants

Twenty-six male and 25 female undergraduate students participated in the formal EEG study as paid volunteers. The participants selected were between 18 and 26 years old (mean [M] = 21.4 years, standard deviation [SD] = 1.98 years). All participants were right-handed (laterality index: M = 87.35, SD = 11.55), had normal or corrected-to-normal vision, and had no personal or family history of psychiatric illness or neurological problems. Handedness was assessed using the Edinburgh handedness inventory [20]. All participants provided written, informed consent prior to the experiment. This study was approved by the ethics committee of Southwest University of China. The study adhered to the guidelines as set out in the Declaration of Helsinki.

2.2. Stimuli

The body-word compound stimuli used in this study were the same as those in our previous study [14]. All of the body stimuli from the bodily expression action stimulus test [8] were screened using a 4-s-duration force–choice judgment task. The resulting data showed that angry and sad body pictures are better recognized than happy or fearful ones. To minimize the influence of accuracy on the behavioral data, we selected for further study 20 angry and 20 sad body-expression images that had been classified with equivalent accuracy during screening. These body images were compounded with Chinese words using Photoshop. Two Chinese characters, "愤怒" ("angry") and "悲伤" ("sad") were superimposed across the body in red color in 28-point Times New Roman font. The position of the word was fixed on the chest of the body in all of the body-word compound stimuli. Finally, 80 compound images, 20 for each of the four possible combinations of body emotion and word emotion, were created. Then the four stimulus types (angry body-angry word, angry body-sad word, sad body-angry word, and sad body-sad word) were divided into congruent (body expression matched emotional word) or incongruent (body expression did not match emotional word) categories. The incongruent category was expected to induce conflict in emotion processing. Following EEG measurement, participants were asked to rate the angry and sad body expressions in terms of arousal and pleasantness using two 9-point scales, with PLEASANTNESS = 1 being the most unpleasant and PLEASANTNESS = 9 being the most pleasant; AROUSAL = 1 indicated the least arousing and AROUSAL = 9 indicated the most arousing stimulus. The results showed that the two emotions were not significantly different from each other for pleasantness rating; angry-body (3.6 ± 1.2) vs. sad-body (3.9 ± 1.23), $t(50) = 1.657$, $p = 0.104$. However, angry-body (5.4 ± 1.17) was much more arousing than sad-body (4.43 ± 1.44), $t(50) = 4.301$, $p < 0.001$.

2.3. Procedure

All of the compound stimuli were programmed using E-Prime software and presented on a Dell 19-inch monitor. Participants were seated in a quiet, dimly lit room with their eyes 80 cm from the screen. The viewing angle of the body-word compound stimuli when shown on the screen extended 9.87° vertically and 6.58° horizontally. Participants completed an emotional-body-word Stroop task, in which they were required to identify the emotion of the body expression and ignore the meaning of the word superimposed across the body. Subjects were told to respond as quickly and accurately as possible by pressing "f" or "j" on the keyboard to indicate the emotion expressed by the body component of the image. Key allocations were counterbalanced across participants. All 80 compound stimuli were presented three times over per participant, generating 240 trials in total, which were separated into three equal blocks. Each block consisted of an equal number of congruent and incongruent trials. In each block, a trial began with a 500-ms fixation display, followed by a blank screen with an inter-stimulus interval that ranged from 300 to 600 ms. Then the target body-word compound stimulus appeared at the center of the screen for 1000 ms and participants were required to respond within this time window. Following this, the blank display was presented for 1200–1800 ms. Participants completed 20 practice trials before beginning the main task. Participants were asked to avoid blinking and other eye movements while an individual experimental trial was in progress.

2.4. EEG recording and analysis

EEGs were collected using a 64-channel Brain Amp MR amplifier (Brain Products, Munich, Germany) and Brain Vision Recorder software (Brain Products, Brain Products GmbH, Stockdorfer, Gilching, Munich, Germany). EEG signals were obtained using Ag/AgCl electrodes applied to the scalp at the standard international 10–20 system locations. Signals were amplified using a 0.01–100 Hz band pass filter and were continuously sampled at 500 Hz/channel with the FCz electrode site as online reference. Horizontal electrooculograms (HEOGs) were recorded from the right orbital rim. Vertical electrooculograms (VEOGs) were recorded from electrodes placed below the right eye. All inter-electrode impedances were maintained below 5 kΩ.

The raw EEG data were then imported for further preprocessing into EEGLAB (version 12.0.2.6b), an open toolbox running under the MATLAB environment. First, based on a previous study exploring ERSP responses in a Stroop task [25], the continuous raw data were high-pass filtered at 1 Hz, low-pass filtered at