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Neural time course of emotional conflict control: An ERP study

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HIGHLIGHTS

- We first investigate the temporal cortical activation patterns underlying the emotional conflict task.
- There was a more negative ERP deflection (N350–550) in the incongruent condition.
- There was a more positivity ERP deflection (P700–800) in the incongruent condition.

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ABSTRACT

Previous imaging studies have revealed brain mechanisms associated with emotional conflict control. However, the neural time course remains largely unknown. Therefore, in the present study a face-word Stroop task was used to explore the electrophysiological correlates of emotional conflict control by using event-related potentials (ERPs). Behavioral data indicated that response time of congruent condition was faster than incongruent condition, while the accuracy rates of congruent condition was higher than incongruent condition, which showed a robust emotional conflict effect. ERP revealed N350–550 and P700–800 components in the incongruent minus congruent condition. N350–550 might be related to conflict resolution and response selection; P700–800 might be related to post-response monitoring.

1. Introduction

Cognitive control is the human ability to select the relevant information or stimuli and avoid interference from irrelevant distractors while implementing a task [3]. Many emotionally salient stimuli in the environment will interfere with our ongoing behavior. In everyday life, people have to inhibit the emotional distractor and resolve the “conflict” of emotion.

Previous studies have investigated the neural underpinnings of emotional conflict control using functional magnetic resonance imaging (fMRI) [8,7,16,13]. For instance, Etkin et al. [8] found that the dorsolateral prefrontal cortices (dlPFC) and amygdale were associated with emotional conflict detection, and that the rostral anterior cingulate cortex (ACC) was associated with conflict resolution. Egner et al. [7] directly compared emotional conflict with nonemotional conflict using the same paradigm and found similar results in the emotional task. However, in contrast to Etkin et al., they observed that the right dlPFC was only activated in the nonemotional task. In addition, Krug and Carter [13] suggested that there were no differences in the activation of prefrontal circuits between emotional conflict and nonemotional conflict resolution in healthy participants.

Although these studies provide some brain imaging evidence relating to emotional conflict control, the electrophysiological correlates remain largely unknown. To our knowledge, Zhu et al. (2010) are the only ones to have used event-related potentials (ERPs) to measure emotional conflict [22]. They found that participants experienced emotional conflict at the early stages of processing; however, they did not address the issue of conflict control and conflict resolution. Therefore, the aim of the present study was to investigate the neural time course of emotional conflict control. In line with previous studies, we decided to use the face-word Stroop task. This task requires participants to judge the emotion of a facial expression and avoid the interference of emotional words presented over the top of the face.

Many previous studies have used ERPs to measure the Stroop effect, often using the color-naming paradigm, in which participants are asked to name the ink-color and ignore the word meaning. Researchers observed that two ERP components were related to conflict control processing: fronto-central N450 and conflict slow potential (SP). N450 at fronto-central sites often coincided with conflict monitoring [15,19] or conflict resolution [17] and showed

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greater amplitude in the incongruent condition than the congruent condition. Conflict SP is a conflict-sensitive positivity over parietal regions, which is often associated with conflict resolution and response selection [6,21], response monitoring [2,5] or conflict adaptation [14].

Previous imaging results have shown that many brain regions involved in emotional conflict overlap with those associated with cognitive control, such as the dorsal ACC and dlPFC [13]. In addition, Kanske and Kotz suggested that the ventral ACC, a brain region often implicated in the processing of emotional information, could also be involved in resolving the conflict under an emotional context [10,11]. They also found that both positive and negative emotion could speed up conflict resolution. These results suggest that emotional information could influence conflict control processing, and that emotional conflict control might have a different pattern of activation compared with cognitive conflict control.

On the basis of the study by Zhu et al. [22], whose findings for the N170 component showed that emotional conflict occurred at an early stage of processing, we predicted that participants would select the right response at an earlier stage under emotional conflict conditions compared with cognitive conflict conditions. Previous studies have suggested that the ERP amplitudes that covary with reaction times (RTs) are an index of response selection [21]. Accordingly, we predicted that two classical ERP effects would be observed in the incongruent minus congruent difference wave: fronto-central negativity and parietal positivity. We also predicted that participants would respond to the emotional conflict at an earlier stage compared to cognitive conflict and that the RTs would covary with the amplitude of the ERP fronto-central negativity.

2. Materials and methods

2.1. Participants

Twenty healthy students (10 male, 10 female; average age 21.5, ranging from 18 to 24 years) from Southwest University in China participated in the study. Participants were right-handed, had normal or corrected-to-normal vision, and had no history of neurological or psychiatric illness. All participants gave written informed consent and were paid at the end of the experiment. The study was approved by the Southeast University Ethics Committee.

2.2. Stimuli and procedure

The stimuli consisted of 10 happy face pictures (5 male, 5 female) and 10 fearful face pictures (5 male, 5 female) selected from the Chinese affective picture system [1]. Two Chinese characters "愉快" (which means "happy") or "恐惧" (which means "fear") were superimposed across the faces in red color. The words and facial expressions were either congruent (e.g., character meaning happy superimposed onto a happy face picture) or incongruent (e.g., character meaning happy superimposed onto a fearful face picture), the latter of which would produce emotional conflict.

The stimulus was programmed by E-Prime and it was presented at a Dell 19-in monitor. Participants sit in quiet room with dim light. And they performed a modified Stroop task in which they were instructed to identify the facial expression while ignoring the meaning of the words. Responses were to be made as quickly and accurately as possible by pressing a button corresponding to "fear" faces (right index finger) or "happy" faces (right middle finger). There were a total of 240 trials, which were divided over 4 blocks, 60 per block. Each block consisted of an equal amount of congruent and incongruent trials. Participants performed in a practice block prior to the main experiment, which comprised 24 trials. The order and timing of a trial was as follows: a fixation dot was presented (for a duration of 500 ms) followed by a variable blank screen (presented for 300–500 ms). Then, the target face picture appeared for 1000 ms on the center of the screen. Participants had to respond within 1500 ms. There was a variable inter-trial interval of between 800 and 1200 ms (see Fig. 1).

2.3. ERP recording and analysis

Brain electrical activity was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (Brain Products GmbH, Gilching, Germany), with the reference electrodes placed on the left and right mastoids. The vertical electrooculogram (EOG) was recorded with electrodes placed above and below the left eye. All inter-electrode impedance was maintained below 5 kΩ. The electroencephalogram (EEG) and EOG signals were amplified using a 0.05–80 Hz bandpass filter and continuously sampled at 500 Hz/channel for offline analysis. Eye movement artifacts (blinks and eye movements) were rejected offline. Trials with EOG artifacts (mean EOG voltage exceeding $\pm 80\,\mu V$) and those contaminated with artifacts due to amplifier clipping, bursts of electromyographic activity, or peak-to-peak deflection exceeding $\pm 80\,\mu V$, were excluded from averaging.

The focus of our analysis was the ERPs elicited by the correct responses of emotional judgments (the ERPs were time-locked with the onset of the target face picture). The averaged epoch for ERPs was 900 ms, including 800 ms post-stimulus and 100 ms pre-stimulus. ERPs were averaged for trials associated with correct responses; at least 100 trials were available in the congruent and incongruent conditions for each subject. Previous studies suggest that the scalp distribution of Stroop-related ERP components (N450 and SP) include the frontal–medial and posterior parietal sites [14]. Therefore, the frontal-medial negative component between 350 and 550 ms at sites Fz, F3, F4, FCz, FC3, FC4, Cz, C3 and C4, and the posterior parietal positive component between 700 and 800 ms at sites Pz, P1, P2, POz, PO3 and PO4 were chosen for quantification analysis. The paired t test was performed on the behavioral data, and repeated measures analyses of variance (ANOVAs), including the within-factors congruency (congruent and incongruent), were computed on the EEG data. The analysis of the EEG data also included the electrode sites. Besides, Pearson correlation analysis was performed between RTs and the amplitude of N350–550 and P700–800, respectively. For all analyses, the p-value was corrected for deviations according to Greenhouse Geisser.

2.4. Dipole source analysis

The brain electrical source analysis program (BESA; MEGIS Software GmbH, Graefelfing, Germany) was used to perform dipole source analysis, using the incorporated four-shell ellipsoidal head model. In order to explore and increase the precision of source location, principal component analysis (PCA) was employed for the ERP difference wave (64 channels). The difference wave was defined as the subtraction of the ERPs evoked by the congruent condition from the ERPs evoked by the incongruent condition. When the dipole points were established, the software automatically determined the location of the dipoles. The relevant residual variance (RV) criterion was used.

3. Results

3.1. Behavioral performance

Behavioral data revealed a significant emotional conflict effect. The RTs were longer for the incongruent trials than the congruent trials [(621 ± 51 ms vs. 592 ± 46 ms), $t(19) = 9.912$, $p < 0.001$].