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Emotional conflict occurs at an early stage: Evidence from the emotional face–word Stroop task

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ABSTRACT

The perceptual processing of emotional conflict was studied using electrophysiological techniques to measure event-related potentials (ERPs). The emotional face–word Stroop task in which emotion words are written in prominent red color across a face was use to study emotional conflict. In each trial, the emotion word and facial expression were either congruent or incongruent (in conflict). When subjects were asked to identify the expression of the face during a trial, the incongruent condition evoked a more negative N170 ERP component in posterior lateral sites than in the congruent condition. In contrast, when subjects were asked to identify the word during a trial, the incongruent condition evoked a less negative N170 component than the congruent condition. The present findings extend our understanding of the control processes involved in emotional conflict by demonstrating that differentiation of emotional congruency begins at an early perceptual processing stage.

Conflict control is a crucial aspect of the executive control mechanism. Conflict not only exists in the cognitive domain but also in emotional systems. The emotional face–word Stroop task [10] is used to study emotional conflict in the laboratory. In this task, the subject is shown a face displaying an emotion with an emotional word written across the face, such that the word and face emotions are either congruent or incongruent. The incongruent condition creates emotional conflict. Recently, several functional magnetic resonance (fMRI) studies have explored the neural basis of emotional conflict [8,10,13]. For the most part, the dorsal ACC (anterior cingulate cortex) has been shown to subserve the detection of emotional conflict. The ACC has generally been thought to be involved in the monitoring of response conflict. Recently, an fMRI study found that activity in the right superior occipital lobe is greater in the congruent vs the incongruent condition in an emotional conflict task [1]. This result suggests that conflict of different valence may occur at perceptual processing stage.

Although fMRI studies have provided important information about brain mechanisms involved in emotional conflict, the timing of this conflict between different sources cannot be studied with precision. Event-related potential (ERP) recordings, on the other hand can provide critical temporal information for precise analysis of the timing of emotional conflict. The aim of the present study was to further investigate the processing stage at which emotional conflict occurs using the emotional face–word Stroop task [10].

Previous studies have shown that emotional information from words and faces can be extracted at an early processing stage. Herbert et al. found enhanced ERP amplitudes in response to emotionally positive and negative adjectives as compared to neutral adjectives at centro-parietal electrodes, starting 180 ms after stimulus onset [15]. The difference between negative and positive emotion is also differentiated at an early processing stage. For example, Scott et al. found a difference between high frequency negative words and high frequency positive words at the P1 (80–120 ms) and N1 (135–180 ms) ERP component windows across several posterior electrodes [23]. Furthermore, Montalan et al. found that the N170 component was modulated by the valence of emotional words, with negative adjectives eliciting larger N170 amplitudes than positive adjectives [20].

As compared to written words, faces carry more direct biological and social relevance. P1 is a positive-direction component appearing at the parieto-occipital electrode between 100 and 130 ms post-stimulus introduction. The P1 component is thought to reflect processing of the low-level features of stimuli. While effects of facial expression on P1 have been reported previously [14], differences in P1 related to distinct emotions have not yet been described [3]. The N170 component is widely regarded as a face sensitive potential. The N170 is observed in the 120–220 ms range and peaks around 170 ms post-stimulus, with its maximum at occipito-temporal sites, and right-hemisphere dominance [4]. It is debatable whether N170 is modulated by different facial

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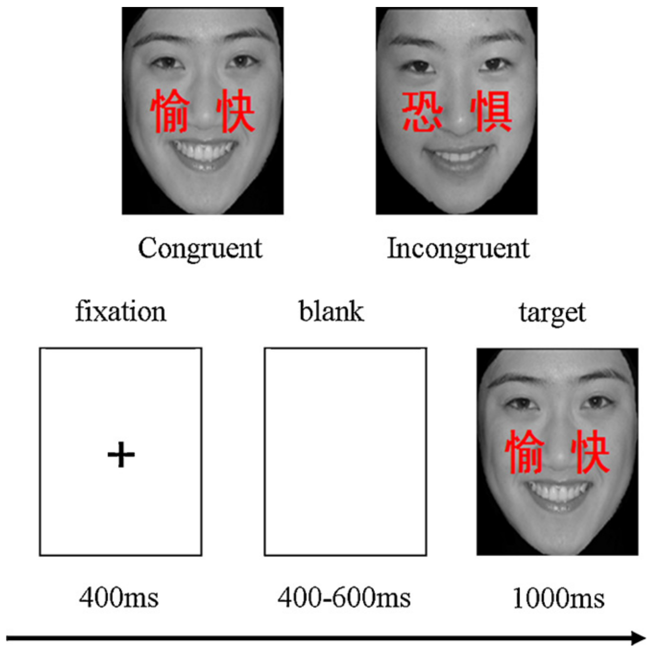

Fig. 1. Stimuli and example timelines used in the emotional conflict task. Subjects were asked to identify the affect of faces with fearful or happy expressions that had either "fear" or "happy" written across them. Stimuli were either congruent or incongruent with respect to facial expression and word, which created emotional conflict.

expressions. While some researchers have found no emotional modulation of N170 [16], there is some evidence that the N170 responds to differences in emotional expressions [3]. Negative and positive emotions can be differentiated at an early processing stage. For instance, larger N170 amplitudes have been reported in response to fearful faces as compared to other emotional [3] or neutral expressions [5,24]. In addition, N170 amplitudes were found to be greater for happy as compared to neutral and sad expressions [18]. Although the above reports differ in some aspects, they reveal that the emotional information of faces can be extracted at an early processing stage.

The focus of the present study was to investigate whether the N170 component of the ERP is modulated by emotional conflict brought about by incongruent information presented during the emotional face–word Stroop task.

There were two experiments in the present study. For the experiment 1, 18 healthy right-handed subjects (9 males and 9 females, aged 18–25) were recruited as paid volunteers from a University. They had no history of brain injury, reported no substance abuse and not on any mood-altering medication. Informed consent was obtained from all subjects. Two male subjects were excluded for analysis due to excessive artifacts.

Happy or fearful facial expression photographs were consisted of 10 male and 10 female faces selected from Chinese affective picture system [2]. The Chinese words "愉快" ("yukuai", means happy) or "恐惧" ("kongju" means fear) written in prominent red color across the faces, such that word and expression were either congruent or incongruent. Words were projected approximately across the noses of faces (Fig. 1). The size of the Chinese characters in bold face was about 1° (horizontal) × 1° (vertical).

Stimulus occurrences were counterbalanced across trial types and response buttons. The experiment consisted of 148 presentations of congruent and incongruent stimuli. Each trial began with the presentation of a fixation for 400 ms. After a random ISI between 400 and 600 ms, the stimuli (3.5° wide, 5° high) appeared in the center. Stimuli were presented for 1000 ms and disappeared once the subjects made a response, with a varying inter stimulus interval (ISI) of 1800–2300 ms the next trial begin. E-prime software package was used for the stimulus presentation and data acquisition (Psychological Software Tools, Pittsburgh, PA). Subjects were seated in a semi dark room facing a monitor placed at 80 cm distance from the eyes. Subjects were instructed to respond as quickly and accurately as possible, by pushing response buttons corresponding to "happy" (right index finger) or "fear" (right middle finger) for the affect expressed on the face.

The electroencephalogram (EEG) was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (NeuroScan Inc., Herndon, Virginia, USA) according to the International 10/20 System. Horizontal electrooculogram (HEOG) was recorded from electrodes placed at the outer canthi of both eyes to record horizontal eye movement. Vertical electrooculogram (VEOG) was recorded from electrodes place above and below the left eye to record vertical eye movements. All electrode recordings were referenced to an electrode placed at the right mastoid. And the impedances of them were all maintained below 5 kΩ. The EEG and EOG were amplified using a 0.05–100 Hz bandpass and continuously sampled at 500 Hz/channel.

After data acquisition, the EEG data were re-referenced offline to linked mastoid electrodes by subtracting from each sample of data recorded at each channel one-half the activity recorded at the left mastoid. Then the data were re-referenced to the global average reference. Ocular artifacts were corrected with an eye-movement correction algorithm suggested by Gratton et al. [11]. The EEG data were low-pass filtered below 30 Hz (12 dB/oct). Separate EEG epochs of 1000 ms (200 ms baseline) were extracted offline for the stimuli. Error trials were discarded from all analyses. All trials in which EEG voltages exceeded a threshold of ±50 mV during the recording epoch were excluded from analysis. At least 60 trials were available for each condition. Finally, the EEG waveform was averaged separated for each participants and each condition.

Inspection of the grand-average waveforms and the difference waves of incongruent minus congruent ERP indicated that there was a major effect of emotional conflict at posterior lateral sites. The N170 component was identified as the average amplitude in the time window 150–190 ms in the bilateral parieto-occipital electrodes (PO8/7, P8/7 and P6/5). Electrode selection was based on previous studies showing maximal amplitudes for N170 on these sites [3,24]. For the N170 amplitude analysis we used the following within subjects factors: congruency (two levels: congruent or in congruent), hemisphere (two levels: left or right) and electrode site (three levels: PO8/7, P8/7 and P6/5), and for all analyses, p values were corrected for deviations according to Greenhouse and Geisser [12].

For the experiment 2, another sixteen healthy right-handed subjects (8 males and 8 females, aged 18–23) were recruited from a University. They had no history of brain injury, reported no substance abuse and not on any mood-altering medication. Informed consent was obtained from all subjects.

The stimuli and general procedures for this experiment were identical to those described for experiment 1 unless the subjects were response to the emotional word written on the face. Subjects were instructed to respond as fast and accurately as possible, by pushing response buttons corresponding to "happy" (right index finger) or "fear" (right middle finger) for the word written on the face.

The RT and ERP results were based on correct responses only. For the experiment 1, a robust emotional conflict effect was obtained as indicated by longer mean RT for the incongruent than congruent stimuli (632 ms vs 596 ms), $t(15) = 4.67$, $p < 0.001$. Subjects were slightly more accurate for congruent trials relative to incongruent trials (97% vs 92%), $t(1, 15) = 4.40$, $p < 0.001$.

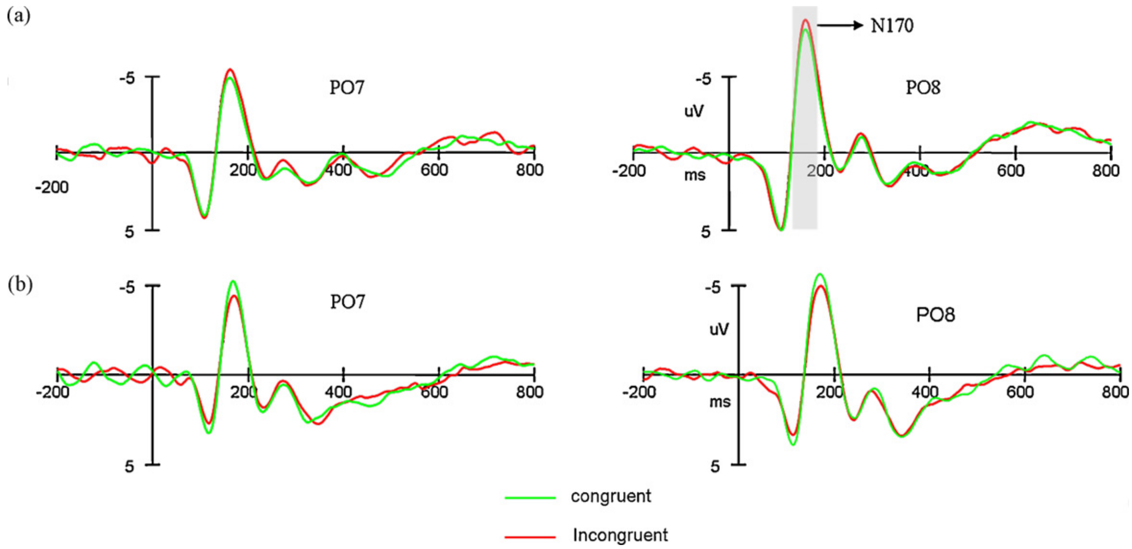

Fig. 2. Results of experiment 1 (a) and experiment 2 (b). Grand-averaged ERPs of the N170 component. The N170 is displayed for PO8/7. Negative amplitudes are plotted upwards.

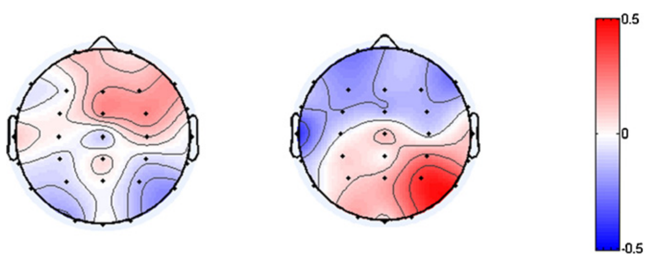

Fig. 3. The topographies of difference waves (incongruent minus congruent) in experiment 1 (left) and experiment 2 (right) were also displayed.

For the experiment 2, RT in the incongruent condition was slower relative to the congruent condition (620 ms vs 603 ms), $t(15) = 5.11$, $p < 0.001$. Mean accuracy was higher in congruent condition than in incongruent conditions (97.3% vs 92.8%), $t(15) = 7.07$, $p < 0.001$.

The ERP results were shown in Table 1 and Fig. 2. For the experiment 1, repeated-measures ANOVAs showed that the main effect of three factors were all significant, a main effect of conflict condition, $F(1, 15) = 22.51$, $p < 0.001$, a main effect of hemisphere, $F(1, 15) = 19.47$, $p = 0.001$, with a larger N170 component in right hemisphere than in left hemisphere, and main effect of electrode sites, $F(2, 30) = 5.25$, $p = 0.01$. The interaction between conflict condition and hemisphere was not significant, $F(1, 15) = 1.10$, $p = 0.31$. The interactions were not significant.

For the experiment 2, repeated-measures ANOVAs showed that the main effect of conflict condition, $F(1, 15) = 5.27$, $p = 0.04$, a main effect of hemisphere was marginally significant, $F(1, 15) = 3.60$, $p = 0.08$, with a larger N170 component in right hemisphere than in left hemisphere, and main effect of electrode sites, $F(2, 30) = 23.36$, $p < 0.001$. The interaction between hemisphere and electrode sites was significant, $F(2, 30) = 4.32$, $p = 0.03$. Simple effect analysis indicated a largest conflict effect in P8, $F(1, 15) = 9.34$, $p = 0.008$. The interaction among the three factors was not significant, $F(2, 30) = 0.71$, $p = 0.48$.

The present study demonstrated that when subjects were instructed to respond to facial expressions, the incongruent condition (conflict) evoked a more negative N170 component than the congruent condition. However when the subjects were instructed to respond to the meanings of emotional words, the incongruent condition evoked a less negative N170 component than did the congruent condition. The present results indicate that the emotion word and emotion face can interfere with each other at an early processing stage.

Previous studies have indicated that the processing of conflict between different sources occurs at an early stage. For example, Meeren et al. [19], using a compound stimulus consisting of a facial expression with an expressive body, found a larger P1 ERP component at posterior brain sites when the expression of the face conflicted with the emotion portrayed by the body than when the face and body expressions were congruent. However, they failed to find a modulatory role of emotional conflict on the N170 component. The N170 component was, however modulated by emotional conflict in the present study. The disparity between the results is possibly due to the face–body compound stimulus holding more biological significance than the face–word compound stimulus used in the present study. The N170 amplitude was affected in another study using compound stimuli consisting of facial expressions and task-irrelevant emotional scenes [22]. These authors found that information from the scene was combined rapidly with information from facial expressions, evidenced by larger N170 amplitudes in response to faces in fearful scenes as compared to faces in happy and neutral scenes. Taken together, the present results and previous results indicate that emotional information from different stimulus sources can be processed in a parallel fashion and integrated at an early stage.

These results provided evidences that selective mechanism was highly specific and related with the task set. It is necessary in an interference task to focus attention on the task specific feature of the stimulus and suppress the processing of task-irrelevant feature. In an early ERP study [17], using the color-word Stroop task, it was found the probes related to the attended feature produced the greater P85 'attention effect' than the unattended feature. And in a recent fMRI study [21], the word area was suppressed and the color area was enhanced in the incongruent condition than in the control condition, indicated the enhancement of the task-relevant information and the suppression of the task-irrelevant information existed in the control of conflict. In the present study, the N170 component was inversely modulated by the emotional conflict in experiment 1 and experiment 2. In experiment 1, the face was task-relevant information, and therefore enhancement of the face processing was necessary in the incongruent condition than in the congruent condition. In experiment 2, the face was task-irrelevant information, so that suppression of the face processing was also necessary in the

Table 1
Amplitude of averaged N170 component.

Task	Congruence	Hemisphere	P08/7	P8/7	P6/5
Emotional (face)	Congruent	R	−6.61 ± 0.86	−6.12 ± 0.60	−4.94 ± 0.98
		L	−4.13 ± 0.97	−4.03 ± 0.60	−2.89 ± 0.88
	Incongruent	R	−7.28 ± 0.84	−6.67 ± 0.64	−5.88 ± 0.82
		L	−4.75 ± 0.91	−4.44 ± 0.68	−3.18 ± 0.94
Emotional (word)	Congruent	R	−5.34 ± 0.77	−5.86 ± 0.67	−2.90 ± 0.42
		L	−4.36 ± 0.93	−3.53 ± 0.76	−1.59 ± 0.39
	Incongruent	R	−4.42 ± 0.71	−5.44 ± 0.67	−2.80 ± 0.44
		L	−3.79 ± 0.83	−3.17 ± 0.70	−1.33 ± 0.44

Mean ± SD values for amplitude of the N170 component measured at electrodes PO8/7, P8/7, P6/5.

incongruent condition than in the congruent condition. We propose that the enhancement of the task-relevant information and suppression of task-irrelevant information exists in the early control of emotional conflict (see Fig. 3).

Previous fMRI studies about emotional conflict generally found the dorsal ACC involved in the detection of emotional conflict and cognitive conflict [9]. ERP studies about cognitive conflict generally found the frontal-central N2 involved in the detection of cognitive conflict [25]. These aforementioned studies provided strong support for the influential conflict monitoring theory [7], which proposed the ACC detect the conflict and send the signal to the DLPFC for the enhanced control. The present results different from the previous studies by affording evidences indicated that emotional conflict occurs very early at perceptual processing stage. In fact, a recent study also found the Stroop conflict effect occurs at the early perceptual processing stage [6]. This previous study and the present results raised an interesting question that whether the detection of conflict can independent of the ACC.

The present study, demonstrated that emotional congruency between a face and a word modulate the N170 component of the ERP. The modulation of the N170 component suggests that enhancement of task-relevant information and suppression of task-irrelevant information begins at an early perceptual processing stage.

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