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EMOTIONAL CONFLICT OCCURS AT A LATE STAGE: EVIDENCE FROM THE PAIRED-PICTURE PARADIGM

Abstract

The present study used paired-picture paradigm, where either congruent or incongruent emotional expressions were presented side by side to measure the neural correlates underlying the processing of emotional conflict effect. Event-related potentials were recorded while participants identified whether the valences of the paired-picture were consistent or not. The results showed that incongruent and congruent picture pairs both elicited larger N2 (210-310 ms) amplitudes than neutral pairs. In contrast, the conflict picture pairs elicited a larger conflict slow potential (conflict SP, 700-1000 ms) than did the positive and neutral picture pairs. There was no significant difference in conflict SP amplitudes between incongruent and congruent picture pairs (i.e., the mean amplitudes of negative and positive picture pairs). The results demonstrated that emotional information was identified and processed during the stage from about 210 ms to 310 ms. However, the emotional conflict effect did not appear until late stage (700-1000 ms). These results supported the distributed attention theory of emotions (DATE).

Keywords

• Conflict slow potential • Emotional conflict effect • Event-related potentials (ERPs) • Paired-picture paradigm

1. Introduction

Previous studies have found that reaction time and accuracy are slower when the valence between the target and distractor is incongruent in the word-face Stroop task and the emotional Flanker task [1-4]. This is the so-called emotional conflict effect. A recent study, which used the word-face Stroop task had a word placed in the middle of a facial picture, found that emotionally incongruent trials (i.e., the valences of the word and face were opposite in each trial) evoked larger negative N170 amplitudes than emotionally congruent trials (i.e., the valences of the word and face were consistent with each other). This indicated that the emotional conflict effect occurred at an early stage [5]. Another study simultaneously exposed subjects to emotional faces and sounds, which were either congruent or incongruent in terms of their valences. The subjects were instructed to react to the auditory stimulus and ignore

the visual stimulus. The results showed that there was a mismatching negative wave (MMN) at 180 ms after the incongruent pair was presented [6]. A similar study instructed subjects to only be attentive to the visual stimulus and ignore the auditory stimulus. The results showed that the incongruent condition elicited larger N1 amplitudes compared to the congruent condition [7]. The above two studies demonstrated that emotional information from both visual and auditory channels were integrated automatically at an early stage, thereby causing the emotional conflict reaction. Moreover, the study using the emotional Flanker task also found that incongruent conditions yielded larger P200 amplitudes and longer latencies than congruent conditions [4].

However, other studies had different findings. For example, the studies on face recognition and expression judgments showed that the conflict identity feature of faces produced longer N270 latencies, while conflict expressions elicited a negative component (350 ms) and N400 at

the midline of the forehead [8, 9]. Schimack and colleagues found that the amplitude of the late-positive potential (LPP) produced by conflict picture pairs was significantly greater than the amplitude for neutral pairs, but there was no significant difference in the average amplitude between positive and negative picture pairs [10]. This indicated that the brain processed both positive and negative pictures at the same time, which induced an emotional conflict effect on the LPP component.

The stimulus processing included at least two stages of evaluation and response execution. The emotional conflict effect may be caused by inconsistent stimuli characteristics or semantic features, as well as competitive reactions activated by the incongruent stimuli. Even if the conflict effect occurred at the evaluation stage, it cannot be reflected in the reaction times, but appeared by means of response selection and execution. In the word-face Stroop task, words and faces were not consistent in stimuli characteristics, semantic

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features and valences. Perhaps, the emotional conflict effect at early stages was caused by the mismatch in stimuli characteristics or semantic features. Similar issues appeared in studies on visual and auditory emotional information integration [6, 7]. Besides the differences of stimuli features, the two sensory channels differed in electroencephalogram (EEG).

Therefore, the emotional conflict effect may be confused with the reactions caused by the stimuli feature differences in previous studies. Thus, it was difficult to determine whether the emotional conflict effect occurred at the evaluation or response execution stage. Moreover, subjects were asked to pay attention to the targets while ignoring the non-target stimuli in both word-face Stroop and emotional Flanker paradigms. Accordingly, attention resources focused on the targets and the processing to non-target stimuli was insufficient, which reduced the degree of emotional conflict effect.

To sum up, previous findings on emotional conflict effect were inconsistent with each other. They were probably confused by the feature differences of stimuli or the bias in attention distribution. In order to reduce the interference of these factors, this present study used the paired-picture paradigm in which either congruent or incongruent emotional expressions were presented side by side to measure the neural correlates underlying the processing of emotional conflict effect. The two pictures in each pair were from the same person, which greatly reduced the differences of facial features. Event-related potentials (ERPs) were recorded while participants were asked to pay attention to the paired-pictures equally and identify whether the valences of the pairs were consistent or not.

2. Methods

2.1. Participants

Twenty healthy undergraduate students (10 males, 10 females, with an average age of 21 years, ranging from 19 to 24) volunteered to participate in the study and gave prior written informed consent. All subjects were right-handed, had no mental illness, color blindness or color weakness, and had normal

or corrected-to-normal vision. Participants were required to complete the Spielberger Trait (State)-Anxiety Scale (STAI) ($M_{\text{state-anxiety}} = 28.91$, $SD = 4.79$; $M_{\text{trait-anxiety}} = 34.43$, $SD = 5.67$) before the formal experiment. According to the Chinese norms for the STAI, the anxiety levels of all participants were normal.

2.2 Materials

The stimuli consisted of 66 emotional faces (positive and negative) and 36 neutral faces selected from the Chinese Facial Affective Picture System (CFAPS) [11]. The pictures were black-and-white photographs, half of whom were females. Pictures were grouped into four categories (Fig. 1B): conflict pairs (PU: one picture was positive and the other was negative), positive pairs (PP: both pictures positive), negative pairs (UU: both pictures negative), and neutral pairs (NN: both pictures neutral). Conflict pairs used happy and sad expressions of the same person while congruent pairs consisted of two identical expressions. Based on these rules, we obtained 96 picture pairs (24 from each of the four above-defined categories). In order to reduce response set errors, another 24 picture pairs consisted of expressions from different people. These picture pairs were used as filler materials.

Both the experimental and filler materials were displayed randomly. The data on the filler materials were excluded from the statistical analysis.

The luminance and contrast ratio of pictures were unified by Photoshop software (Adobe Systems, San Jose, CA, USA), and the resolution of the images used was 260×300 pixels.

2.3 Task and procedure

The present study used the paired-picture paradigm, and the independent variable was the types of emotional picture pairs, which were of four different types: PU, PP, UU, and NN. Participants were asked to pay attention to the paired-pictures equally and identify whether the valences of the pairs were consistent or not. When the valences were consistent, subjects needed to press the button "1", and, if not, to press the button "2". The pressing order of buttons was counterbalanced across participants.

There was one practice block with 32 trials and four test-blocks including 480 trials. All stimuli were presented in a random manner. Subjects could take a 3 min rest for each block. The experimental procedure is illustrated in Fig. 1A. A white fixation cross was displayed in the middle of a screen with a black background color. The paired-pictures were symmetrically

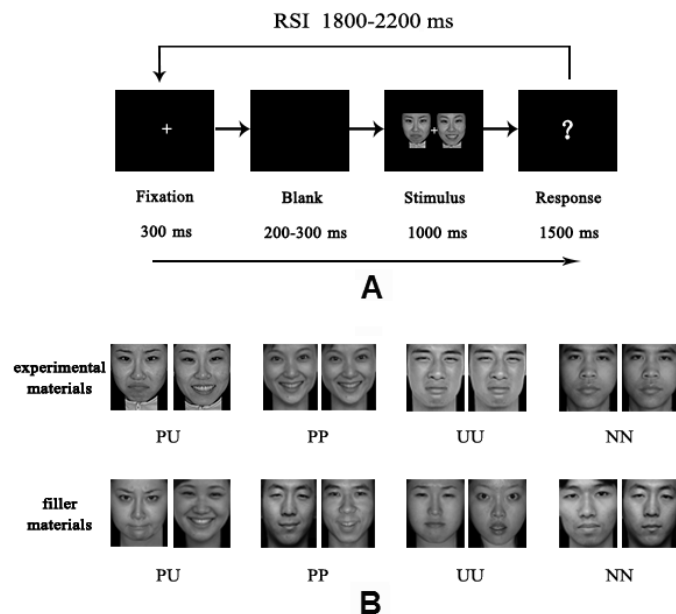


Figure 1. A. Experimental procedure, B. Examples of experimental materials and filler materials. RSI, response-stimulus interval.

located on both sides of the fixation point at a distance of 1 cm from the center [4.2 degrees (horizontal) $\times$ 4.8 degrees (vertical)]. Participants were required to keep their eyes on the fixation throughout the experiment and to control their blinking as much as possible to reduce errors from eye movement and blinking.

2.4 ERPs recording and analysis

2.4.1 EEG data recording

Electroencephalography was recorded via a 64-channel HydroCel Geodesic Sensor Net (Electrical Geodesics, Inc., Eugene, OR, USA) (20K standard increasing, band-pass filter 0.01-100 Hz), with the reference on Cz electrode and a ground electrode on COM. The sampling frequency was 500 Hz and all interelectrode impedances were kept below 5 K Ω . Horizontal electrooculography (HEOG) was recorded from the outer canthi of the eyes and vertical electrooculography (VEOG) was recorded medially at the upper and lower eye pits. EEG data was exported for off-line analysis using the NetStation software (Electrical Geodesics Inc., Eugene, OR, USA; low-pass = 40 Hz, translating Cz into the bilateral mastoid and automatically adjusting artifacts of eye movements and blinking).

2.4.2 EEG data analysis

ERPs waveforms were time-locked to the onset of each picture pair. The average epoch was 1200 ms, including 200 ms prestimulus baseline and 1000 ms post-stimulus time. Trials with incorrect responses and amplitudes exceeding ± 50 μ V were excluded from averaging.

We selected 19 electrodes for analysis of N2 and conflict SP, such as Fz, F3, F4, F7, F8, Fcz, Fc3, Fc4 (frontal area and the frontal zone), Cz, C3, C4, Cp1, Cp2 (central area and central parietal area), and Pz, P1, P2, Poz, Po3, Po4 (parietal area and parieto-occipital area).

An adaptive mean method was used to measure the average amplitudes of N2, where the peak negative amplitude between 210 ms and 310 ms was designated as a reference point and the average amplitudes were calculated from 15 ms prior to the peak to 15 ms after the peak. According to the previous studies, the conflict SP was quantified as the mean amplitude from 650 ms to 1000 ms post-stimulus presentation [12, 13].

A two-factor (picture-pair types and electrode sites) repeated-measures analysis of variance (ANOVA) was used to analyze the average amplitudes of N2 and conflict SP. The *P*-value was corrected for deviations in all the analyses, according to the Greenhouse-Geisser method.

3. Results

3.1 N2 amplitude analysis

The ANOVA revealed that paired-picture types had the main effect on the average N2 amplitudes, $F_{(3, 57)} = 3.66$, $\eta^2 = 0.16$, $P < 0.05$, and paired-comparisons showed that the N2 amplitudes in the PU ($M = 1.02$, $P < 0.05$) and UU ($M = 1.41$, $P < 0.05$) conditions were significantly greater than in the NN condition ($M = 0.08$) (Fig. 2). There were no other significant differences in N2 amplitudes in regard to other conditions ($P > 0.05$), except for the difference between PP ($M = 0.79$) and NN conditions, which was marginally significant ($P = 0.052$). The main effect of electrode sites was also significant, $F_{(18, 342)} = 5.07$, $\eta^2 = 0.21$, $P < 0.001$. The N2 was mainly distributed in the central area, and the amplitudes varied in the central and central parietal region, with a maximum amplitude in the central area. The interaction between paired-picture types and electrode sites was not significant, $F_{(54, 1026)} = 0.99$, $P > 0.05$.

3.2 Conflict SP amplitude analysis

The average amplitudes per every 50 ms were measured in the range from 650 ms to 1000 ms to analyze the effect on conflict SP. The main effects of paired-picture types on average amplitudes were found in all above-defined intervals, except in the 650-700 ms interval.

A similar trend from 700 ms to 1000 ms was shown on the mean amplitudes. So, we used a two-factor repeated-measures ANOVA to analyze the conflict SP in this time window, which showed a significant main effect of paired-picture types, $F_{(3, 57)} = 6.87$, $\eta^2 = 0.27$, $P < 0.001$ (Fig. 3). Multiple comparisons revealed that the difference between the PU ($M = 5.84$) and UU ($M = 6.19$) conditions were not significant ($P > 0.05$). However, the differences between the PU and PP ($M = 4.30$) or between the PU and NN ($M = 3.82$) were significant ($P < 0.05$). The average amplitudes of the incongruent condition (the PU) did not differ significantly from the congruent conditions (the mean of the PP and UU), $F_{(1, 19)} = 1.10$, $\eta^2 = 0.06$, $P > 0.05$ (Fig. 4). The main effect of electrode sites was significant on the conflict SP, $F_{(18, 342)} = 5.47$, $\eta^2 = 0.22$, $P < 0.001$, which was mainly distributed in the forehead and central parietal areas.

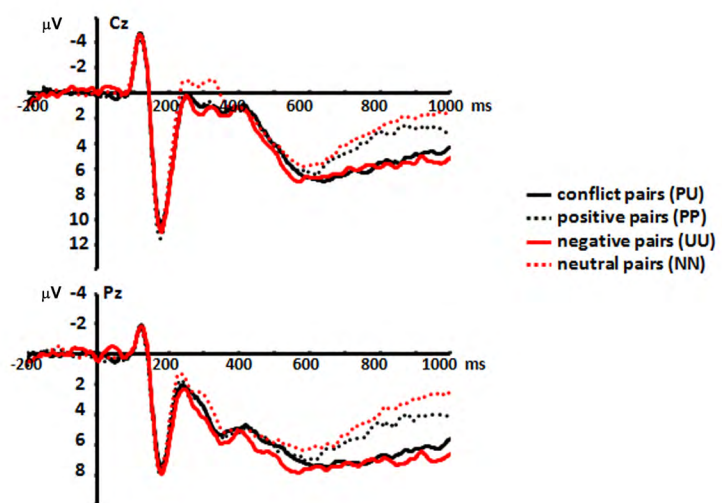


Figure 2. N2 waveform between the three types of picture-pairs and the neutral pairs.

Table 1. Results of the analyses of the differences in the average potentials of the conflict slow potential during different time windows.

Time windows (ms)	Main effect of paired-picture		Paired picture x Electric sites	
	F _(3,57)	P	F _(54,1026)	P
650-700	2.31	0.086	0.76	0.894
700-750	4.32	0.008	0.97	0.539
750-800	6.28	0.001	1.19	0.169
800-850	6.51	0.001	1.40	0.032
850-900	9.01	0.000	1.39	0.036
900-950	8.02	0.000	1.19	0.171
950-1000	8.18	0.000	1.39	0.036

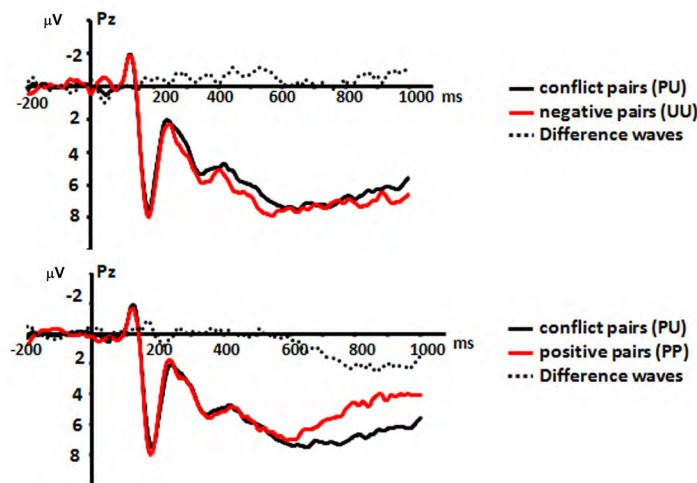


Figure 3. Difference waves of the conflict pairs, negative pairs, and positive pairs, on average potentials.

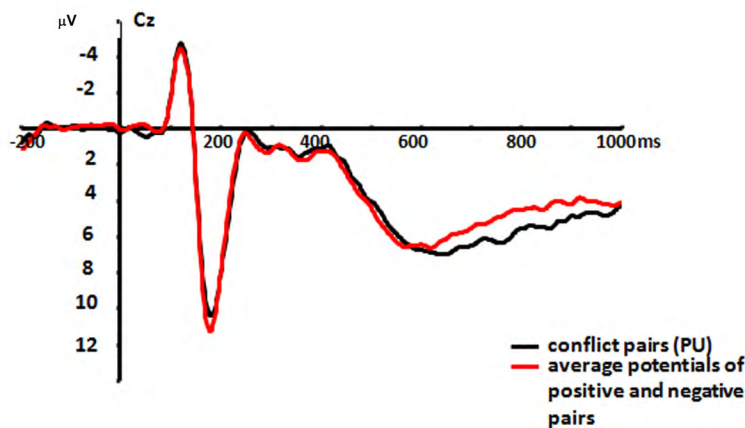


Figure 4. Comparisons between the average potentials of the negative and positive pairs and the conflict pairs.

4. Discussion

The present study found a significant emotional effect in the paired-picture paradigm, which was observed mainly in the N2. The emotional conflict effect was mainly shown in the conflict SP, which was adjusted by attention.

An obvious negative peak (the N2) was elicited in about 230 ms. The results of this study revealed significant differences in average amplitudes between neutral pairs and conflict or negative pairs. The difference between positive and neutral pairs was marginally significant. There was emotional information in the conflict, positive, and negative pairs. The neutral pairs provided evidence for the emotional effects. Previous studies found that the EEG patterns in this stage were affected by the stimulus characteristics and internal attention regulation at the same time. The selection role of attention may occur at this stage [14]. The differences in N2 amplitude between the neutral pairs and the three pairs of emotional pictures in this present study demonstrated that the emotional information was identified and processed at this stage.

There was a positive peak from 700 ms to 1000 ms, which was the typical conflict SP according to previous studies [12, 13]. Conflict SP was distributed in the central-parietal and parietal-occipital areas, and mainly reflected cognitive control and regulation. In this present study, the conflict SP was an index of the positive and negative emotional reactions. The results showed that four types of picture pairs significantly differed from 700 ms to 1000 ms, and this effect remained stable throughout the late stage. Further analysis indicated that the average amplitudes of the conflict pairs were significantly larger than those of the positive pairs, but not different from the negative pairs. As one of the two pictures in conflict pairs was positive and the other was negative, whereas the valences of the two pictures in negative pairs were all negative, the difference between the conflict and negative pairs was mainly produced by the interference of the positive picture in conflict pairs. Similarly, the difference between the conflict and positive pairs mainly reflected the moderating effect of the negative picture in conflict pairs. The difference wave

between conflict and negative pairs was not apparent, which indicated that the interference of positive stimulus was not significant. However, the difference wave between the conflict and positive pairs was significant, which showed that the interference caused by negative stimulus was relatively larger. These results have been consistent with previous studies that used the emotional Flanker paradigm. When positive stimulus was used as a distractor, amplitudes of P200 decreased, whereas the amplitudes increased when the distractor was replaced by a negative stimulus. These findings suggested that the interference of negative stimuli was more apparent, and induced a greater emotional conflict effect [3, 4]. Negative stimuli were more likely to attract attention resources, which could elicit a greater conflict effect when they acted as distractors [15].

It was generally recognized that the late positive components (P3, LPC, and conflict SP) were the main physiological indexes of emotion recognition and experience. They reflected an endogenous top-down emotional processing and the accommodation of attention regulation and cognitive control to emotional stimuli [16]. In the present study, the amplitudes of conflict SP on conflict pairs were significantly larger than those on neutral pairs, which indicated that evident emotional reactions were induced. Meanwhile, there had been no significant differences found between the amplitudes of conflict pairs and the mean amplitudes of positive and negative pairs, which suggested that the intensity of emotional experience elicited by conflict pairs was almost equivalent to half of the sum intensity of the experience induced by positive and negative pairs, respectively [17].

The “mutual exclusivity” concept of response to positive and negative emotions has suggested that positive and negative

emotions are mutually exclusive in experience: “When you are happy, it is absolutely impossible for you to be sad and vice versa” [18]. When both emotions appear at the same time, they may cancel each other out. So, according to that concept, the experience of conflict emotion cannot exist. The “complete independence” concept of positive and negative emotions has indicated that the processing of positive and negative emotions occur independently and do not interfere with each other. Therefore, conflict emotion would be induced as long as the conflict emotional stimuli exists, and the intensity of the conflict emotion will be equal to the sum of the positive and negative emotions, but stronger than any single emotion [19]. The distributed attention theory of emotion (DATE) has proposed that conflict emotional experience depended on attention and that the attention resources could be adjusted and distributed among different objects. According to that concept, if an emotional stimulus receives more attention resources, it would induce a stronger experience [10]. The intensity of the conflict experience is directly determined by the distribution of attention resources. If the positive and negative emotions cancel each other out, the emotional experience induced by conflict emotions is inevitably weaker than that induced by a single positive or negative emotion, or there may not even be any experience. On the other hand, if the positive and negative emotions were completely independent, the emotional experience caused by conflict stimuli is inevitably larger than that induced by a single positive or negative stimulus. The results of the present study showed that the processing of conflict pairs induced obvious emotional reactions and that positive and negative emotions did not cancel each other out, instead, they co-existed. In addition, we showed that

the intensity of emotional conflict reaction was adjusted and controlled by attention resources. This was manifested by the fact that the amplitudes of conflict pairs were similar to the means of positive and negative pairs. Altogether, these results have been consistent with an ERP study of conflict emotions, which was previously conducted by Schimmack *et al.* [10]. Furthermore, these results were mostly in accordance to the DATE concept.

In summary, the present study investigated the time-course and the neural correlates underlying the processing of emotional conflict effect. After reducing the differences in stimulus features, the emotional conflict effect did not appear in the early stage, but rather in the late stage, which suggested that the emotional conflict effect found on N1 [7], N170 [5], or P200 [4] in previous studies was more likely to be induced by the differences of stimuli features. It has been generally acknowledged that emotional experience is mainly reflected by the late positive components. The results obtained in this study indicated that the emotional conflict effect was probably occurring in response to emotional experience, which has been in accord with the results of many studies on mixed emotions [20-26].

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