Conflict adaptation in the perception of emotional valence in a Stroop task*

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Abstract Interference effects are commonly observed when conflicts arise between task-relevant and task-irrelevant dimensions of stimuli. Compared with responses to congruent trials in which the two dimensions are compatible, responses to incongruent trials are usually slower and less accurate. Moreover, the performance in a given trial is affected by the nature of the preceding trial, in that the interference effect for the current incongruent trial is reduced when it follows an incongruent trial than when it follows a congruent one. This conflict adaptation effect has been generally ascribed to the functioning of the cognitive control system, in which higher controls are recruited after conflicts to further constrain the processing of the task-irrelevant dimension. However, due to its uniqueness in neural and cognitive processes, whether the perception of emotional valence shows the same conflict adaptation effect in the conflicting context is an open question. This study adopted a variant of the Stroop task in which the task-relevant dimension was the affective facial expression while the task-irrelevant dimension was the meaning of an emotional word superimposed on the face. Results suggest that the perception of emotional valence in the conflicting context can have aspects that are both similar and dissimilar to the control of conflict for non-emotional information. The capturing of attention by emotional information can alter the functioning of the cognitive control system.

Keywords: emotional processing, conflict adaptation, Stroop effect.

The interference effect in a conflict task (e. g. the Stroop task, the flanker task, or the Simon task) refers to longer reaction times (RTs) and lower accuracies in response to incongruent trials than to congruent trials. The task-relevant and task-irrelevant dimensions of stimuli in these trials could be either compatible, having the same perceptual representations and/or corresponding to the same response codes, or incompatible, having different perceptual representations and/or corresponding to different response codes. For example, in the classical Stroop task[1], the participant of the experiment is instructed to name the color used to write a color words (e. g., red, green, or blue). This color could be same as the meaning of the word (e. g., using red ink to write "RED") or different from the meaning of the word (e. g., using blue ink to write "RED"). The interference effect is observed for the incongruent trials, as compared with the congruent trials. This effect results from the inappropriate processing of the task irrelevant information, as many cognitive and neuroscientific studies have demonstrated.

As humans are highly adaptive in resolving conflicts and making adjustment to their cognitive processes and behavioral performance, it is interesting to note that the participants of studies show larger or smaller interference effects for the current trials, depending on whether the preceding trials are congruent or incongruent. Such sequential conflict adaptation effect has been observed in a number of conflict tasks, including the Flanker task[2] and variants of the Stroop task[3,4]. Typically, the performance is better on incongruent trials immediately following other incongruent trials than on those following congruent ones. Moreover, the performance is better on congruent trials immediately following congruent ones than on those following incongruent ones.

These findings are accounted for by the conflict control hypothesis which assumes that these behavioral adjustments are the consequences of the stronger conflict between the task-relevant and task-irrelevant dimensions in the preceding incongruent trials. The processing of these dimensions in a preceding trial leads to the conflict being detected by the cognitive control system. The system has to function fully to suppress the impact of the task-irrelevant dimension and resolve the conflict. This suppression of the conflicting task-irrelevant dimension could extend to the

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current conflicting trial, reducing the cost of inhibiting this dimension in the subsequent trial, if this trial is also an incongruent one. The reduction of competition between the task-relevant and task-irrelevant dimensions hence leads to a reduced interference effect for the current incongruent trial. On the other hand, the inhibition of the task-irrelevant dimension in the previous trial could extend to the current congruent trial, reducing the beneficial impact of this dimension on the processing of the task-relevant dimension. Thus compared with the situation in which the current congruent trial is preceded by a incongruent one, the response to the current trial is delayed.

All the previous studies on the sequential adaptation effect were conducted with stimuli that have no emotional components. It is not clear whether such adaptation could also be found when the task-relevant and task-irrelevant dimensions are affective. Many cognitive and neurophysiological studies have demonstrated that the processing of emotional information, unlike the processing of non-emotional information such as color, shape or object identity, is much less affected by the availability of attentional resources and awareness[5,6]. For example, it was found that the processing of facial expressions is not affected by the manipulation of perceptual load and hence attentional resources[7]. The neural substrates of emotional processing, including amygdala, superior colliculus and thalamus[8], are activated when the fearful facial expression is presented subliminally, using techniques such as backward-masking[5,9]. If the processing of emotional information, whether it is task-relevant or task-irrelevant, is not or much less constrained by the availability of attentional resources, one might predict that the suppression of the task-irrelevant emotion in a previous trial could be easily recovered, hence causing no long-lasting impact upon the processing of the current trial. The sequential adaptation effect should not then be observed. On the other hand, if the processing of task-relevant and task-irrelevant emotional information is subjected to the same constraints of the cognitive control system, we should then observe the same pattern of sequential adaptation on emotional stimuli.

To test these predictions, we employed a variant of the Stroop task but with both the task-relevant and the task-irrelevant dimension that varied along the emotional valence. An affective picture of a face could show the expression of either happy or angry while a Chinese two-character compound word on the face could express the same or incongruent emotion, resulting in congruent and incongruent trials. The participant of the study was asked to judge, by pressing a response key, whether the facial expression was happy or angry while ignoring the emotional word. Given that lexical processing is rather automatic and possibly more efficient than the processing of facial expression, we expected to find the congruency (Stroop) effect between congruent and incongruent trials. The crucial empirical question was whether a sequential adaptation effect could be found for such stimuli.

1 Method

1.1 Participants

Participants were 12 right-handed native Chinese-speaking volunteers (5 female) with normal or corrected-to-normal vision (mean age = 24-years-old, with a range between 22 and 25). They had been screened to exclude people with previous or current neurological or psychiatric conditions, current medication use, colorblindness, and dyslexia. An written informed consent was obtained from each participant in accordance with the institutional guidelines.

1.2 Design and procedures

The experiment used a 2×2 design in which the first factor was the emotional valence of the facial expression (happy vs. angry), while the second factor was the congruency between the facial expression and the emotional word, which could be either happy or angry. In analyzing the sequential adaptation effect, we collapsed the happy and angry expressions and divided the trials into congruent and incongruent ones. These trials were classified into the previous and the current trials, and the sequential relations between the previous and the current trials were then categorized and labeled. This formed 4 types of relations: congruent-congruent, congruent-incongruent, incongruent-congruent, and incongruent-incongruent. Each participant received a particular randomized sequence of stimuli, but the computer program ensured that there were roughly equal numbers of trial pairs for the 4 types of relations.

There were 40 happy and 40 angry pictures of affective faces, with 20 each of male and female faces in each category. These pictures were standard-

ized[10]. In addition, there were 20 happy and 20 angry emotional words. All these words were two-character compound words, with equivalent mean frequencies for the two categories.

The whole experiment had 160 trials of stimuli which were divided into two blocks, each with 80 trials. For congruent-congruent and incongruent-incongruent trials, the faces and the emotional words were not repeated over the pairs. A practice section containing 20 trials was administered before the formal experiment.

For each trial, a fixation sign ("+") was presented at the center of screen for 1000 ms, followed by a stimulus (i.e., an affective face with a word superimposed in the center of the face) for 2000 ms. An interval of 1000 ms was scheduled between the consecutive trails. Participants were instructed to respond to the valence of the facial expression (happy or angry) by pressing a button (P or Q on the keyboard) with the index finger of their left or right hand. The assignment of the key to the emotional valence of the face was counterbalanced over the participants.

2 Results

Two participants were excluded from data analysis because of their excessive response errors (over 15%). Erroneous trials in the remaining participants' data were also deleted. We first conducted overall data analyses for RTs and accuracies of response, with emotional valence and congruency as the two factors. The overall mean RTs for the four conditions were calculated by averaging over each participant's the median RTs in conditions. Mean RTs and accuracies are presented in Table 1.

Table 1. RTs and response accuracies in the four experiment conditions for the overall data analysis

Trial	RT (ms)	SD	Accuracy (%)	SD
Angry_Con	776	71	96.7	4.0
Angry_Incon	828	79	91.0	6.0
Happy_Con	629	67	95.7	3.7
Happy_Incon	688	90	92.5	5.0

RTs and accuracy percentages were analyzed in 2 (facial expression valance: angry vs. happy) * 2 (congruency between face and word: incongruent vs. congruent) ANOVAs. For the RT data, there were significant main effects of both congruency, $F(1,9) = 27.39$, $p < 0.001$, and facial expression, $F(1,9) = 28.22$, $p < 0.001$. Responses were slower to the incongruent trials (758 ms) than to the congruent trials (702 ms), and were slower to the angry faces (802 ms) than to the happy faces (658 ms). There was no interaction between the two factors. For the accuracy data, only the main effect of congruency was observed, $F(1,9) = 14.5$, $p < 0.005$, with more accurate response to the congruent trials than to the incongruent trials.

To examine the sequential adaptation effect, 2 (congruency of the preceding trial: congruent vs. incongruent) × 2 (congruency of the current trial: congruent vs. incongruent) ANOVAs were conducted for the RT and accuracy data (see Table 2). For RTs, the main effects of the congruency of the preceding trial was significant, $F(1,9) = 8.35$, $p < 0.05$; so as the main effect of the congruency of the current trial, $F(1,9) = 7.69$, $p < 0.05$. Importantly, there was a significant interaction between the two congruencies, $F(2,9) = 7.44$, $p < 0.05$. Further tests showed that while RTs to the incongruent trials did not show difference (1 ms) when they followed congruent or incongruent trials, $t(9) < 1$, RTs to the congruent trials were significantly slower (81 ms) when these trials followed incongruent ones than when they followed congruent ones, $t(9) = 3.50$, $p < 0.005$.

Table 2. RTs and response accuracies for the current trials as a function of the relationship between the preceding and the current trials

Preceding-Current	RT (ms)	SD	Accuracy (%)	SD
Con_Con	695	48.4	96.5	3.2
Con_Incon	765	87.5	93.4	5.1
Incon_Con	776	98.7	96.0	3.9
Incon_Incon	764	61.7	91.2	5.6

3 Discussion

As predicted, a significant interference effect was observed for the incongruent trials as compared with the congruent ones in this variant of Stroop task, suggesting that the task-irrelevant emotional words were automatically processed and the activation of lexical meanings interfered with the processing of the task-relevant facial expressions. More importantly, we observed a sequential adaptation effect for the processing of emotional information in the conflicting context, with slower responses to congruent trials following incongruent ones than following congruent

ones. Unlike the case in conflict tasks involving non-emotional stimuli, however, responses to the incongruent trials did not show the typical conflict adaptation effect.

The conflict adaptation effect for the congruent trials can be explained in the same way as for the effect for non-emotional stimuli. The suppression of the task-irrelevant dimension in processing the preceding trial lasts a relatively long period of time and this affects the processing of the task-irrelevant dimension (i.e., emotional words) of the current congruent trial. The inhibition of this task-irrelevant dimension reduces the dimension's beneficial impact upon the processing of the task-relevant dimension (i.e., the facial expression), which is congruent with this dimension. The response to the current trial is hence delayed. In contrast, when the preceding trial is a congruent one, no such inhibition of the task-irrelevant dimension would take place.

The surprising finding of the null effect for the current incongruent trials demonstrates the uniqueness of emotional information in capturing attention. We suggest that the task-irrelevant dimension is more likely to capture attention when it is incongruent with the task-relevant dimension than when it is congruent with the latter dimension. An emotional word inconsistent with the current task set may simply "pop out" and capture attention, as many previous studies have been demonstrated[5,8]. Thus the processing of this dimension is not influenced by whether this dimension has been inhibited in the preceding trial, and the processing of this task-irrelevant dimension interferes with the processing of the task-relevant dimension in the current trial anyway.

To conclude, by using a variant of the Stroop task with emotional valence, we demonstrate that the sequential adaptation in conflict control can have both similar and dissimilar aspects between the processing of emotional and non-emotional information in the conflicting context. The capturing of attention by emotional information can alter the functioning of the cognitive control system.

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