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Research article

Influence of inhibitory tagging (IT) on emotional and cognitive conflict processing: Evidence from event-related potentials

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HIGHLIGHTS

- We simultaneously investigated the modulation of inhibitory tagging (IT) on emotional and cognitive conflict.
- The conflict effects of emotional and cognitive conflicts were equally reduced at the cued location.
- The effect of N450 in both emotional and cognitive conflicts was absent at the cued location.
- The N1 wave was more negative for the emotional task than for the cognitive task.

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ABSTRACT

Inhibitory tagging (IT), a flexible central control mechanism based on the current task goals, reduces the cognitive conflict effect at the cued location by blocking the incompatible stimulus-response (S-R) code. However, it is unknown whether IT has a similar effect on emotional conflict. Thus, we combined the face-word Stroop task with the manipulation of inhibition of return (IOR) and used event-related potential (ERP) technology to simultaneously examine the modulation effect of IT on emotional and cognitive conflict processing. At the cued location, we found that the two types of conflict effect were significantly reduced and that the conflict processing-related N450 effect was absent. Our data further revealed that IT had similar effects on emotional and cognitive conflict processing. Although a negative difference wave (Nd) was found in the time window of 160 and 220 ms, which may reflect the impaired early perceptual processing of the target at the cued location, the effect of Nd was not affected by stimulus congruency. These results illustrate that the cueing effect of conflict processing does not arise from the early stage of perceptual processing, but rather results from the blocked S-R code of the distractors due to IT functioning during the later stage of processing.

1. Introduction

In the classical cue-target paradigm [20], response times (RTs) to targets appearing at the cued (inhibited) location are typically longer than RTs to targets appearing at the uncued location if the cue-target stimulus onset asynchrony (SOA) exceeds 300 ms. This phenomenon is labelled inhibition of return (IOR) and is generally thought to promote visual search efficiency by preventing attention from reverting to the recently inspected location [13,20].

Some theories contend that IOR is associated with the impaired early perceptual processing due to limited attentional resources [12,13,15], as this limitation causes delayed responses to targets at the cued location. To further understand the impact of IOR and to determine the stage in which information processing IOR occurs, several studies have combined the Stroop and Flanker tasks with an IOR procedure and have found that the interference effect was reduced or eliminated when conflicting information surfaced at the cued location [2,17–19]. The reduced conflict effect at the inhibited location is unlikely to be explained by the theory of attentional or early perceptual inhibition given that the perceptual processing of interference and task-relevant stimuli is equally inhibited at the cued location according to the theory [12,22]. In such a case, the conflict effect at the cued location should be similar to the effect at the uncued location.

Therefore, a complementary mechanism of IOR, inhibitory tagging (IT), was proposed [5,18]. IT is associated with the executive network of attention and is relatively independent of attentional orienting or early perceptual inhibition [7,19]. As such, IT is a flexible central control mechanism that is based on the current task goals [18], and it functions by preventing the perceptual represen-

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tation of the distractor to access its response code when conflicting information appears at the cued location. As a result, the response conflict between the task-relevant stimuli and the distractors is reduced, ultimately causing the reduced or eliminated interference effect at the cued location. Furthermore, the anterior cingulate cortex (ACC) and the lateral prefrontal cortex (LPFC) are thought to be involved in the interaction between IT and conflict processing [7,22].

It has been well documented that IT promotes cognitive conflict control [2,6,18,19], e.g., reduced color-word Stroop interference at the cued location. However, it remains unknown whether the emotional conflict can be reduced or eliminated by IT. Further, if IT precisely affects emotional conflict processing, the question, then, is whether the modulation effect of IT on emotional conflict varies from the influence of IT on cognitive conflict. Hence, the purpose of this study was to simultaneously investigate the time-course of the modulation effect of IT on emotional and cognitive conflict processing by combining a modified Stroop task with an IOR procedure.

Although some studies assume that IT may act during the late stage of the processing of information [17,18], little attention has focused on the time-course marker of this neural process. To our knowledge, only one study combined the color-word Stroop task with the manipulation of IOR and directly investigated the event-related potential (ERP) correlates of the cueing effect of cognitive conflict processing [23]. At the behavioural level, this one study found a reduced conflict effect at the cued location. Furthermore, although the conflict monitoring-related late ERP component N450 yield by conflicting trials was greater than the yield of congruent trials at the uncued location, the congruence effect of N450 disappeared when stimuli appeared at the cued location, thus suggesting that N450 can be used as an index for the modulation of IT on cognitive conflict processing.

Although previous studies have found that the control mechanisms of emotional conflict and cognitive conflict are dissociable [1,3], these mechanisms may share a common conflict-monitoring mechanism related to the ACC [3]. Previous ERP studies, using a face-word Stroop task, have simultaneously investigated the neutral correlates of the emotional and cognitive conflicts [16,21]. Their results consistently revealed that the conflict monitoring-related N450 for the conflicting stimuli was more negative than it was for the congruent stimuli in both types of conflict, supporting the view that emotional conflict and cognitive conflict share a common conflict-monitoring mechanism. Whereas the cueing effect of N450 can interpret the reduced cognitive conflict effect at the cued location using IT [23], a similar congruence effect of N450 can be found also in both emotional and cognitive conflict tasks. Thus, we infer that the regulation of IT on emotional conflict may also be reflected on N450.

The present study employed the face-word Stroop task, which has been widely used to simultaneously examine emotional and cognitive conflicts [3,21]. In this task, emotional words or gender words are superimposed across facial expressions. In the cognitive conflict version, participants were required to ignore the gender word and judge the gender of the facial expression, whereas in the emotional conflict version, participants were required to ignore the emotional word and identify the facial expression.

Taken together, the conflict monitoring-related N450 served as a neural marker for the modulation of IT on cognitive conflict, while at the same time, a similar N450 effect was observed in both the emotional and cognitive conflict versions of the face-word Stroop task. Therefore, in the current study, we used the N450 as an indicator to simultaneously investigate the modulation effect of IT on emotional and cognitive conflict processing through a combination of an IOR procedure and the face-word Stroop task. Based on previous studies, we assumed that if IT is as capable of regulating emotional conflict processing as it is regulating cognitive conflict processing, then at the behavioural level, the conflict effect of these two types of conflict would be significantly reduced at the cued location. IT functions during the later stage of processing and promotes conflict processing at the cued location by disconnecting the stimulus-response (S-R) code of distractors. Based on this point, then at the neural level, the interaction between conflict processing and the cueing effect should not be reflected on the ERP components that are associated with early perceptual processing, e.g., N1. Rather, it would be reflected on the conflict monitoring-related N450. Specifically, the congruence effect of N450 would be observed at the uncued location but not at the cued location.

2. Methods

2.1. Participants

Forty-one healthy right-handed college students volunteered to participate in this study and were paid approximately $8 for their participation. Twenty-one participants (10 males, 11 females; average age 21.8 years; age range 19–25 years) performed the emotional task, and 20 participants (9 males, 11 females; average age 22.1 years; age range 20–25 years) performed the cognitive task. All participants provided informed written consent, and the study was approved by the Ethical Committee of Shanghai Normal University. All participants had normal or corrected-to-normal vision.

2.2. Stimuli and procedure

Twenty-four pictures of fear expressions (12 female, 12 male) and 24 pictures of happy expressions (12 female, 12 male) were obtained from the native Chinese Facial Affective Picture System (CFAPS) [8] and served as the target stimuli. The pictures were similar in size, brightness, contrast grade, and other physical properties. Each facial picture was used as a target for either the emotional conflict task (facial expression recognition) or the cognitive conflict task (gender judgment). In the emotional conflict task, two Chinese characters, 愉快 (happy) and 恐惧 (fear), were superimposed across the faces in red. The words and facial expressions were either congruent, i.e., character meaning happy superimposed onto a happy face picture, or incongruent, i.e., character meaning happy superimposed onto a fear face picture. In the cognitive conflict task, two Chinese characters, 男士 (male) and 女士 (female), were superimposed across the faces in red. The words and facial expressions were either congruent, i.e., character meaning female superimposed onto a female face picture, or incongruent, i.e., character meaning female superimposed onto a male face picture. Under each task condition, all faces and characters combined to form 96 compound pictures. The pictures covered a visual angle of approximately $5.7^\circ \times 6.1^\circ$ at a viewing distance of approximately 65 cm. All pictures were programmed by E-prime 2.0 (Psychology Software Tools Inc., Pittsburgh, USA) and were presented on a Lenovo 17-in monitor.

Upon arrival at the laboratory, which was quiet and dimly lit, the participants were familiarized with the standard spatial cueing procedure [15]. The procedure for each trial was as follows (Fig. 1). At the beginning of each trial, a central fixation cross accompanied by two black empty squares (each $8.4^\circ \times 6.6^\circ$) appeared, one on the left side and one on the right side, for 750 ms. The distance from the centre of each square to the central fixation cross was 8.4°. The cues, a hollow black $4.4^\circ \times 6.2^\circ$ ellipse, were displayed for 200 ms in one of the two frames, with equal probability. After an interval of 50 ms, during which the fixation cross was displayed, the fixation cross was replaced by a black dot for 150 ms (the central cue). The fixation cross was then randomly presented for 100–500 ms, followed by the target, which appeared for 1000 ms either at the cued or the uncued location with equal probability.