



Cognitive conflict increases processing of negative, task-irrelevant stimuli



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ABSTRACT

The detection of cognitive conflict is thought to trigger adjustments in executive control. It has been recently shown that cognitive conflict increases processing of stimuli that are relevant to the ongoing task and that these modulations are exerted by the dorsolateral prefrontal cortex (DLPFC). However, it is still unclear whether such control influences are unspecific and might also affect the processing of task-irrelevant stimuli.

The aim of the study was to examine if cognitive conflict affects processing of neutral and negative, task-irrelevant pictures. Participants responded to congruent (non-conflict) or to incongruent (conflict-eliciting) trials of a modified flanker task. Each response was followed by a presentation of a neutral or negative picture. The late positive potential (LPP) in response to picture presentation was used to assess the level of picture processing after conflict vs non-conflict trials. Connectivity between the DLPFC and attentional and perceptual areas during picture presentation was analysed to check if the DLPFC might be a source of these modulations.

ERP results showed an effect of cognitive conflict only on processing of negative pictures: LPP in response to negative pictures was increased after conflict trials, whereas LPP in response to neutral pictures remained unchanged. Cortical connectivity analysis showed that conflict trials intensified information flow from the DLPFC towards attentional and perceptual regions.

Results suggest that cognitive conflict increases processing of task-irrelevant stimuli; however, they must display high biological salience. Increase in cognitive control exerted by the DLPFC over attentional and perceptual regions is a probable mechanism of the effect.

1. Introduction

Every time we encounter a difficult situation, we might subsequently be more careful. Research has shown that encountering a cognitive conflict boosts control processes by increasing processing of information relevant to the ongoing task. Little is known, however, if such control influences may also affect processing of task-irrelevant information. The present study, which is based on ERP and effective connectivity methods, examines how cognitive conflict evoked by the flanker task influences processing of neutral and negative, task-irrelevant pictures.

1.1. Cognitive conflict and cognitive control

Cognitive control is the ability to guide thoughts and actions in accord with internal intention, even in the face of interfering stimulation or conflicting response tendencies. In laboratory settings, cognitive control is studied with the use of conflict-inducing tasks that activate two opposing response options at the same time (Botvinick et al., 2001). For example, in the Eriksen flanker task subjects are instructed to

respond to the direction of the central stimulus surrounded by flankers (Eriksen and Eriksen, 1974). A version of this task uses arrows as stimuli: a single trial consists of 5 horizontally arrayed arrows simultaneously presented on the screen. Participants respond according to the direction of the centrally located arrow (task-relevant target), while ignoring the direction of the four flanking arrows (task-irrelevant flankers). The flankers either point in the same direction as the target (e.g., > > > > > : the congruent condition), or in the opposite direction (e.g., > > < > > : the incongruent condition).

Subjects respond more slowly to incongruent trials than to congruent trials; this is considered a behavioural indicator of a cognitive conflict. However, on trials following conflicting ones, flanker interference is reduced, thus indicating that cognitive control is enhanced just after facing a conflict. According to the conflict monitoring theory, detection of conflict recruits additional resources to increase processing of upcoming incongruent trials (Botvinick et al., 2001, 2004; Carter and van Veen, 2007). Consequently, subjects are faster on incongruent trials that follow incongruent trials than those that follow congruent trials. This phenomenon is known as conflict adaptation (Gratton et al., 1992).

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1.2. Brain mechanism of conflict adaptation

The conflict monitoring theory proposes that the brain recruits a specific mechanism to recognize the conflict and to mitigate its consequences. This mechanism, known as the conflict-control loop, involves two brain structures: the anterior cingulate cortex (ACC) and the dorsolateral prefrontal cortex (DLPFC) (Carter and van Veen, 2007). ACC recognizes the conflict triggered by incongruent trial and signals the need for increased control to the dorsolateral prefrontal cortex (DLPFC). The DLPFC, in turn, exerts increased cognitive control in subsequent trials by biasing attentional systems to processes task-relevant stimuli more deeply (Banich, 2009; Egner and Hirsch, 2005).

Conflict-related activity of the ACC might be measured by evoked response potentials (ERP). Specifically, the amplitude of the ERP N2 component is larger (more negative) on incongruent trials than congruent trials (Ullsperger et al., 2005). The component has a fronto-central distribution and peaks approximately 200–400 ms after stimuli presentation (Yeung et al., 2004). The N2 component reflects not only the degree of evoked cognitive conflict, but also serves as an index of conflict adaptation. As compared to an incongruent trial preceded by a congruent trial (cI trials), numerous flanker task studies using ERP methodology have shown that two consecutive incongruent trials (iI trials) display decreased N2 amplitude and increased performance (e.g. Clayson and Larson, 2011; Freitas et al., 2009; Larson et al., 2013, 2015, 2012a, 2012b). In fact, N2 amplitude decreases across up to four consecutive incongruent trials, suggesting decreased conflict and increased cognitive control after processing of conflict trials (Clayson and Larson, 2011). N2 amplitudes also tend to be larger on cC trials in comparison to iC trials due to reduced control influences after a non-conflict trial; however, this effect is subtle and not always present (Clawson et al., 2013; Clayson and Larson, 2012; Larson et al., 2012a). One might also observe an effect of switching between trial congruency: response to a congruent trial preceded by an incongruent trial (iC) is slower and less accurate than for congruent trials preceded by another congruent trial (cC) (Egner, 2007). The N2 adaptation effect has been also proved to be a reliable, stable, and dependable measure with test-retest stability over a two week period (Clayson and Larson, 2013).

In the present study, we focus mostly on the effect of the iI trials vs cI as they most accurately reflect increased cognitive control (Larson et al., 2014). Importantly, despite some doubts about the nature of the conflict adaptation, recent studies have provided convincing evidence that conflict adaptation reflects the increase in cognitive control predicted by conflict monitoring theory; it does not only reflect a repetition of the incongruent stimuli (effects of repetition priming) (Duthoo et al., 2014; Freitas and Clark, 2015; Larson et al., 2016). Taken together, N2 reliably represents conflict-related activity of the ACC and conflict adaptation effects.

The second structure related to dealing with cognitive conflict is the DLPFC. The exact downstream mechanism of the cognitive control exerted by the DLPFC is still a matter of debate; however, evidence from both EEG and fMRI studies point to increased selective attention towards task-relevant stimuli after a conflict trial. Yeung et al. (Yeung and Cohen, 2006; Yeung et al., 2007) suggest that the N2 component is sensitive to the extent to which participants attend to task-irrelevant stimuli compared to task-relevant targets; the more attention paid to task-irrelevant flankers, the greater the N2 component. Thus, the authors propose that decreased N2 over consecutive incongruent trials reflects shifting attention from task-irrelevant distracters to task-relevant targets.

Other EEG studies based on the flanker task and using N1/P1 visual evoked potentials (VEPs) (Nigbur et al., 2015; Scerif et al., 2006) generally confirm increased attention towards task-relevant stimuli after a conflict. For example, the study by Nigbur et al. (2015) used the N1 component in response to task-irrelevant and task-relevant information and showed that enhanced processing of the target underlies conflict adaptation. Moreover, the study concluded that the N1

enhancement reflects top-down sensitisation of attention towards processing of the task-relevant stimuli. In other words, after a conflict trial, the attentional system is sensitised for detecting task-relevant stimuli and responds more strongly, with effects being visible immediately after the appearance of task-relevant information.

Similar results were achieved in fMRI studies. They have shown that the activity of the DLPFC modulates target elaboration by upregulating the regions associated with processing of task-relevant stimuli and enhancing attentional focus (Chechko et al., 2014; Egner, 2007; Egner and Hirsch, 2005). For example, a study by Egner and Hirsch (2005) manipulated the level of cognitive control during a modified Stroop task. Subjects discriminated between actors and political figures, either based on the face stimuli (face-target condition) or written name (face-distracter condition). Stimuli could be either congruent (e.g. politician's face, politician's name) or incongruent (e.g. actor's face, politician's name). The study showed that after incongruent trials, processing of subsequent faces increased, but only when they were task-relevant. Moreover, these trials were associated with amplified activation of the DLPFC and increased responses from sensory cortical areas related to task-relevant information (FFA, face fusiform area).

Overall, studies on the conflict adaptation mechanism strongly support the view that it is related to increased attentional processing of task-relevant stimuli exerted by the DLPFC. Interestingly, conflict adaptation effects might be transferred across different tasks. For example, in a study in which participants performed the Flanker and Stroop task intermittently in randomized order, the conflict adaptation effect was preserved from trial to trial, even when two consecutive trials come from different tasks (Freitas et al., 2007; Freitas and Clark, 2015). This suggests that cognitive conflict triggers changes in selective attention that are not restricted to the particular type of the stimuli, but are more global and universal.

1.3. Cognitive conflict and processing of task-irrelevant pictures

Although the studies described above show that the conflict adaptation mechanism influences processing of task-relevant stimuli, knowledge about its influence on processing of task-irrelevant stimuli remains scarce. Studies have shown that cognitive conflict has either no effect on task-irrelevant stimuli (Egner and Hirsch, 2005; Nigbur et al., 2015; Scerif et al., 2006), or have suggested that cognitive conflict decreases processing of task-irrelevant stimuli (Yeung and Cohen, 2006; Yeung et al., 2007). However, the studies described were primarily designed to assess the effect of conflict on task-relevant stimuli, which could cause inferences about processing of task-irrelevant stimuli to be less clear.

Most importantly, past studies used the same stimuli as both task-relevant targets and task-irrelevant distracters; a task-relevant target in a one trial could become a task irrelevant distracter in a subsequent trial. In that sense, task-irrelevant stimuli, even if not relevant in the current trial, are “potentially task-relevant”. Thus, the representation of both task-relevant and task-irrelevant stimuli is available before it appears. Little is known how cognitive conflict could affect the processing of task-irrelevant stimuli not related to the task.

Moreover, previous procedures have presented task-relevant and task-irrelevant information at the same time. For example, participants simultaneously had to react to faces and ignore the names presented (e.g. Egner and Hirsch, 2005). In flanker task studies (Nigbur et al., 2015; Scerif et al., 2006), task-irrelevant information (flankers) was also presented simultaneously with task-relevant information (targets). Again, this approach is useful for explaining the mechanism of resolving conflict; however, it is not optimal for inferring about processing of task-irrelevant stimuli after a cognitive conflict, as their processing might be limited at the expense of the processing of task-relevant information (e.g. Erthal et al., 2005; MacNamara et al., 2011; Okon-Singer et al., 2007). Lastly, no study has compared the effects of cognitive conflict on task-irrelevant stimuli of varying valence.

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