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Congruency sequence effect in cross-task context: Evidence for dimension-specific modulation ☆

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ABSTRACT

The congruency sequence effect refers to a reduced congruency effect after incongruent trials relative to congruent trials. This modulation is thought to be, at least in part, due to the control mechanisms resolving conflict. The present study examined the nature of the control mechanisms by having participants perform two different tasks in an alternating way. When participants performed horizontal and vertical Simon tasks in Experiment 1A, and horizontal and vertical spatial Stroop task in Experiment 1B, no congruency sequence effect was obtained between the task congruencies. When the Simon task and spatial Stroop task were performed with different response sets in Experiment 2, no congruency sequence effect was obtained. However, in Experiment 3, in which the participants performed the horizontal Simon and spatial Stroop tasks with an identical response set, a significant congruency sequence effect was obtained between the task congruencies. In Experiment 4, no congruency sequence effect was obtained when participants performed two tasks having different task-irrelevant dimensions with the identical response set. The findings suggest inhibitory processing between the task-irrelevant dimension and response mode after conflict.

1. Introduction

Interference paradigms, such as the flanker-compatibility task, the Stroop task, and the Simon task, have been used to investigate the automatic aspect of the human cognitive system. In these paradigms, interference occurs when different stimulus features activate different responses. For example, in the Simon task, in which participants are to make a left or right response to the color of the target stimulus appearing at the left or the right side of fixation, responses are faster and more accurate when the color and the location of the target stimulus activate the same response than when they activate different responses. It has been thought that these congruency effects occur because of the automatic activation of a competing response by task-irrelevant information (e.g., Kornblum, Hasbroucq, & Osman, 1990).

Interestingly, the congruency effects have been reported to be modulated by the previous trial congruency (Gratton, Coles, & Donchin, 1992). Using the flanker-compatibility task, Gratton et al. found a smaller flanker-compatibility effect after incongruent trials than after congruent trials. Specifically, the congruent trials following a congruent trial (cC) were faster and more accurate than the trials following an incongruent trial (iC). Incongruent trials were faster and more accurate when the preceding trials were incongruent (iI) than when the preceding trials were congruent (cI). Such finding was replicated in other interference paradigms, such as the Stroop task (Kerns et al., 2004; Notebaert, Gevers, Verbruggen, & Liefooghe, 2006) and the Simon task (Hommel, Proctor, & Vu, 2004; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002; Wühr, 2005). To explain this congruency sequence effect, two classes of accounts have been proposed. One is based on the repetition of stimulus–response features (Mayr, Awh, & Laurey, 2003), and the other is based on the conflict-driven modulation by the cognitive control mechanism (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001).

Mayr et al. (2003) suggest that the congruency sequence effect is due to repetition priming. A repetition benefit occurs when stimuli are repeated (e.g., Altmann, 2011). Because 50% of the cC and iI trials, but none of the cI and iC trials, are stimulus repetitions (target and flanker repetition) in a two-forced choice task, the cC and iI trials are faster than the cI and iC trials, resulting in the congruency sequence effect. In their experiment, in which participants were to perform vertical and horizontal arrow flanker tasks alternately in a trial-by-trial manner to eliminate immediate stimulus–response repetition, the flanker compatibility effect was modulated by n-2 congruency but not by n-1 congruency. According to Mayr et al., the congruency sequence effect disappears when the lower-level repetition priming effect is removed.

However, other researchers suggested that the congruency sequence effect is the consequence of cognitive control processes (e.g., Botvinick et al., 2001; Gratton et al., 1992). According to the conflict monitoring theory (Botvinick et al., 2001), the congruency sequence effect is due to the heightened level of control induced by the conflict of the proceeding trial. That is, after an incongruent trial the cognitive system

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adaptively biases information processes to improve performance. In an fMRI study, Botvinick, Nystrom, Fissell, Carter, and Cohen (1999) showed that the peak activation of the dorsal anterior cingulated cortex (dACC) was greater during incongruent than congruent trials. Most importantly, the enhanced dACC activation of incongruent trials interacted with the previous congruency, being greater following congruent than incongruent trials. Based on these results, they suggested that the conflict is detected by a conflict-monitoring mechanism, located in dACC, which then triggers the lateral prefrontal cortex (LPFC), known to be specialized in resolving conflicts (e.g., Kerns et al., 2004; MacDonald, Cohen, Stenger, & Carter, 2000).

Empirical findings suggest that both the repetition priming and the control mechanism triggered by conflict contribute to the congruency sequence effect (e.g., Akçay & Hazeltine, 2007; Davelaar & Stevens, 2009; Egner, 2007; Verguts & Notebaert, 2008). For example, the congruency sequence effect was obtained after trials which did not have any conflict (Hommel et al., 2004; Liepelt, Wenke, Fischer, & Prinz, 2011). However, other studies have reported a robust sequential effect while controlling the effect of repetition priming (Akçay & Hazeltine, 2007; Hazeltine, Akçay, & Mordkoff, 2011; Kerns et al., 2004; Notebaert et al., 2006; Ullsperger, Bylsma, & Botvinck, 2005). For example, when multiple target and distractor features were used to control for the repetition priming effect, a significant congruency sequence effect was obtained (Akçay & Hazeltine, 2007; Kerns et al., 2004; Notebaert et al., 2006).

Recently, many researchers were interested in the nature of the control mechanisms. Some argue that conflict is modulated by a single global control mechanism (e.g., Kunde & Wühr, 2006), but many others suggest that conflict is thought to be resolved by independent local control mechanisms based on conflict types or task structures (Akçay & Hazeltine, 2008; Egner, Delano, & Hirsch, 2007; Funes, Lupiáñez, & Humphreys, 2010). Egner et al. (2007) reported that modulation that comes from previous trial conflict does not produce crosstalk between tasks of different conflict types. In a combined Stroop–Simon color naming task, in which participants responded to the color of the target word while ignoring the word meaning (Stroop conflict) and the word location (Simon conflict), the congruency sequence effect was found only between the identical conflict types but not between different conflict types. The Stroop conflict was defined as a *stimulus-based conflict* because the conflict arises between the task-relevant stimulus feature (ink color) and task-irrelevant stimulus feature (color word) at the stimulus level. On the other hand, the Simon conflict was defined as a *response-based conflict* because the conflict arises between the task-relevant stimulus feature (ink color) and the task-irrelevant stimulus feature (location) only after the task-relevant stimulus feature is processed at the response selection stage. Egner and his colleges suggested that the absence of crosstalk between the Stroop and Simon conflicts is due to independent control mechanisms which resolve a specific type of conflict. More specifically, they claimed that the stimulus-based conflict is resolved by enhancing the processing of task-relevant information, whereas the response-based conflict is resolved by suppressing the output of automatic route processing. The absence of the crosstalk between different conflict types was replicated in a combined Simon–flanker compatibility task. The congruency sequence effect was obtained within a same conflict type (e.g., Simon; Flanker; Stroop) but not across different conflict types (e.g., Akçay & Hazeltine, 2011; Egner et al., 2007; Funes et al., 2010).

Funes et al. (2010) also found that the crosstalk occurred only between the same type of conflicts but not between different types of conflict. In their Experiment 2, participants were to make left–right responses to the direction of an up–down pointing arrow appearing in left, right, above or below a fixation point. That is, spatial Stroop conflict was assumed to occur when the arrow was presented above or below the fixation point, whereas Simon conflict when the arrow was presented to the left or right side of it. This allowed the manipulation of conflict type to switch or repeat between trials while keeping the task-relevant dimension and response mode constant. The congruency sequence effect was obtained when the two types of conflict were common but not when they were switched.

However, other studies show that tasks with the same source of conflict do not yield crosstalk in certain settings (Akçay & Hazeltine, 2008; Mayr et al., 2003). Akçay and Hazeltine (2008) reported that two different Simon tasks which had independent sets of stimuli-responses did not show crosstalk. When participants were to perform two Simon task with different task-relevant dimension but a common response set, the congruency sequence effect occurred between the two task congruencies. Akçay and Hazeltine suggested that the scope of control is determined by the task structure, rather than the source of conflict, and that if the stimulus–response sets overlap between the two tasks, conflicts are resolved by a single control mechanism. Otherwise, conflicts are resolved by task-specific control mechanism recruited by each task set. Thus, when two tasks are conceptualized into a single task, the control mechanisms triggered by the conflict of one task modulate the congruency effect of the other.

Verguts and Notebaert (2008, 2009) proposed an associative learning model to explain sequential modulation of the congruency effect parsimoniously. According to this account, the congruency sequence effect is due to arousal leading to strengthening the associations of task-relevant information with its corresponding response after conflict. In Braem, Verguts, and Notebaert's (2011) experiments, in which participants performed two different Simon tasks in a random order, a congruency sequence effect was obtained between two different congruencies when the two tasks were performed with the same response effectors. Based on this result, they suggested that the influence of the task-irrelevant information is reduced because the association of task-relevant information with its corresponding response is strengthened after conflict.

In sum, many studies have shown that conflict is modulated in a domain-specific fashion (Akçay & Hazeltine, 2008; Funes et al., 2010; Schlaghecken, Refaat, & Maylor, 2011; Verguts & Notebaert, 2008), but the factors determining the scope of control are still unclear. That is, the findings that no crosstalk was obtained between two congruencies having the same type of conflict (Akçay & Hazeltine, 2008; Mayr et al., 2003) indicate that the source of conflict does not determine the scope of control. Also, the findings that no crosstalk was obtained between two different types of conflict when the task-relevant dimension and response mode were constant (e.g., Funes et al., 2010) indicate that conflict is not modulated by independent local control mechanisms based on task structures.

The present study examines the nature of the control mechanisms by manipulating the conflict type, the target dimension, the distractor dimension, and/or the response set of two different tasks. If independent control mechanisms modulate stimulus-based conflict and response-based conflict, as Egner et al. (2007) suggested, the congruency sequence effect should be evident when the tasks share the source of conflict. Counter to this hypothesis, Mayr et al. (2003) have demonstrated that horizontal and vertical flanker congruencies, both stimulus-based conflicts, did not crosstalk if the tasks had no repetitions. Experiments 1A and 1B were conducted in order to expand this finding to other task types. In Experiment 1A, participants performed vertical and horizontal Simon tasks in an alternating fashion. According to the account of Egner et al., the congruency sequence effect should be evident between the horizontal and vertical Simon tasks which have response-based conflicts. In Experiment 1B, participants performed horizontal and vertical spatial Stroop tasks in an alternating fashion. Again, if a single control mechanism resolves stimulus-based conflicts a crosstalk should be obtained between horizontal and vertical spatial Stroop tasks.

A second possible strategy to overcome conflict is to suppress the processing of the task-irrelevant information (Stoffels, 1996; Stürmer et al., 2002). Stoffels suggested that the congruency effect disappears after incongruent trials because of the suppression of the unconditional