



Congruency sequence effect without feature integration and contingency learning[☆]

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ABSTRACT

The magnitude of congruency effects, such as the flanker-compatibility effects, has been found to vary as a function of the congruency of the previous trial. Some studies have suggested that this congruency sequence effect is attributable to stimulus and/or response priming, and/or contingency learning, whereas other studies have suggested that the control process triggered by conflict modulates the congruency effect. The present study examined whether sequential modulation can occur without stimulus and response repetitions and contingency learning. Participants were asked to perform two color flanker-compatibility tasks alternately in a trial-by-trial manner, with four fingers of one hand in Experiment 1 and with the index and middle fingers of two hands in Experiment 2, to avoid stimulus and response repetitions and contingency learning. A significant congruency sequence effect was obtained between the congruencies of the two tasks in Experiment 1 but not in Experiment 2. These results provide evidence for the idea that the sequential modulation is, at least in part, an outcome of the top-down control process triggered by conflict, which is specific to response mode.

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1. Introduction

Human task performance is continuously influenced by the context in which it occurs. For example, past experience modulates all aspects of human information processing, including perception, attention, memory, and many other higher cognitive activities. Most interesting, the influence of task-irrelevant distractors on the task performance at hand is modulated by the amount of conflict the performer has just experienced (e.g., Gratton, Coles, & Donchin, 1992). That is, the congruency effect is smaller when the previous trial was incongruent than when it was congruent. This *congruency sequence effect* (Gratton effect or conflict-adaptation effect) has been found across a variety of versions of conflict tasks, including the Simon task, the Stroop task, and the flanker-compatibility task.

Many researchers attribute this reduced congruency effect after an incongruent trial to conflict adaptation, which refers to conflict being regulated by biasing the processing of a task-relevant stimulus feature

or that of task-irrelevant conflicting stimulus features (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Kerns et al., 2004; MacDonald, Cohen, Stenger, & Carter, 2000). Botvinick and colleagues developed the *conflict monitoring* model which describes how conflicts are detected and regulated. According to this model, conflicts between the correct response and the response triggered by task-irrelevant conflicting stimulus features are detected by a conflict monitoring system, which is located in the dorsal anterior cingulate cortex (dACC). Then, the dACC projects signals to dorsolateral prefrontal cortex (DLPFC) to regulate the detected conflicts. The DLPFC reduces conflicts on the following trial by allocating different attentional weights to the task-relevant dimension and the task-irrelevant conflicting stimulus dimension. For example, the task-relevant dimension is weighted more after experiencing conflict to focus more on the task demand, and/or the weighting on the task-irrelevant conflicting stimulus dimension is reduced to ignore the distractors.

However, other researchers have argued that the congruency sequence effect is attributed to a bottom-up memory-related process rather than a top-down control process (Hommel, Proctor, & Vu, 2004; Mayr, Awh, & Laurey, 2003). Hommel et al. suggested that the feature-integration is the major source of the congruency sequence effect. Once a stimulus is presented and its response is executed, an event-file, which binds the stimulus and response features, is formed. If one of the stimulus features in the event-file is presented on the

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following trial, the other features in the event file, including the bound response, are retrieved automatically. If the retrieved response is different from the correct response, it takes longer time to execute the correct response, because the bound response has to be inhibited before the execution of an overt response. When the stimulus and response of a given trial are the same as the previous trial, a fast response is possible. A fast response is also possible when the stimulus and response of a given trial are completely different from those of the previous trial, because any stimulus feature on the current trial was not integrated into an event file in the previous trial, so that no response would be automatically activated.

Hommel et al. (2004) pointed out that the effects of conflict adaptation and feature integration are completely confounded in many experiments. Specifically, the sequences of previously congruent and currently congruent trials (cC) and the sequences of previously incongruent and currently incongruent trials (iI), which consist of only the complete repetition trials and the complete alternation trials in a two-choice task, are faster to respond to than the sequences of previously congruent and currently incongruent trials (cI) and the sequences of previously incongruent and currently congruent trials (iC), all of which are partial repetition trials. Hommel et al.'s finding of a congruency sequence effect without conflict is inconsistent with the idea that the reduced congruency effect after an incongruent trial is due solely to the allocation of different attentional weights on the task-relevant dimension and the task-irrelevant conflicting stimulus dimension after detecting conflict.

One way to avoid confounding the top-down adjustment modulation with the bottom-up priming is to increase the number of stimulus (and response) alternatives. Akçay and Hazeltine (2007) had participants perform a four-choice reaction task and analyzed only completely alternated trials which were the only subset that includes all types of sequence. Although they also removed negative priming trials, which make iI trials additionally slower, Akçay and Hazeltine found a significant congruency sequence effect. Kerns et al. (2004) also showed a congruency sequence effect in the color–word Stroop task after removing the trials on which the target color or distractor word was repeated from their analysis. Ullsperger, Bylsma, and Botvinck (2005) Experiment 2 demonstrated that significant sequential modulation occurred in the flanker-compatibility task with a larger stimulus set when they analyzed only the trials on which all stimulus features were completely different from the previous trial. Notebaert, Gevers, Verbruggen, and Liefvooghe (2006) found the evidence of both top-down and bottom-up sources of the congruency sequence effect using two different response stimulus intervals (RSI) using a flanker compatibility task with larger stimulus and response sets. When the RSI was extremely short (50 ms), the sequential modulation was found only in the trials with feature repetition. However, when the RSI was relatively long (200 ms), significant sequential modulation was found in both completely alternated trials and completely repeated trials. These results indicate that the congruency sequence effect can occur without the contribution of the process of binding.

On the other hand, it has been suggested that increasing the numbers of stimulus and response alternatives to avoid the confounding effects of the top-down control and the stimulus or response repetition causes a confounding effect of the contingency between the distractor and correct response because researchers tended to present congruent trials equally frequently with incongruent trials (Mordkoff, 2012; Schmidt, Crump, Cheesman, & Besner, 2007; Schmidt & De Houwer, 2011). For example, when performing a 4-choice color naming Stroop task, the congruent color word is presented more frequently (50%) than any incongruent color word. Because the congruent word is presented higher than the chance level (25%), participants learn these contingencies, resulting in faster and more accurate responses on the congruent trials than incongruent trials (e.g., Schmidt et al., 2007). Moreover, the contingency effect is modulated by previous contingency (Schmidt et al., 2007). The effect of the contingency

was more evident following a high contingency trial than a low contingency trial. According to Schmidt et al., if the distractor predicts the correct response in the previous trial (high contingency trials), participants are more likely to use the contingency information. On the other hand, if the distractor is paired with an unusual target, they are unlikely to use that information. Therefore, there would be a larger contingency effect after high contingency trials than the effect after the low contingency trials.

Mayr et al. (2003) separated repetition and alternation trials in their first experiment, and made their task without stimulus and response repetitions and the contingency of the distractor with the correct response in their second experiment. According to them, performance for the cC sequence trials and the iI sequence trials is better than performance for the cI sequence trials and the iC sequence trials because the half of these trials are the exact stimulus and response repetition trials in the flanker-compatibility task which has only two stimulus alternatives and two corresponding response alternatives. In their first experiment, they replicated the congruency sequence effect using the arrow version of the flanker-compatibility task, and they also showed that this effect was present only in the stimulus repetition trials and was completely absent in the stimulus alternation trials. They demonstrated no significant sequential modulation when a horizontal arrow flanker task and vertical arrow flanker task were presented alternately in a trial-by-trial manner in their second experiment to exclude the effects of the stimulus repetition and the contingency learning. Based on these results, Mayr et al. suggested that the congruency sequence effect is due to bottom-up priming rather than top-down adjustment modulation.

However, Ullsperger et al. (2005) suggested that the lack of the congruency sequence effect in Mayr et al.'s (2003) second experiment, in which every trial was a switching trial, was possibly due to a task switch affecting the control process. Another possibility for the lack of sequential modulation in the Mayr et al.'s experiment is that different task-specific control mechanisms may have been employed for each of the arrow flanker-compatibility tasks. There is ample evidence that cognitive control process is specific to domains (Akçay & Hazeltine, 2008; Egner, 2007; Kiesel, Kunde, & Hoffmann, 2006; Notebaert & Verguts, 2008). To account for these findings, Verguts and Notebaert (2008, 2009) proposed a model to account for the congruency sequence effect. They emphasized the role of a Hebbian learning mechanism in their cognitive control model. According to them, when conflict is detected on incongruent trials, a neuromodulatory system increases the level of arousal, resulting in strengthening the associations between task-relevant stimulus feature and response via a Hebbian learning process, based on the currently activated task rule. Because the Hebbian learning rule is local, no congruency sequence effect between two tasks is expected to occur when they have different stimulus or response dimensions.

Akçay and Hazeltine (2008) suggested that participant's task representation might determine the scope of the control process. In their Experiment 1, the congruency sequence effect between two different response sets was obtained when the stimulus sets for the two response sets overlapped but not when they were separated. According to them, the task was represented as a single task when there was overlap in the stimulus dimension, while it was represented as separated subtasks when there was no overlap in stimulus–response pairs. When participants represent a task as several different subtasks, local control mechanisms were recruited for each subtask.

Recently, Lee and Cho (2013) suggested that the control process is specific to the response mode as well as the task-irrelevant conflicting stimulus feature. When they had participants perform a horizontal Simon task, in which a left or right keypress response was made to the color of a target presented to the left or right of fixation, and a vertical Simon task, in which an above or below keypress response was made to the color of a target presented above or below fixation, no sequential effects was obtained between the horizontal and vertical Simon

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