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The congruency sequence effect transfers across different response modes

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ABSTRACT

The congruency effect observed in distracter interference tasks is usually smaller after incongruent relative to congruent trials. However, the nature of control processes underlying this congruency sequence effect (CSE) remains a topic of active debate. For example, while some researchers have suggested that these processes are recruited only when participants utilize the same response mode (e.g., the same hand) to respond in consecutive trials, others have argued that these processes can operate independently of response mode. To distinguish between these views, we investigated whether changes of response mode across consecutive trials influence the CSE in a prime-probe task (Experiment 1) or a flanker task (Experiment 2). Such changes did not influence the CSE in either task. Further, the CSE was significant even when participants utilized different response modes (i.e., different hands) to respond in consecutive trials. These findings indicate that control processes underlying the CSE can operate independently of response mode and thereby clarify the nature of control processes that minimize distraction from irrelevant stimuli.

1. Introduction

Researchers often employ distracter interference tasks to investigate selective attention (MacLeod, 1991). In such tasks, participants are instructed to identify a target stimulus while ignoring one or more distracters. For instance, in the classic Stroop task (Stroop, 1935), participants are instructed to identify the ink color in which a word is printed independent of the word's identity. As in other distracter interference tasks, in the Stroop task there are usually two types of trials: congruent trials, in which the distracter and the target engender the same response (e.g., RED printed in red ink), and incongruent trials, in which the distracter and the target engender different responses (e.g., RED printed in blue ink). Typically, response times and error rates are greater in incongruent relative to congruent trials. This congruency effect indicates that selective attention does not completely filter the influence of irrelevant stimuli on performance.

Some researchers have suggested that the efficiency of selective attention varies across time. Consistent with this possibility, the congruency effect in distracter interference tasks is typically smaller when the previous trial was incongruent as compared to congruent (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Gratton, Coles, & Donchin, 1992; Stürmer, Leuthold, Soetens, Schroter, & Sommer, 2002). This congruency sequence effect (CSE) is often interpreted as reflecting one of two types of cognitive control processes: (1) a shift of attention toward the target and/or away from the distracter after incongruent relative to congruent trials (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Dreisbach & Fischer, 2012; Gratton et al., 1992) or (2) a modulation (e.g., inhibition) of the response engendered by the distracter after incongruent relative to congruent trials (Logan, 1985; Logan & Zbrodoff, 1979; Ridderinkhof, 2002a; Stürmer et al., 2002). In the vast majority of previous studies, the CSE was confounded with feature integration and/or contingency learning processes that can engender a CSE independent of the control processes posited by the attentional shift and response modulation accounts mentioned above (Duthoo et al., 2014b; Hommel, Proctor, & Vu, 2004; Mayr, Awh, & Laurey, 2003; Mordkoff, 2012; Schmidt, 2013; Schmidt & De Houwer, 2011). In line with these accounts, however, recent findings indicate that a CSE can also be observed without such confounds (Freitas & Clark, 2014; Kim & Cho, 2014; Kunde & Wuhr, 2006; Schmidt & Weissman, 2014; Weissman, Egner, Hawks, & Link, 2015; Weissman, Jiang, & Egner, 2014).

1.1. Which class of cognitive control processes underlies the confound-minimized CSE?

Recent findings from confound-controlled tasks suggest that the confound-minimized CSE is more consistent with the response modulation account than with the attentional shift account. According to the

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response modulation account, control processes that engender a CSE are more effective when they have time to modulate (e.g., inhibit) the response associated with the distracter before the target response comes online. In line with this view, the confound-minimized CSE is greater when the distracter is presented before, relative to with, the target, regardless of whether the congruency effect is larger in the former or the latter condition (Weissman et al., 2015).

In addition, the confound-minimized CSE in the prime-probe task is associated with a reverse, or negative, congruency effect after incongruent trials when a long (e.g., 1s) inter-stimulus-interval (ISI) separates the distracter from the target (Weissman et al., 2015). A negative congruency effect is not consistent with a process that shifts attention toward the target. Indeed, even shifting all of one's attention toward the target would engender, at best, a null congruency effect. On the other hand, a negative congruency effect is consistent with a process that modulates the response signaled by the distracter following incongruent trials. Inhibiting the distracter response, for example, should make it harder to respond to a congruent target that demands the same response, thereby reducing, or even reversing, the congruency effect (Machado, Wyatt, Devine, & Knight, 2007; Ridderinkhof, 2002a). These findings are more consistent with the response modulation account than with the attentional shift account. However, they do not exclude the possibility that an attentional shift also contributes to the confound-minimized CSE (Weissman et al., 2014).

1.2. A potential role for a common task representation in engendering the CSE

As discussed in a recent review (Braem, Abrahamse, Duthoo, & Notebaert, 2014), prior findings from tasks with feature integration and/or contingency learning confounds suggest that the CSE is heavily influenced by whether participants employ the same task representation in consecutive trials. For example, in the prime-probe task the CSE is reduced when the sensory modality in which task-relevant stimuli are presented changes in consecutive trials (Hazeltine, Lightman, Schwarb, & Schumacher, 2011). It is also reduced when participants respond to stimuli from different stimulus sets (e.g., letters versus circles) in consecutive trials (Akcay & Hazeltine, 2008; Hazeltine et al., 2011). Similarly, in other tasks the CSE is reduced when there is a change in the task-relevant dimension (Notebaert & Verguts, 2008; Wühr, Duthoo, & Notebaert, 2015), the task-irrelevant dimension (Egner, 2008; Egner, Delano, & Hirsch, 2007), or the entire task (Kiesel, Kunde, & Hoffmann, 2006). These findings suggest that observing a CSE depends not only on the distracter being processed before the target (Weissman et al., 2014, 2015), but also on whether participants employ the same task representation in consecutive trials. The latter perspective is often called the *task representation view* of the CSE (Hazeltine et al., 2011).

An important assumption of the task representation view is that changing a task across consecutive trials leads participants to update the task representation that guides performance, which reduces the CSE, only when the change is salient or task-relevant (Hazeltine et al., 2011). In line with this assumption, while the CSE in the prime-probe task is reduced when task-relevant stimuli in consecutive trials appear in different sensory modalities, this effect is observed only when the sensory modality in which task-relevant stimuli appear provides a salient means for categorizing those stimuli (Hazeltine et al., 2011). Also in line with this assumption, the CSE in the prime-probe task is reduced when different stimulus sets are employed in consecutive trials (e.g., letters versus circles). However, this effect occurs only when those stimulus sets are assigned to non-overlapping response sets, a task-relevant parameter that may encourage participants to employ distinct task representations (Hazeltine et al., 2011). In short, whether changes to a task influence CSE magnitude often depends on whether those changes are salient and/or task-relevant.

1.3. Does a common task representation engender the confound-minimized CSE?

Building upon these prior findings, Kim and Cho (2014) hypothesized that the confound-minimized CSE is also sensitive to whether participants employ the same task representation in consecutive trials. Analogous to Hazeltine and colleagues' hypothesis about the influence of response set on the CSE described above (Akcay & Hazeltine, 2008; Hazeltine et al., 2011), Kim & Cho hypothesized that the same task representation – and hence the same control processes – can be employed when participants utilize the same "response mode" (e.g., the same hand) to respond in consecutive trials, leading to a significant CSE. In contrast, they argued that different task representations – and, hence, different control processes – must be employed when participants utilize different response modes (e.g., different hands) to respond in consecutive trials, resulting in the absence of a CSE.[2]

Before proceeding, it is important to clearly define what it means for two tasks to employ different response modes. According to Kim and Cho (2014), two tasks employ different response modes when the responses for those tasks are linked to different modes of action, such as the left and right hands. Further, consistent with Hazeltine et al. (2011), Kim & Cho posit that when two tasks are associated with different modes of action, they are necessarily associated with different underlying task representations. In line with this view, switching between different response modalities (e.g., vocal to manual, manual to foot, foot to vocal, etc.), which are also different modes of action, incurs substantial task switch costs in reaction time even when the other task parameters remain the same (Philipp & Koch, 2011).

Although the left and right hands are both examples of the "manual" response modality, Kim and Cho (2014) argued that they constitute different modes of action for three reasons. First, it has been suggested that response alternatives are hierarchically organized and that the specification of hand takes place at a higher level than the specification of finger (Rosenbaum, 1983). Second, based on their interpretation of prior work (Proctor & Vu, 2010), Kim & Cho suggested that different response alternatives are always more salient when they are mapped to different fingers on different hands as compared to different fingers on the same hand. Third, several findings from tasks with feature integration and/or contingency learning confounds suggest that the CSE is reduced when the responses participants make in consecutive trials are mapped to (a) different hands as compared to the same hand (Braem, Verguts, & Notebaert, 2011; Hazeltine et al., 2011; Lee & Cho, 2013) or (b) a hand and a foot as compared to a single type of effector (e.g., a hand) (Braem et al., 2011). While some data appear inconsistent with the first two of these three assumptions (Miller, 1982; Proctor & Vu, 2010), Kim & Cho nonetheless hypothesized that two tasks employ different response modes when the responses for those tasks are divided between the left and right hands. In other words, they posited that control processes underlying the CSE are specific to a particular response mode, such that a CSE can only be observed when participants utilize the same response mode (e.g., the same hand) in consecutive trials.

To test their *response mode* hypothesis, Kim and Cho (2014) employed a four alternative forced choice (4-AFC) color flanker task. To ensure that the stimuli in each trial came from a distinct stimulus set, they predictably alternated between two stimulus sets across consecutive trials. More specifically, they divided their 4-AFC color flanker ask into a pair of 2-AFC color flanker tasks and alternated between the colors associated with these tasks across trials. To further differentiate

[2] The response mode hypothesis is agnostic with regard to the control process that engenders a CSE when participants utilize the same response mode across trials. However, Kim and Cho (2014) suggested it is a process that suppresses the response engendered by the distracter to a greater extent after incongruent as compared to congruent trials (Ridderinkhof, 2002a; Stürmer et al., 2002).