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Resisting distraction and response inhibition trigger similar enhancements of future performance☆

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ABSTRACT

Resisting distraction and response inhibition are crucial aspects of cognitive control. Interestingly, each of these abilities transiently improves just after it is utilized. Competing views differ, however, as to whether utilizing either of these abilities (e.g., resisting distraction) enhances future performance involving the other ability (e.g., response inhibition). To distinguish between these views, we combined a Stroop-like task that requires resisting distraction with a restraint variant of the stop-signal task that requires response inhibition. We observed similar sequential-trial effects (i.e., performance enhancements) following trials in which participants (a) resisted distraction (i.e., incongruent go trials) and (b) inhibited a response (i.e., congruent stop trials). First, the congruency effect in go trials, which indexes overall distractibility, was smaller after both incongruent go trials and congruent stop trials than it was after congruent go trials. Second, stop failures were less frequent after both incongruent go trials and congruent stop trials than after congruent go trials. A control experiment ruled out the possibility that perceptual conflict or surprise engendered by occasional stop signals triggers sequential-trial effects independent of stopping. Thus, our findings support a novel, integrated view in which resisting distraction and response inhibition trigger similar sequential enhancements of future performance.

1. Introduction

Resisting distraction and response inhibition are crucial aspects of cognitive control (Friedman & Miyake, 2004). For instance, children who are able to resist distraction from a marshmallow's hedonic qualities, and thereby stop themselves from consuming it, grow up to achieve higher SAT scores and experience better health outcomes than children who give in to temptation (Mischel et al., 2011). Given these advantages, it is important to advance our understanding of the cognitive control processes that enable humans to effectively resist distraction and inhibit responses. To investigate the control processes that enable humans to resist distraction, researchers typically use Stroop-like tasks. To investigate the control processes that enable humans to inhibit responses, researchers use stop signal and go/no-go tasks.

1.1. Resisting distraction

In Stroop-like tasks (e.g., the Stroop task: Stroop, 1935; the flanker task: Eriksen & Eriksen, 1974; the Simon task: Simon, 1969), participants identify a relevant target while ignoring an irrelevant distracter (MacLeod, 1991). In the arrow version of the prime-probe task, for example, they identify the direction in which a target arrow points (e.g., left or right) while ignoring a preceding distracter arrow (Kunde & Wuhr, 2006). In congruent trials, the distracter and target prime the same response because they point in the same direction. In incongruent trials, these stimuli prime different responses because they point in opposite directions. Typically, participants respond more slowly in incongruent than in congruent trials. This *congruency effect* indexes, at least partly, a failure to resist distraction.

Most accounts of cognitive control posit that resisting distraction in an incongruent trial involves biasing attentional systems to favor task-relevant processing over task-irrelevant processing (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Dreisbach & Fischer, 2012; Gratton, Coles, & Donchin, 1992; Ridderinkhof, 2002). Consistent with this view, the congruency effect is smaller after incongruent trials than after congruent trials (Gratton et al., 1992). Furthermore, researchers have observed this *congruency sequence effect* (*CSE*) even in “confound-minimized” task protocols, wherein the CSE does not reflect feature integration and/or contingency learning confounds (Freitas & Clark, 2015; Jimenez & Mendez, 2014; Kim & Cho, 2014;

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Schmidt & Weissman, 2014). Researchers may therefore use such protocols to investigate the nature of cognitive control processes that underlie the CSE.

There are two main cognitive control accounts of the CSE. First, according to the *attentional shift* account, the CSE indexes a shift of attention toward the target and/or away from the distracter after incongruent relative to congruent trials. In different variants of this account, this shift of attention is triggered by (1) expectations about whether the distracter will perceptually resemble the target (Gratton et al., 1992), (2) response conflict (Botvinick et al., 2001), or (3) negative affect (Botvinick, 2007; Dreisbach & Fischer, 2012). Second, the *response modulation* account posits that the CSE indexes a modulation (e.g., inhibition) of the response engendered by the distracter after incongruent relative to congruent trials. In different variants of this account, this modulation is triggered either by (1) the need to suppress an incorrect response (Ridderinkhof, 2002) or (2) identifying stimuli that cue multiple responses (Alexander & Brown, 2011, 2014; Logan, 1985; Logan & Zbrodoff, 1979; Weissman, Colter, Drake, & Morgan, 2015).

Findings from confound-minimized protocols are generally more consistent with the response modulation account than with the attentional shift account. For example, even when a 1000 ms inter-stimulus-interval (ISI) separates a distracter from an upcoming target, thereby eliminating the overall congruency effect (i.e., the behavioral signature of response conflict (Yeung, Cohen, & Botvinick, 2011)), it is possible to observe the CSE (Weissman, Egner, Hawks, & Link, 2015; Weissman, Hawks, & Egner, 2016). Moreover, in this same task context, the CSE is associated with a small positive congruency effect after congruent trials and a small *negative* congruency effect (i.e., faster response times in incongruent relative to congruent trials) after incongruent trials. A negative congruency effect is inconsistent with every variant of the attentional shift account. Even completely shifting attention to the target and/or away from the distracter would lead to the absence of a congruency effect rather than to a negative congruency effect. In contrast, a negative congruency effect is consistent with the response modulation account. Inhibiting the response signaled by the distracter after an incongruent trial, for example, should slow responses more in congruent trials (wherein participants must execute an inhibited response) than in incongruent trials (wherein participants must execute an uninhibited response). In the absence of an overall congruency effect, such selective slowing in congruent trials could engender a negative congruency effect after incongruent trials (Weissman et al., 2015).

Findings from a recent study further indicate that identifying stimuli that cue multiple responses plays a greater role in triggering the CSE than the need to suppress an incorrect response (Weissman, Colter, Grant, & Bissett, 2017). In this study, a 1000 ms ISI separated a large arrow from a subsequent small arrow. In standard trials (66.66%), both arrows were white. Participants indicated the direction in which the small arrow pointed (left, right, up, or down) without responding to the preceding large arrow, which functioned as a distracter as in typical prime-probe tasks. In catch trials (33.33%), the large arrow was yellow instead of white. In these trials, participants indicated (1) the direction in which the large yellow arrow pointed (left, right, up, or down) before the small white arrow appeared and, then, (2) the direction in which the small white arrow pointed. Critically, the large yellow arrow in incongruent catch trials could not engender incorrect response activation. Indeed, the response it signaled was correct because the researchers told the participants to make this response. The researchers nonetheless observed a robust CSE following both catch and standard trials. Further, they observed these effects in the absence of an overall congruency effect. They therefore concluded that identifying stimuli that cue multiple responses plays a more important role in triggering the CSE than either incorrect response activation or response conflict. This conclusion is consistent with the variants of the response modulation account discussed earlier in which identifying stimuli that cue multiple responses triggers control processes that lead to sequential-trial effects (Alexander & Brown, 2011, 2014; Logan, 1985; Logan & Zbrodoff, 1979; Weissman et al., 2015).

1.2. Response inhibition

Response inhibition is another important aspect of cognitive control. For example, when a traffic light turns red, a driver needs to stop pressing the accelerator before he or she can press the brake. The ability to inhibit a response is often measured in stop-signal tasks, wherein participants are normally instructed to make a choice reaction time (RT) response to each target (e.g., "A" or "B") unless an infrequent stop signal is presented (e.g., an auditory tone or a visual stimulus) (Lappin & Eriksen, 1966; Logan & Cowan, 1984; Verbruggen & Logan, 2008a; Vince, 1948). Stop signals typically appear in a minority of trials (e.g., 25–33%), either concurrent with or at some point following target presentation (Logan & Cowan, 1984; Schachar, Logan, Chen, Ickowiz, & Barr, 2007). When the delay between the target and the stop signal (i.e., the stop-signal delay, SSD) is short, participants are usually able to inhibit the target response. As the SSD increases, however, they become less able to inhibit this response. Failures to inhibit a response in stop trials are often called *stop failures*.

The independent race model provides an explanation for these basic findings from the stop-signal task (Logan & Cowan, 1984; Logan, Van Zandt, Verbruggen, & Wagenmakers, 2014). It posits that a go process triggered by the target races against a stop process triggered by the stop signal. If the go process wins the race, then the participant fails to inhibit the target response. If the stop process wins the race, then the participant is able to inhibit the target response. The SSD biases the race between the go and stop processes. Longer SSDs bias the race in favor of the go process. Shorter SSDs bias the race in favor of the stop process.

As in Stroop-like tasks, the nature of the preceding trial influences performance in stop-signal tasks. The most extensively studied phenomenon is *post-stop-signal slowing*, in which participants respond more slowly in go trials that follow stop trials (Bissett & Logan, 2011; Rieger & Gauggel, 1999). Researchers have proposed several explanations for this phenomenon. These include post-error slowing (because slowing is sometimes greater after stop failures than after stop successes) (Schachar et al., 2004; Verbruggen, Logan, Liefooghe, & Vandierendonck, 2008), post-surprise slowing (i.e., slowing after relatively infrequent stop events) (Castellar, Kuhn, Fias, & Notebaert, 2010; Notebaert et al., 2009), and a strategic shift in goal priorities to emphasize caution rather than speed (Bissett & Logan, 2011, 2012a, 2012b; Leotti & Wager, 2010; Liddle et al., 2009).

Bissett and Logan (2011) reported two findings that distinguished among these competing explanations of post-stop-signal slowing. First, they reported similar post-stop-signal slowing after stop successes and stop failures. This finding is consistent with the goal-priority hypothesis, but it is inconsistent with the post-error slowing hypothesis. Second, they observed greater post-stop-signal slowing when stop signals appeared more frequently (i.e., 40% of all trials) as compared to less frequently (i.e., 20% of all trials). This finding is inconsistent with the post-surprise slowing hypothesis. Taken together, these findings are most consistent with the goal-priority hypothesis.[1]

Two additional post-stop-signal adjustments are also consistent with the goal-priority hypothesis. First, participants stop more quickly after

[1] Another account of post-stop-signal slowing, the memory hypothesis, is that the target in a stop trial becomes associated with stopping a response. If such a target stimulus is repeated in a subsequent go trial, then the association between that target and stopping is retrieved, resulting in a slower response. While there is considerable evidence to support the memory hypothesis (Bissett & Logan, 2011; Verbruggen et al., 2008; Verbruggen & Logan, 2008b, 2008c), post-stop-signal slowing occurs even when stimulus and response repetitions are removed (Bissett & Logan, 2011). Further, no such exact target repetitions occur in the critical trials of the present experiments. We therefore do not further discuss the memory hypothesis.