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Contingent attentional capture triggers the congruency sequence effect☆

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ABSTRACT

The congruency effect in distracter interference tasks is often reduced after incongruent as compared to congruent trials. Here, we investigated whether this congruency sequence effect (CSE) is triggered by (a) attentional adaptation resulting from perceptual conflict or (b) contingent attentional capture arising from distracters that possess target-defining perceptual features. To distinguish between these hypotheses, we varied the perceptual format in which a distracter (word or arrow) and a subsequent target (word or arrow) appeared in a prime-probe task. In Experiment 1, we varied these formats across four blocks of a factorial design, such that targets always appeared in a single perceptual format. Consistent with both hypotheses, we observed a CSE only when the distracter appeared in the same perceptual format as the target. In Experiment 2, we varied these formats randomly across trials within each block, such that targets appeared randomly in either format. Consistent with the attentional capture account but inconsistent with the perceptual conflict account, we observed equivalent CSEs in the same and different perceptual format conditions. These findings show for the first time that contingent attentional capture plays an important role in triggering the CSE.

1. Introduction

Humans are notoriously distractible. A prototypical example from the laboratory comes from the Stroop task (Stroop, 1935), wherein people are instructed to identify the color in which a word is printed. Although the word's identity is irrelevant, participants respond more slowly when the word is incongruent with the print color (e.g., BLUE printed in red ink) as compared to congruent (e.g., GREEN printed in green ink). Analogous *congruency effects* have been observed in a variety of other distracter interference tasks including the flanker task (Eriksen & Eriksen, 1974), the Simon task (Simon & Rudell, 1967), and the prime-probe task (Neumann & Klotz, 1994). The ubiquity of such effects indicates that selective attention usually fails to eliminate the influence of distracters on performance.

Some researchers have argued, however, that the degree to which selective attention minimizes the influence of distracters on performance varies with the nature of distraction on the previous trial. Consistent with this view, the congruency effect in distracter interference tasks is smaller after incongruent as compared to congruent trials (Gratton, Coles, & Donchin, 1992). This *congruency sequence effect* (CSE) is often attributed to attentional control processes that (a) enhance the processing of relevant stimuli and/or responses and/or (b) reduce the processing of irrelevant stimuli and/or responses when the previous trial was incongruent as compared to congruent (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001). While some have argued that highly-prevalent feature integration and contingency learning confounds are the true source of the CSE in many paradigms (Hommel, Proctor, & Vu, 2004; Mayr, Awh, & Laurey, 2003; Mordkoff, 2012; Schmidt & De Houwer, 2011), CSEs remain robust in some tasks even after removing these confounds (Kim & Cho, 2014; Kunde & Wühr, 2006; Schmidt & Weissman, 2014; Weissman, Egner, Hawks, & Link, 2015; Weissman, Jiang, & Egner, 2014).

What distinguishes tasks that engender a CSE in the absence of the typical confounds from those that do not? One factor is whether the distracter is processed before the target, such that it can activate a response before the target does (Weissman et al., 2014). For example, the CSE is highly robust in the prime-probe task, wherein the distracter precedes the target (Schmidt & Weissman, 2014; Weissman et al., 2015). A second factor is whether the distracter appears at the location of an upcoming target, such that it cannot be filtered by spatial attention (Weissman et al., 2014). In the present study, we investigated a third potential factor, which is whether the distracter is perceptually similar to a potential target. Consistent with this possibility, the distracters that engendered "confound-minimized" CSEs in recent studies of the prime-probe task possessed target-defining shapes and colors (Kunde & Wühr, 2006; Schmidt & Weissman, 2014; Weissman et al., 2014, 2015). For instance, the words "Left," "Right," "Up," and "Down" were used as both target and distracter stimuli in Schmidt and Weissman

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(2014, Experiment 2). Thus, each distracter (e.g., “Left”) looked like a potential target.

There are at least two reasons why the CSE might be larger when distracters are more versus less visually similar to targets in the prime-probe task. First, *perceptual conflict* might serve as a signal to attentional adjustment. For instance, perceiving visually-mismatching distracter and target stimuli on a previous incongruent trial (e.g., “Left” priming “Right”) might lead to a narrowing of attention toward the target on the following trial. Thus, smaller congruency effects would be expected relative to when the target and distracter matched on the previous trial (e.g., “Left” priming “Left”). In this account, a CSE would not be observed if distracters and targets were presented in different perceptual formats (e.g., words and arrows), because both congruent stimuli (e.g., “Left” priming an arrow pointing to the left) and incongruent stimuli (e.g., “Left” priming an arrow pointing to the right) are visually mismatching and therefore induce equivalent perceptual conflict.

Second, *attentional set* might be an important determinant of the CSE. A distracter that possesses a target-defining perceptual feature involuntarily attracts attention (e.g., Chun & Jiang, 1998; Cosman & Vecera, 2014; Moore & Weissman, 2010; Serences et al., 2005; Thomson, Willoughby, & Milliken, 2014). Critically, this phenomenon, known as contingent attentional capture, could enhance the CSE in any of several ways. First, it could raise the probability that the distracter is translated into a response before the target, thereby allowing control processes to better modulate (e.g., suppress) that response before the target response reaches threshold (e.g., Ridderinkhof, 2002). Second, it could increase the size of the congruency effect, which is the primary determinant of CSE magnitude in some accounts (e.g., Botvinick et al., 2001; Dreisbach & Fischer, 2012). Third, it could aid the formation of a memory about whether the previous trial was congruent or incongruent, which control processes might employ to modulate distracter and/or target processing in the current trial (Egner, 2014; Gratton et al., 1992). The goal of the present study was not to distinguish among these and other mechanisms by which contingent attentional capture might trigger the CSE. It was merely to establish whether such capture is necessary to trigger the CSE. Thus, for now, we refer to these mechanisms collectively as the attentional capture hypothesis.

As explained above, both the *perceptual conflict* and *attention capture* accounts would suggest that the CSE should be larger when the perceptual features of distracters match those of potential targets than when they do not. Experiment 1 tests this hypothesis, and Experiment 2 attempts to distinguish between these two alternative perspectives.

2. Experiment 1

To investigate whether the perceptual similarity of distracter and target stimuli impacts the magnitude of the CSE, we asked participants to perform a variant of the prime-probe tasks employed by Schmidt and Weissman (2014). In each trial, a distracter preceded a target that participants were asked to identify. Specifically, participants indicated which of four possible directions – left, right, up, or down – was indicated by the target by making a spatially-compatible response. Critically, in each trial the distracter and the target appeared in one of two perceptual formats: a word format (“Left,” “Right,” “Up,” or “Down”) or an arrow format (“<,” “>,” “∧,” or “∨”). The four possible combinations of distracter format and target format were presented in four separate blocks. As we noted earlier, both the perceptual conflict and attentional capture hypotheses predicted that the CSE would be larger in blocks wherein the distracter and target formats matched than in blocks wherein these formats mismatched.

2.1. Method

2.1.1. Participants

Twenty-four Ghent University undergraduates participated in Experiment 1 in exchange for €5.

2.1.2. Apparatus

Stimulus and response timing were controlled by E-Prime 2 (Psychology Software Tools, Sharpsburg, PA). Participants responded to left words and left arrows with the “F” key using the left middle finger, to right words and right arrows with the “G” key using the left index finger, to up words and up arrows with the “J” key using the right middle finger, and to down words and down arrows with the “N” key using the right index finger. The study was conducted using a PC laptop equipped with an AZERTY keyboard and a 15″ monitor.

2.1.3. Materials and design

The stimuli were presented in white, bold Courier New font on a black screen and consisted of four arrow stimuli (<, >, ∧, and ∨) and four Dutch direction words (Links [Left], Rechts [Right], Boven [Up], and Beneden [Down]). Distracter and target arrows, respectively, were presented in 36 and 18 point fonts. Analogously, distracter words and target words, respectively, were presented in 20 and 10 point fonts. Thus, distracters were always twice as large as targets. Note that arrows were presented in larger fonts than words to roughly equate the subjective size of these stimuli. Indeed, when presented in the same font size, single character arrows take up much less horizontal space than multiple character words.

As in our other recent studies (Schmidt & Weissman, 2014; Weissman et al., 2014, 2015), we employed the following procedures to avoid feature integration and contingency learning confounds that are often confounded with the CSE. To prevent feature integration confounds, which are induced by repeating stimuli and/or responses across adjacent trials, we alternated between a “Left–Right” task (odd trials), which involved left and right arrows and words, and an “Up–Down” task (even trials), which involved up and down arrows and words. In each task, there were two congruent distracter-target pairings (“Left–Right” task: Left–Left & Right–Right; “Up–Down” task: Up–Up & Down–Down) and two incongruent pairings (“Left–Right” task: Left–Right & Right–Left; “Up–Down” task: Up–Down & Down–Up). As noted earlier, participants responded with different fingers in the two tasks. Thus, our design precluded all stimulus and response repetitions and, hence, feature integration confounds. To prevent contingency learning biases, which occur when each congruent distracter-target pairing is presented more often than each incongruent distracter-target pairing, we presented the congruent and incongruent distracter-target pairings in each task approximately equally often (trials were selected randomly with replacement).

2.1.4. Procedure

The four combinations of distracter perceptual format (word, arrow) and target perceptual format (word, arrow) were presented in four 120-trial blocks. We presented these blocks in four orders that were counterbalanced across participants: (1) arrow–arrow, word–arrow, word–word, arrow–word; (2) word–arrow, arrow–arrow, arrow–word, word–word; (3) word–word, arrow–word, arrow–arrow, word–arrow; and (4) arrow–word, word–word, word–arrow, arrow–arrow. An instruction screen appeared at the beginning of each block.

Each trial consisted of several sequential events. To begin, there was a distracter (133 ms), a blank screen (33 ms), the target (133 ms), and a second blank screen (1367 ms, or until a response was made). Correct responses were followed by another 500 ms blank screen. Incorrect responses and trials in which participants failed to respond within 1367 ms were followed by a red “X” for 1500 ms. All stimuli appeared at the center of the screen.

2.1.5. Data analysis

Mean response times (RTs) for correct trials and mean percentage error rates were assessed in each of the four blocks. Trials following errors were removed, as was the first trial of each block. One participant was excluded for performing with less than 70% accuracy in one block. Indeed, this participant responded incorrectly in all incongruent trials