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More conflict does not trigger more adjustment of cognitive control for subsequent events: A study of the bivalency effect

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ABSTRACT

Encountering a conflict triggers an adjustment of cognitive control. This adjustment of cognitive control can even affect subsequent performance. The purpose of the present study was to determine whether more conflict triggers more adjustment of cognitive control for subsequent performance. To this end, we focussed on the bivalency effect, that is, the adjustment of cognitive control following the conflict induced by bivalent stimuli (i.e., stimuli with relevant features for two tasks). In two experiments, we tested whether the amount of conflict triggered by bivalent stimuli affected the bivalency effect. Bivalent stimuli were either compatible (i.e., affording one response) or incompatible (i.e., affording two different responses). Thus, compatible bivalent stimuli involved a task conflict, whereas incompatible bivalent stimuli involved a task and a response conflict. The results showed that the bivalency effect was not affected by this manipulation. This indicates that more conflict does not trigger more adjustment of cognitive control for subsequent performance. Therefore, only the occurrence of conflict – not its amount – is determinant for cognitive control.

1. Introduction

Cognitive control refers to the ability to select task-relevant features while suppressing distracting ones in the face of conflict (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004). Specifically, encountering a conflict induces an adjustment of cognitive control for the conflict-loaded trial as well as for subsequent performance (e.g., Botvinick et al., 2001; Egner, 2007; Woodward, Meier, Tipper, & Graf, 2003). So far, it is unclear whether the characteristics of the conflict – such as its amount – would affect the adjustment of cognitive control for subsequent performance. The present study is the first to investigate this question.

In their seminal account, Botvinick et al. (2001) proposed that once a conflict is detected, an adjustment of cognitive control is triggered, which can linger across subsequent trials. Importantly, they assumed that the adjustment of cognitive control "conveys only a very nonspecific type of information, indicating that the conflict has occurred in some unspecified form at some unspecified point" (p. 645). Accordingly, the characteristics of conflict are not determinant to trigger an adjustment of cognitive control.

Recent research, however, does not seem to support this claim when the characteristic is the *source of conflict* (see Egner, 2008). In those studies in which Stroop and Flanker tasks were intermixed[1], the results showed that responding to a Stroop conflict triggered an adjustment of cognitive control on subsequent performance only when the subsequent trials were Stroop trials, but not Flanker trials (see, e.g., Egner, Delano, & Hirsch, 2007; Funes, Lupiáñez, & Humphreys, 2010; Notebaert & Verguts, 2008; Schlaghecken, Refaat, & Maylor, 2011). This finding was interpreted as the result of an adjustment of cognitive control affected by the source of conflict (Egner, 2008).

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[1] In the Stroop task, participants are usually asked to indicate the color of a color word. For some stimuli, the color and the word are congruent (e.g., the word "red" written in red); for some other stimuli, the color and the word are incongruent (e.g., the word "red" written in blue). In the Flanker task, stimuli consist of strings of letters (e.g., HHH or SHS), and participants are asked to indicate the identity of the central letter. Congruent Flanker stimuli are letter strings in which the central and flanking letters are the same (e.g., HHH); incongruent Flanker stimuli are letter strings in which the central letter is different from the flanking letters (e.g., SHS). In both tasks, the results typically showed a congruence effect (i.e., a performance decrement on incongruent trials compared to congruent trials) and a congruence sequence effect (i.e., a reduction of the congruence effect after incongruent trials). The congruence sequence effect has been mainly explained by an adjustment of cognitive control, which is caused by the conflict induced by incongruent trials and which persists across subsequent trials (see Botvinick et al., 2001; Egner, 2007; Ullsperger, Bylsma, & Botvinick, 2005). However, it must be noted that this effect has also been assumed to result from other properties of incongruent stimuli than their conflict (e.g., their low perceptual fluency, see Dreisbach & Fischer, 2011; their aversive signal, see Dreisbach & Fischer, 2012; their contingency bias, see Schmidt & De Houwer, 2011; or the false expectations they induced, see Gratton, Coles, & Donchin, 1992).

The source of conflict is not the only characteristic of conflict. Another characteristic may be the *amount of conflict*. In previous studies, the amount of conflict has been found to affect the adjustment of cognitive control but only for the conflict-loaded trial. For example, when simulating a Flanker task, conflict was measured as the product of the activation of the competing responses induced by the central and flanking letters. Thus, its amount varied on each trial, depending on each activation level. The simulations revealed that reaction times (RTs) for response execution increased when the product of the activation of the competing responses – the amount of conflict – increased (e.g., Yeung, Botvinick, & Cohen, 2004; Yeung, Cohen, & Botvinick, 2011). Another way to manipulate experimentally the amount of conflict was to present either compatible or incompatible bivalent stimuli (Rogers & Monsell, 1995; Steinhauser & Hübner, 2007, 2009). Bivalent stimuli are stimuli with relevant features for two different tasks. When participants are asked, for example, to switch between a color decision (red vs. blue) and a case decision (uppercase vs. lowercase), red or blue letters are bivalent stimuli because both color and case decisions can be performed. Thus, per definition, bivalent stimuli involve a *task* conflict. Moreover, when participants are asked to press the same two response keys for both tasks, bivalent stimuli can afford either a compatible response (e.g., a right key press for both the color and case decisions) or an incompatible response (e.g., a right key press for the color decision but a left key press for the case decision). Thus, while compatible bivalent stimuli involve a task conflict only, incompatible bivalent stimuli involve both a task and a *response* conflict. Typically, performance is slower for incompatible bivalent stimuli than for compatible bivalent stimuli, which, in turn, is slower than for univalent stimuli (i.e., stimuli with relevant features for one task). This pattern of results shows that more conflict triggers a larger cost on the conflict-loaded trial. However, it remains unknown whether this larger cost persists across subsequent trials.

The purpose of the present study was to determine whether more conflict triggers more adjustment of cognitive control for subsequent performance. This question is particularly important in order to assess the original view of Botvinick et al. (2001) according to which the adjustment of cognitive control following a conflict is not affected by the characteristics of this conflict. We focussed on the adjustment of cognitive control following bivalent stimuli, which has been coined the bivalency effect (Meier, Woodward, Rey-Mermet, & Graf, 2009; Woodward et al., 2003; Woodward, Metzak, Meier, & Holroyd, 2008; see Meier & Rey-Mermet, 2012a, for a review). The paradigm typically used to investigate the bivalency effect involves three blocks with regular switches between a parity decision (odd vs. even), a color decision (red vs. blue), and a case decision (uppercase vs. lowercase; see Fig. 1). In the first and third blocks (the pure blocks), all stimuli are univalent (i.e., black numerals for the parity decision, colored symbols for the color decision, and black letters for the case decision). In the second block (the mixed block), some letters for the case decisions appear in red or blue color, which turn them into bivalent stimuli. The bivalency effect is the slowing occurring on all univalent trials following bivalent stimuli, including those sharing no relevant features with bivalent stimuli (i.e., the parity-decision trials).

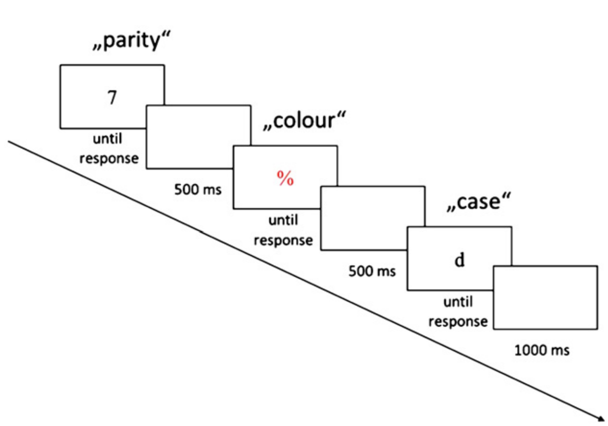

Fig. 1. Example of one univalent task triplet. Participants carried out a parity decision (odd vs. even) on numerals, a color decision (red vs. blue) on symbols, and a case decision (upper- vs. lowercase) on letters. They pressed the key *b* to respond "even", "red", and "uppercase", and the key *n* to respond "odd", "blue", and "lowercase". On a bivalent task triplet (not pictured here), the letters were presented in either blue or red.

In two experiments, we tested whether the magnitude of the bivalency effect was similar after compatible and incompatible bivalent stimuli. In Experiment 1, half of bivalent stimuli were compatible, and the other half incompatible. In Experiment 2, bivalent stimuli were compatible for half of the participants and incompatible for the other half.

We hypothesized that if the characteristics of the conflict affect the adjustment of cognitive control (see Egner, 2008; Yeung et al., 2004, 2011), more conflict would trigger more adjustment of cognitive control for the subsequent trials. In this case, the bivalency effect would be larger after incompatible than after compatible bivalent stimuli. In contrast, if only the occurrence of a conflict, but not its characteristics, affects the adjustment of cognitive control (Botvinick et al., 2001), we would not expect a modification of the bivalency effect.

2. Experiment 1

2.1. Method

2.1.1. Participants

Participants were 20 students (6 men, mean age = 21.6, *SD* = 2) from the University of Bern. The study was approved by the local ethical committee of the University of Bern.

2.1.2. Materials

For the parity decision, the stimuli were the numerals 1 through 8, each displayed in black. For the color decision, the stimuli were the symbols %, #, $, and §, each displayed in either blue or red. For the case decision, the stimuli were the upper- or lowercase consonants d, f, r, t, each displayed in black. We created a set of 16 bivalent stimuli by presenting the same four consonants (d, f, r, t) either in blue or red and either in upper- or lowercase. Specifically, red lowercase and blue uppercase letters were compatible bivalent stimuli, while red uppercase and blue lowercase letters were incompatible bivalent stimuli. All stimuli were presented at the center of the computer screen in 60-point Times New Roman font (cf. Rey-Mermet & Meier, 2012a).

2.1.3. Procedure

Participants were tested individually. They were informed that the experiment involved three different tasks: parity decisions about numerals, color decisions about symbols, and case decisions about letters. They were instructed to press one of two computer keys (*b* and *n*) with their left and right index fingers respectively, for each of the three tasks. The mapping information, printed on paper, was presented below the computer screen throughout the experiment. Participants were informed that, for some of the case decisions, the letters would be presented in either blue or red. They were specifically instructed to ignore color information and to focus on making letter decisions.

After these instructions, a block of 30 task triplets was presented for practice. Each task triplet required making a parity decision, a color decision, and a case decision, always in the same order, as illustrated in Fig. 1. The stimulus for each trial was determined randomly and was displayed until the participant responded. Then, the screen blanked for 500 ms and then the next stimulus appeared. After each task triplet, an additional blank interval of 500 ms was included. After the practice block and a brief break, each participant completed three experimental blocks without break between blocks. The first block included 32 task triplets, with the first two task triplets serving as "warm-up" triplets