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# Flexible Conflict Management: Conflict Avoidance and Conflict Adjustment in Reactive Cognitive Control

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Conflict processing is assumed to serve two crucial, yet distinct functions: Regarding task performance, control is adjusted to overcome the conflict. Regarding task choice, control is harnessed to bias decision making away from the source of conflict. Despite recent theoretical progress, until now two lines of research addressed these conflict-management strategies independently of each other. In this research, we used a voluntary task-switching paradigm in combination with response interference tasks to study both strategies in concert. In Experiment 1, participants chose between two univalent tasks on each trial. Switch rates increased following conflict trials, indicating avoidance of conflict. Furthermore, congruency effects in reaction times and error rates were reduced following conflict trials, demonstrating conflict adjustment. In Experiment 2, we used bivalent instead of univalent stimuli. Conflict adjustment in task performance was unaffected by this manipulation, but conflict avoidance was not observed. Instead, task switches were reduced after conflict trials. In Experiment 3, we used tasks comprising univalent or bivalent stimuli. Only tasks with univalent revealed conflict avoidance, whereas conflict adjustment was found for all tasks. On the basis of established theories of cognitive control, an integrative process model is described that can account for flexible conflict management.

*Keywords:* cognitive control, conflict monitoring, task switching, Gratton effect, outcome evaluation

*Supplemental materials:* http://dx.doi.org/10.1037/xlm0000089.supp



Cognitive control is the ability to regulate thoughts and behavior according to goals. Cognitive control becomes necessary when goal-directed and impulsive-action tendencies collide. In such situations, people can manage a conflict in two different ways: They can either invest more effort in the current task to overcome the conflict (*conflict adjustment*; e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001), or they can avoid conflict by switching to another task (*conflict avoidance*; e.g., Holroyd & Coles, 2002). These two conflict management strategies are the result of partially incompatible constraints on action control.[1] The importance to maintain an adequate balance of stability and flexibility becomes obvious when the conflict management strategies are out of balance (Allport, 1989; Goschke, 2000). For example, some patients with frontal lobe damage show so-called "preservation errors" in tasks that require an updating and maintenance of varying task rules (e.g., the Wisconsin card sorting task). These patients suffer from a deficit in flexibility (Milner, 1963). In contrast, other patients with frontal lobe damage suffer from a deficit in stability and show shortcomings to resist goal incompatible action tendencies triggered by some object irrespective of the current goal (Duncan, 1986; Lhermitte, 1983). To understand these failures of control better, a first step is to specify how cognitive control mechanisms of healthy participants orchestrate flexibility and stability constraints on behavior.

Although theories have repeatedly stressed the importance of both strategies for cognitive control (e.g., Botvinick, 2007; Goschke, 2013), they were rarely investigated jointly in a single paradigm. To fill this gap, the present study used a voluntary task-switching paradigm that allowed us to probe both conflict-management strategies simultaneously. Following conflict trials, participants could choose to switch to another task, exhibiting conflict avoidance. In addition, and independently of an avoidance tendency, participants could also put more effort in the response performance in a subsequent trial, exhibiting conflict adjustment. The setup thus allowed us to examine whether participants use only one conflict management strategy or whether they make use

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[1] *Strategy* is here used in line with Gratton, Coles, and Donchin (1992) who stated that in conflict situations

> the choice of the level of processing to adopt for initiating or completing overt responses, or both, may be strategic: That is, several courses of action are possible, and the subject's choice of which course of action to adopt is dictated by an analysis of the costs and benefits (i.e., the relative utility) associated with each choice. (p. 480)

Furthermore the author's clarify that the "choice of a strategy may be conscious or deliberate. However, this is not necessarily the case, because the selection of a particular strategy may reflect the operation of some adjustment mechanism that is not under conscious control" (p. 480).

of both strategies. In the following section, we briefly review the relevant research literature on conflict adjustment and conflict avoidance. Then, we spell out a critical distinction of two control modes, over and above the different conflict management strategies, before we introduce the specifics of our paradigm.

## Conflict Adjustment: The Conflict Monitoring Account

When people detect conflict, they often increase effort to overcome the conflict (Ach, 1932). Evidence for this strategy comes from tasks in which the selection of a correct response to a target conflicts with automatic response tendencies instigated by an irrelevant task feature, such as the spatial position of a target (Simon task; Simon, 1969) or the perception of distracter stimuli (Flanker task; Eriksen & Eriksen, 1974). Responses are typically faster and less error prone in these tasks when the irrelevant feature affords the same response as the target (congruent trials) compared with when they afford different responses (incongruent trials), producing a congruency effect (Kornblum, Hasbroucq, & Osman, 1990).

Gratton, Coles, and Donchin (1992) demonstrated in a seminal study that the size of the congruency effect is influenced by the congruency level of the previous trial. When the previous trial was incongruent, the congruency effect was reduced in the current trial compared with when the previous trial was congruent (i.e., the so-called Gratton effect; see also Akcay & Hazeltine, 2007; Kerns et al., 2004). The Gratton effect is a well-established marker for increased adjustment to conflict that is sensitive to a broad range of cognitive control deficits (see, e.g., Clawson, Clayson, & Larson, 2013; Clayson & Larson, 2013; Larson, Clawson, Clayson, & Baldwin, 2013; Patino et al., 2013).

The conflict monitoring account by Botvinick and colleagues (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004) explains the Gratton effect with an automatic increase of mental effort after a conflict situation. A conflict is solved by strengthening the representation of relevant task features (Egner & Hirsch, 2005) and by weakening or inhibiting (Stürmer et al., 2002) the representation of irrelevant task features. Consequently, irrelevant task features instigating conflicting action tendencies have less influence on task performance in the subsequent trial.

## Conflict Avoidance: The Outcome Evaluation Account

A second strategy to deal with conflict is active avoidance of a conflict situation. Evidence for this strategy comes mainly from studies that investigated the modulation of the error-related negativity (ERN), a negative deflection in the event-related potential that peaks shortly after subjects made in incorrect response (Gehring, Coles, Meyer, & Donchin, 1995) or after subject received feedback that is indicative of an error (Miltner, Braun, & Coles, 1997). Nieuwenhuis, Yeung, Holroyd, Schurger, and Cohen (2004) showed that the ERN is sensitive to reward signals and is used as a reward-prediction error that guides task selection in the upcoming task (see also Frank, Woroch, & Curran, 2005). Theories have explained such avoidance effects with reinforcement learning theory (Holroyd & Coles, 2002). The anterior cingulate cortex (ACC) registers and evaluates (negative) outcomes and uses this information for action selection.

Botvinick and coworkers developed task procedures in which participants can choose between two response options that are associated with different levels of conflict (Botvinick & Rosen, 2009; Kool, McGuire, Rosen, & Botvinick, 2010). When participants experienced conflict frequently in one task and less frequently in another task, they preferred the easier task and chose the effortful one less frequently. These experiments showed that people learn over time to avoid conflict when possible.

## An Integrative Framework of Conflict Management

Adjustment and avoidance have often been understood as mutually exclusive strategies to deal with conflict situations (see e.g., Nachev, 2006). Botvinick (2007; see also Shenhav, Botvinick, & Cohen, 2013) recently extended the conflict monitoring account to integrate both strategies in one model. According to this model, conflict generates an aversive signal that is detected in the ACC. This aversive signal is subsequently used for a strengthening of task sets to adjust control settings to conflict and at the same time used to bias task selection to avoid conflict. Supportive evidence for an aversive experience of conflict comes from a study by Dreisbach & Fischer (2012; Fritz & Dreisbach, 2013; see also Van Steenbergen, Band, & Hommel, 2009). In this study, congruent and incongruent Stroop displays were presented as primes, and positive and negative stimuli served as targets. Responses to negative targets were faster after priming with incongruent Stroop primes relative to priming with congruent Stroop primes, and vice versa, with responses to positive targets. Furthermore, Schouppe, De Houwer, Ridderinkhof, and Notebaert (2012) argued that the detection of conflict triggers avoidance actions. In this study, participants moved a virtual manikin either toward or away from a color word according to a specific mapping. Results revealed that avoidance actions were faster and less error prone in response to incongruent stimuli compared with in response to congruent stimuli. These research findings support the assumption that conflict situations are aversive, prompting participants to seek out responses that avoid these situations (Botvinick, 2007).

According to Botvinick (2007; see also Dreisbach & Fischer, 2011), the detection of a conflict signal in the ACC can trigger adjustment and avoidance strategies simultaneously in a behavioral task: Conflict increases compensatory adjustments in control and motivates avoidance of a conflict task. For an empirical test of the contributions of both strategies to conflict management, it is necessary (1) to examine separate behavioral markers of each strategy, and (2) to set up task conditions that allow for a simultaneous use of both strategies.

## Behavioral Markers for Adjustment to and Avoidance of Conflict

The research literature has used different dependent variables for an operationalization of the two conflict-management strategies. Conflict adjustment is typically indexed by a systematic change in task-performance measures (reaction time [RT], error rates) such as the previously mentioned Gratton effect. An enhanced Gratton effect indicates a stronger recruitment of cognitive control in the service of an adjustment to the current task demands. Avoidance of conflict is typically indexed by systematic preferences or changes in the choice of tasks (switch rates).

A straightforward operationalization of conflict management strategies is however complicated by the fact that cognitive control functions can involve distinct mechanisms: a reactive control mode and proactive control mode (Braver, 2012; Koriat, Ma'ayan, Nussinson, 2006). A *proactive control mode* refers to a sustained and anticipatory maintenance of goal relevant information. It is assumed to operate on a longer time scale and relies on learning processes (Braver et al., 2009; Verguts & Notebaert, 2009). In contrast, the *reactive control mode* reflects a transient stimulus-driven goal activation operating on a short timescale (Braver et al., 2009). Botvinick's (2007) account conceptualized adjustment to conflict as a transient effect that is based on reactive control, whereas avoidance is usually assessed on the basis of learning, relying on proactive control. For example, in the demand selection task, avoidance of the more conflict associated option gradually accumulates over time (see Botvinick, 2007; Kool et al., 2010). Thus, this sustained, anticipatory effect of conflict on cognitive control fits nicely with a proactive but not a reactive control mode. In contrast, the adjustment to conflict strategy as indicated by the Gratton effect is the result of a very short-lived, transient control process. Thus, the Gratton effect fits nicely with a reactive but not a proactive control mode. Given the fact that proactive and reactive control are clearly dissociable on a functional (Funes, Lupiáñez, & Humphreys, 2010) and neurophysiological level (Braver et al., 2009), we were cautious whether a first test of the simultaneous implementation of the two control strategies would be complicated if different modes of control were mixed. To circumvent the problem of different control modes, we decided to restrict our analyses to reactive control and strived to come up with a behavioral marker for conflict avoidance that operates in a reactive fashion.

Given the observation by Schouppe et al. (2012) that conflict facilitates a motivational tendency on a trial-by-trial level, we reasoned that this effect should generalize to decision making. Thus, we expected that participants should switch away from a task after experiencing a conflict, even though both tasks had an equal probability of conflict. Please note that this effect cannot be explained with proactive control because learning is not possible in our task, and conflict avoidance must proceed in a trial-by-trial fashion. A strong bias to switch to another task after a conflict trial would thus indicate a reactive action tendency to escape from an immediately experienced conflict situation.

## Probing Adaption and Avoidance in a Single Paradigm

For a test of both conflict management strategies, an experimental setup is required that allows participants to apply both strategies simultaneously. This was not the case in previous studies examining one strategy or the other. For example, conflict adjustment is typically investigated with response interference tasks that examine variations in performance as a function of the previous conflict level (e.g., Gratton effect) without task choice. Thus, avoidance of conflict is not possible in these paradigms. On the other hand, conflict avoidance is typically investigated with tasks in which participants can choose between two tasks that are associated with different levels of conflict. This setup measures effects on task choice as a function of conflict probability (e.g., conflict avoidance); however, adjustment to conflict was not investigated with these paradigms.

To allow participants to apply both conflict management strategies, we combined response-interference tasks with a variation of the voluntary task-switching (VTS) paradigm (Arrington & Logan, 2004, 2005). In a standard VTS paradigm, participants view a series of bivalent stimuli and decide which of two available tasks they want to perform on a target stimulus on each trial. Participants are free to select the task to perform but are instructed to avoid a predictable pattern of choices and to choose both tasks an approximately equal number of times. In the VTS paradigm, task choice is measured in addition to performance-related variables (RTs, error rates), and a typical finding is a strong bias to repeat a previously selected task (Arrington & Logan, 2004, 2005; Liefooghe, Demanet, & Vandierendonck, 2009).

Orr, Carp, and Weissman (2012) used a VTS paradigm in combination with two conflict tasks. In their experiment, a small digit (e.g., *1*) and a large digit (e.g., *9*) were presented simultaneously on an upper and a lower position on the screen. One of the digits was shown in a small font and the other in a large font, creating incongruent (i.e., small digits in large font; large digits in small font) and congruent stimulus displays (i.e., small digits in small font; large digits in large font). Participants were to indicate whether the top or the bottom digit is larger by responding to either the numerical size or to the font size of the digits. It is important to note that the decision was free in each trial regardless of whether participants chose to perform the magnitude task or the size task. The experimental design of Orr et al. (2012) allows for a simultaneous test of both conflict strategies. However, the results provided evidence for the conflict adjustment strategy only. A Gratton effect was observed in the RTs, suggesting that participants invested more effort in a task following a conflict trial. Contrary to the assumption of an avoidance strategy, participants repeated the same task more often after a conflict trial than after a nonconflict trial. The authors interpreted the latter finding as further evidence for conflict adjustment, which affects not only performance-related measures but also task choice.

However, characteristics of the stimulus material used by Orr and colleagues (2012) can explain why results did not show avoidance after conflict.[2] Consider a conflict trial in which the magnitude task is performed on an incongruent stimulus pair (e.g., the digit *3* in large font, and the digit *7* in small font). Such a bivalent stimulus affords both the magnitude and the size task at the same time. For a resolution of conflict, the representation of the numerical size must be strengthened and the representation of the font size must be weakened. Consequently, the likelihood that the now-dominant magnitude task is repeated in a subsequent trial is increased, whereas the likelihood for a switch to the now-inhibited size task is decreased. The mutual influence of task representations in bivalent tasks (i.e., between-task interference) can explain the tendency to repeat tasks after a conflict trial. Participants could not avoid conflict because bivalent stimuli entailed relevant attributes for both tasks.

[2] It should be noted that the study by Orr et al. (2012) was not meant as a test for both conflict strategies but was designed as an exclusive test of an adjustment strategy (conflict monitoring account).

## Purpose of the Present Research

As set out above, what is missing is a paradigm that provides empirical evidence for the simultaneous implementation of two different control strategies. The present article suggests such a paradigm (see Figure 1 for illustration). Participants switched voluntarily between two univalent response-interference tasks. We measured task choice (switch rates) as an index of conflict avoidance. Performance-related measures (RT, error rate) indexed conflict adjustment. As we show in following paragraphs, conflict adjustment in performance measures and conflict avoidance in choice rates are jointly observed with this paradigm (Experiment 1). Experiment 2 presented bivalent instead of univalent stimuli, reproducing the experimental condition of Orr et al. (2012). Adjustment to conflict found in performance measures was not affected by this manipulation, but critically choice rates revealed a tendency to repeat tasks following conflict, reproducing the finding of Orr and colleagues. Experiment 3 tested directly our prediction that task-switch rates following conflict are reduced for bivalent stimulus sets, whereas switch rates after conflict are increased for univalent stimuli. In this experiment, participants could select between a task with univalent stimuli and a task with bivalent stimuli. As expected, conflict avoidance in choice rates was found for the task with univalent stimuli but not for the task with bivalent stimuli. Conflict adjustment in performance measures (RTs, errors) was robust irrespective of the use of univalent and bivalent stimuli.

## Experiment 1

Experiment 1 probed conflict avoidance and conflict adjustment jointly. In each trial, participants freely decided whether they wanted to perform a flanker task or a Simon task. Participants responded in the flanker task to the identity of a centrally presented target letter that was flanked by distracter letters. In the Simon task, digits were presented on the left and right side of the computer screen and were categorized as less than or greater than five. Both categorization tasks involved presentations of univalent stimuli. More precisely, task-relevant stimulus dimensions (i.e., letter identity for the flanker task and numerical size for the Simon task) and task-irrelevant stimulus dimensions (i.e., flanker stimulus for the flanker task and spatial location for the Simon task) were clearly distinct and did not overlap across tasks.

Task choice (switch rates) was used as an index of conflict avoidance. If participants respond with an avoidance strategy, task switches should be more frequent after (incongruent) conflict trials relative to (congruent) nonconflict trials. Task performance (RT, error rate) was used as an index for conflict adjustment. If participants use an adjustment strategy, a Gratton effect should be observed.

### Method

**Participants.** Thirty-eight participants (32 women, 18–42 years old) were paid for participation. Exclusion criteria were the same for all reported experiments. Data from participants were removed from analyses when the number of task switches in the voluntary task-switching procedures was too high or too low (proportion of task repetitions $<$5% or $>$95%). One participant in Experiment 1 was excluded due to this criterion. Furthermore, data sets were excluded from participants who produced extremely long series of task repetitions and/or task switches that resulted in empty cells for some conditions. Two participants in Experiment 1 were excluded because of this criterion.

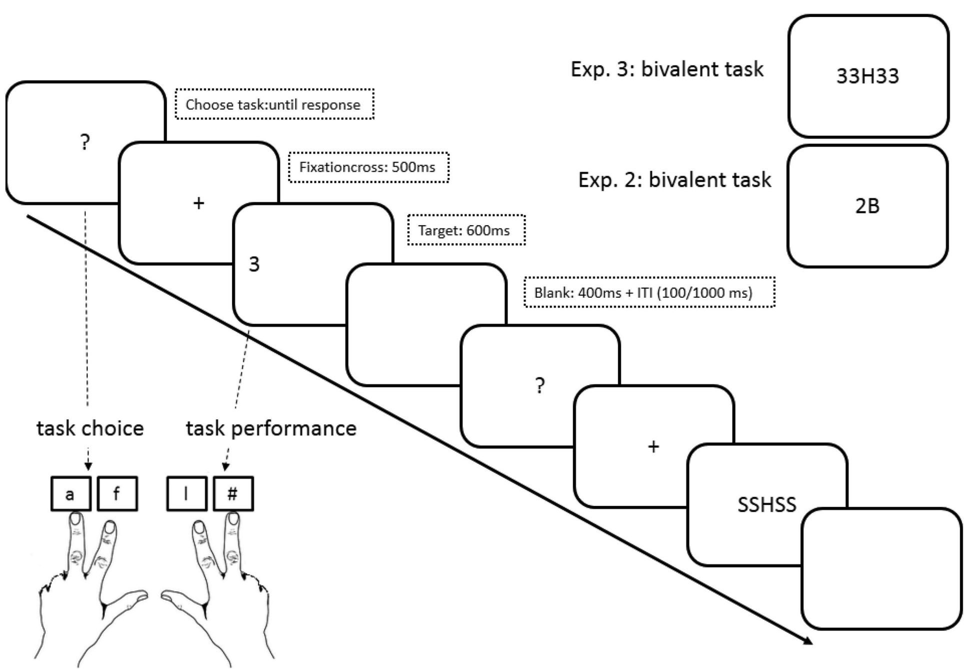


*Figure 1.* Trial sequence in Experiment 1 with univalent tasks. Examples for bivalent stimuli in Experiment 2 and 3 are depicted in the upper right corner.

Finally, participants with extremely high error rates (>3 standard deviations) were excluded. This criterion led to a removal of two participants in Experiment 1.

**Stimuli.** The letters *H* and *S* served as targets (presented at a central position) and as flanker stimuli (presented at lateral positions) for the flanker task. Digit numbers were categorized as smaller (digits 1–4) and larger (digits 6–9) than 5 in the Simon task. The digit appeared on the left or right side of fixation on the computer screen.

**Procedure.** After 50 practice trials of each task (counterbalanced task order), participants were informed that they can now choose freely which of the two tasks they want to perform in a given trial. However, it was also stated that they should select each task about equally often without using a strategy (for a similar procedure see Arrington & Logan, 2004). We used a double-registration procedure (Arrington & Logan, 2005, Experiment 6; Orr et al., 2012). More precisely, participants indicated their task choice by pressing the keys *A* and *F* using the index and middle fingers of their left hand. Participants performed the interference tasks using the index and middle finger of their right hand by pressing the *1* and *#* keys that were marked with green color patches. The task to key mapping and the stimulus to key mapping in both tasks were counterbalanced across participants.

Figure 1 shows the sequence of events in an experimental trial. A question mark was presented on the screen until a task was selected with a corresponding key press. Then a fixation cross appeared for 500 ms followed by a flanker or a Simon display. After 600 ms, a blank screen was presented until response registration. In cases of anticipated (RT <100 ms), incorrect, or late response (RT >1000 ms) an error message appeared for 1000 ms. The next trial started after a variable intertrial interval of either 100 or 1000 ms. The experiment consisted of 10 blocks of 50 trials. After each block, participants received feedback about the proportion of task choices.

## Results

The first trial in each block was not analyzed. Trials with erroneous responses (13.4%) and posterror trials (9.4%) were discarded from the RT and switch-rate analyses. In addition, RTs were removed that exceeded more than 3 standard deviations from the cell mean for each condition (0.3%).

**Task choice.**

***Switch rates.*** In line with the task instructions, both tasks were selected about equally often (Simon task: $M$ = 49.5%; flanker task: $M$ = 50.4%), $t(32) = 1.02$, $p = .311$). The mean switch rate was 32.5%. This result is in line with previous VTS studies that observed an analogous bias to repeat a previously performed task (see, e.g., Arrington & Logan, 2004).

Following the analyses of Orr et al. (2012), a repeated-measures analysis of variance (ANOVA) with the factors *previous congruency* (congruent, incongruent), *previous task transition* (repeat, switch), and *previous task* (Simon, flanker) was used to analyze the switch rates. This analysis revealed a main effect of previous congruency. Participants switched tasks after an incongruent trial ($M$ = 33.3% switches) more often than after a congruent trial ($M$ = 30.9% switches), $F(1, 32) = 5.16$, $p = .030$, $\eta_p^2 = .139$. This effect in the switch rates is in line with an avoidance strategy. Conflict avoidance was further qualified by an interaction with previous task transition, $F(1, 32) = 9.15$, $p = .005$, $\eta_p^2 = .223$. Participants switched tasks more often after incongruent trials compared with congruent trials when the previous trial involved a task alternation, $t(32) = 3.01$, $p = .005$, relative to conditions in which the previous trial involved a task repetition, $t(32) = -.57$, $p = .569$ (see Figure 2).

**Task performance.**

***Reaction times.*** A repeated-measures ANOVA with the factors *previous congruency* (congruent, incongruent), *current congruency* (congruent, incongruent) and *current task* (Simon, flanker), yielded a significant main effect of current congruency, $F(1, 32) = 121.95$, $p < .001$, $\eta_p^2 = .792$. Responses were faster in congruent trials ($M$ = 497 ms) compared with incongruent trials

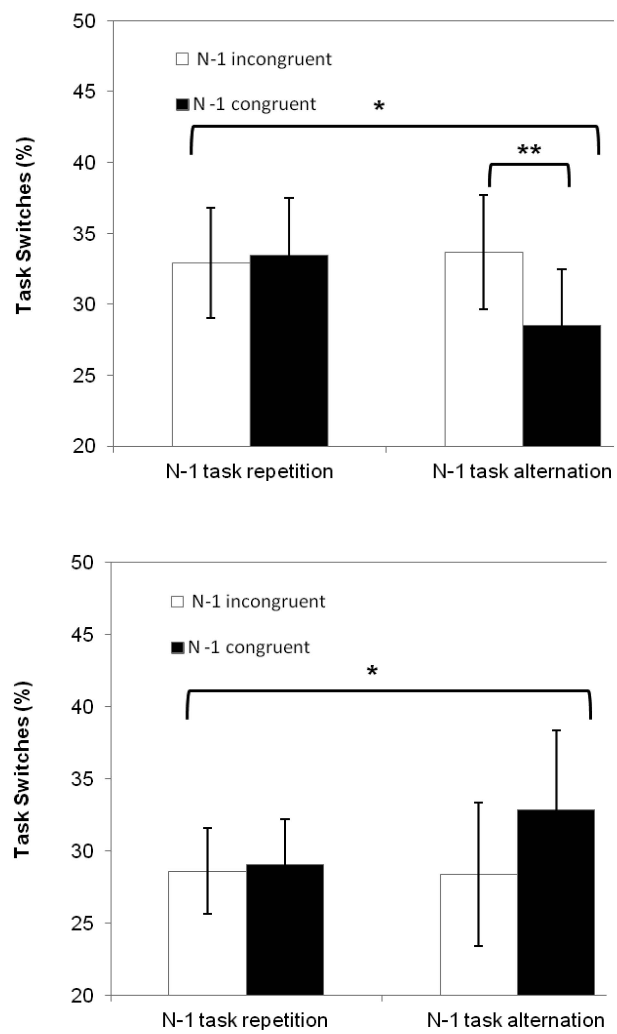


*Figure 2.* Switch rates with univalent tasks in Experiment 1 (upper panel) and with bivalent tasks in Experiment 2 (lower panel) as a function of congruency in the previous trial (*N*–1). † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$. Error bars show standard errors of the mean.

($M$ = 523 ms).[3] The main effect of current task was also significant, $F(1, 32) = 208.44$, $p < .001$, $\eta_p^2 = .792$. Responses were faster in flanker trials ($M$ = 474 ms) compared with Simon trials ($M$ = 546 ms). The interaction between current task and current congruency was significant, $F(1, 32) = 44.96$, $p < .001$, $\eta_p^2 = .584$. The congruency effect was stronger in the flanker task than in the Simon task. More important, a Gratton effect was observed as indexed by a significant interaction between previous congruency and current congruency, $F(1, 32) = 22.77$, $p < .001$, $\eta_p^2 = .416$ (see Table 1). The congruency effect was reduced after a previous incongruent trial compared with a previous congruent trial. This Gratton effect indicates an adjustment strategy.

***Error rates.*** An analogous ANOVA of the error rates revealed a main effect of current congruency, $F(1, 32) = 28.61$, $p < .001$, $\eta_p^2 = .472$, showing that participants made fewer errors in congruent trials ($M$ = 7.7%) compared with incongruent trials ($M$ = 11.4%). The main effect of current task was also significant, $F(1, 32) = 13.83$, $p < .001$, $\eta_p^2 = .302$. Participants made fewer errors in flanker trials ($M$ = 8.4%) compared with Simon trials ($M$ = 10.7%).

The Gratton effect, indicated by the interaction between previous congruency and current congruency was significant, $F(1, 32) = 17.22$, $p < .001$, $\eta_p^2 = .350$. This interaction was further qualified by a three-way interaction between previous congruency and current congruency and current task, $F(1, 32) = 6.28$, $p = .017$, $\eta_p^2 = .164$. The Gratton effect was stronger for the Simon task compared with the flanker task.

## Discussion

Experiment 1 provided clear evidence that people can adjust to and avoid conflict situations simultaneously in one task, suggesting some flexibility in the management of conflict situations. A Gratton effect was observed for task performance (RTs and error rates), indicating reactive adjustment to conflict. In addition, for task choice more switches after a conflict trial in task alternation trials were observed, indicating reactive avoidance of conflict.

It is interesting to note that task avoidance was particularly strong after a previous task alternation. Task-set priming ("autogenous priming") can account for this effect (Monsell, Sumner, & Waters, 2003). Task-set priming occurs from repeating the same task in succession. Ruthruff, Remington, and Johnston (2001; see also Sumner & Ahmed, 2006) observed increased switch costs in a series of task repetitions. Thus, task repetition may have increased the activation level of the repeated task. This enhanced activation of a repeated task may then have overshadowed an impulse to switch to another task following a conflict. This overshadowing is however absent after task switches, explaining why avoidance of conflict was strongest in this condition (see the General Discussion for a more thorough treatment of this point).

# Experiment 2

The goal of Experiment 2 was to test the assumption that conflict avoidance can only be observed with tasks that use univalent stimuli but not with tasks that use bivalent stimuli (Orr et al., 2012). As outlined in the introduction, bivalent stimuli afford responses for both tasks and thus cause between-task interference. Experiment 2 used similar procedures as Experiment 1 with the major change that a bivalent stimulus set was used in this study. In each trial, a digit and a letter appeared centrally on the computer screen (cf. Rogers & Monsell, 1995). Participants could freely decide whether they wanted to perform the letter task or the digit task. In the letter task, participants were to categorize the letter as one of the first four letters of the alphabet by pressing one button or as one of the last 4 letters of the alphabet by pressing the other button. In the digit task, participants were to categorize the numbers as less or greater than five. Thus, the stimuli were bivalent in respect to both categorization tasks.

As in Experiment 1, we assessed a Gratton effect in task performance (RT and error rates) as an index for conflict adjustment. However, as shown by Orr and colleagues (2012) bivalent stimuli impede possible avoidance. Instead, participants should persist with the previous active task after conflict; hence switch rates should be lower after a conflict trial compared with a nonconflict trial.

## Method

**Participants.** Fifty participants (39 women, 18–54 years) were paid for participation. We excluded data from nine participants because of an inadequate number of task switches and five participants because of an extremely long series of task repetitions and/or task switches.

**Stimuli and procedure.** Experiment 2 resembles Experiment 1 except for the following changes. The letters *A, B, C, D* and *V, W, X, Y* served as targets for the letter task. The digits 1–4 and 6–9 were targets for the digit task. Letters and digits were printed in white. In each trial, one letter and one digit was presented at a central position next to each other.

## Results

The first trial in each block was not analyzed. Trials with erroneous responses (13.4%). and post-error trials (10.7%) were discarded from analyses of RTs and switch rates. In addition, RTs were removed that exceeded more than 3 standard deviations from the mean (0.9%).

**Task choice.**

***Switch rates.*** Both tasks were selected about equally often (Simon task: $M$ = 50.7%; flanker task: $M$ = 49.2%), $|t| < 1$. The mean switch rate was 30.4%.

An ANOVA with the factors previous congruency (congruent, incongruent), previous task transition (repeat, switch), and previous task (letter, number) revealed more frequent task switches after a congruent trial ($M$ = 30.6% switches) than after an incongruent

[3] In contrast to Orr et al. (2012), we did not include the factors response-cue-interval (RCI) and current task transition in the analysis. Exploratory analysis showed that RCI did not interact with any of the effects of interest in the experiments. Including this factor resulted in empty cells for some conditions, leaving a much smaller dataset for analyses. The same applies to current task transition. After including this factor we observed typical switch costs. Critically, none of these factors influenced adjustment effects in the performance data or avoidance effects in the switch rates.

Table 1
*Means (and Standard Deviations in Parentheses) of Reaction Times (in ms) and Error Rates (in Percentages) in Each Experiment as a Function of Congruency in the Previous Trial and Congruency in the Present Trial*

| Trial Type | Experiment 1 | | Experiment 2 | | Experiment 3 | |
|---|---|---|---|---|---|---|
| | RT | Error rate | RT | Error rate | RT | Error rate |
| Incongruent trial following an incongruent trial (iI) | 521 (11) | 10.2 (0.7) | 515 (7) | 13.7 (0.1) | 543 (7) | 10.3 (0.7) |
| Congruent trial following an incongruent trial (iC) | 502 (10) | 8.4 (0.7) | 515 (7) | 10.6 (0.1) | 538 (7) | 9.5 (0.7) |
| Incongruent trial following a congruent trial (cI) | 525 (9) | 12.6 (0.9) | 518 (7) | 15.0 (0.1) | 547 (7) | 11.3 (0.8) |
| Congruent trial following a congruent trial (cC) | 491 (10) | 7.0 (0.7) | 512 (7) | 10.9 (0.1) | 529 (7) | 8.0 (0.6) |
| Gratton effect: (cI−cC) −− (iI)− (iC) | $15^{***}$ | $3.7^{***}$ | $6^{*}$ | 0.9 | $13^{***}$ | $2.4^{**}$ |

*Note.* Standard deviations are shown in parentheses. Gratton effects were computed by subtracting congruency effects following incongruent trials From congruency effect following congruent trials.
$^{\dagger}$ $p < .10$. $^{*}$ $p < .05$. $^{**}$ $p < .01$. $^{***}$ $p < .001$.

trial ($M$ = 28.8% switches), $F(1, 35) = 4.36$, $p = .044$, $\eta_p^2 = .111$. No other effects reached significance.

**Task performance.**

***Reaction times.*** An ANOVA with the factors previous congruency (congruent, incongruent), current congruency (congruent, incongruent) and current task (letter, number) yielded a significant main effect of current task, $F(1, 35) = 5.77$, $p = .022$, $\eta_p^2 = .142$. Responses were faster in the digit task ($M$ = 512 ms) compared with the letter task ($M$ = 518 ms). A Gratton effect was observed as indexed by a significant interaction between previous congruency and current congruency, $F(1, 35) = 4.22$, $p = .047$, $\eta_p^2 = .108$. Surprisingly, the main effect for current congruency was not significant. A follow-up test revealed that this was due to the Gratton effect. After previous compatible trials the difference between congruent trials ($M$ = 512 ms) and incongruent trials (518 ms) was significant, $t(35) = 2.92$, $p = .006$, but not after previous incompatible trials $t < 1$ (see Table 1).

***Error rates.*** An analogous ANOVA of the error rates revealed only a main effect of current congruency, $F(1, 35) = 21.69$, $p < .001$, $\eta_p^2 = .383$. Participants made fewer errors in congruent trials ($M$ = 10.7%) compared with incongruent trials ($M$ = 14.4%). All other effects were not significant.

## Discussion

In Experiment 2, conflict adjustment as indexed by a Gratton effect was similar to Experiment 1. However, the conflict avoidance strategy was not observed when tasks consisted of bivalent stimuli. Instead, reproducing the findings of Orr et al. (2012), participants switched tasks more frequently after nonconflict trials. Arguably, this effect is due to between-task interference. Bivalent stimuli afford responses for both tasks. To resolve this between-task interference, the representation of the currently relevant task must be strengthened and the representation of the currently irrelevant task must be weakened. As a consequence, a switch to this task is less likely.

# Experiment 3

Experiment 3 tested more directly the assumption that avoidance of conflict is reflected in switch rates for univalent stimuli but not for bivalent stimuli. We modified the flanker task of Experiment 1 in a way that the task involved presentations of bivalent stimuli. In Experiment 3, the distracter stimuli surrounding the target (*S* or *H*) in the flanker task were digit numbers that were also used as targets in the (univalent) Simon task. Thus, the stimulus displays were bivalent for the flanker task and univalent for the Simon task. We hypothesized that a conflict in the bivalent flanker task is solved by weakening the (irrelevant) number representation and thus affecting both tasks. In contrast, conflict in the univalent Simon task is solved by weakening the representation of the (irrelevant) location. Overcoming this conflict should not affect the alternative flanker task. Hence, participants should show increased switch rates after conflict compared with nonconflict trials after performing the univalent Simon task but reversed pattern for the bivalent flanker task. Statistically this should become apparent in a three-way interaction for switch rates among previous congruency, previous task, and previous switch.

## Method

**Participants.** Sixty students (43 women, 19–36 years) were paid for their participation. We excluded data from nine participants because of a failure to produce an adequate number of task switches in the voluntary task switching procedures (proportion of task repetitions below 5% or above 95%). Furthermore we excluded three participants who showed extremely long series of task repetitions and/or task switches that resulted in empty cells for some conditions. In addition, we had to exclude data of four participants due to an error of the experimenter who labeled the response keys incorrectly.

**Stimuli and procedure.** Experiment 3 was identical to Experiment 1 with the single exception that flanker stimuli were now the numbers 1–4 and 6–9. These digits also served as targets in the Simon task. Congruency in the bivalent flanker task was defined in respect to the responses to the digits in the Simon task.

## Results

The first trial in each block was removed from the analyses. Trials with erroneous responses (9.4%) and post-error trials (8.8%) were discarded from the RT and switch-rate analyses. Furthermore, RTs that exceeded more than 3 standard deviations from the mean were excluded from analyses (0.3%).

**Task choice.**

***Switch rate.*** Participants chose the bivalent flanker task and the univalent Simon task about equally often (Simon task: 49.9%,

|t| < 1). Like in Experiments 1 and 2, there was a tendency to repeat the previously performed task (switch rate: 37.2%).

An ANOVA with the factors previous congruency (congruent, incongruent), previous task transition (repeat, switch), and previous task (univalent Simon task, bivalent flanker task) revealed only a significant three-way interaction, $F(1, 43) = 5.07$, $p = .029$, $\eta_p^2 = .106$. As expected, task switches after a previous incongruent trial were more frequent after performing the univalent Simon task but not after performing the bivalent flanker task (see Figure 3). Like in Experiment 1, the conflict-avoidance effect in the univalent Simon task was restricted to trial sequences with previous task alternations: After a previous task alternation, participants working on the univalent Simon task switched more frequently to the bivalent flanker task following incongruent ($M = 36.7\%$) relative to congruent Simon trials ($M = 33.7\%$) $t(43) = 1.83$, $p = .036$ (one-tailed), whereas no difference was observed after a previous task repetition. Working on congruent and incongruent trials in the bivalent flanker task had no effect on switch rates (all $p$s > .41).

**Task performance.**

***Reaction times.*** An ANOVA with previous congruency (congruent, incongruent), current congruency (congruent, incongruent), current task (univalent Simon, bivalent flanker) as factors revealed a main effect of current congruency, $F(1, 43) = 24.19$, $p < .001$, $\eta_p^2 = .360$, and a main effect of current task, $F(1, 43) = 384.75$, $p = .001$, $\eta_p^2 = .899$. Participants responded faster in congruent trials ($M = 533$ ms) than in incongruent trials ($M = 545$ ms) and faster in the bivalent flanker task ($M = 494$ ms) than in the univalent Simon task ($M = 584$ ms).

A Gratton effect was observed, as indexed by a significant two-way interaction between current congruency and previous congruency, $F(1, 43) = 14.77$, $p < .001$, $\eta_p^2 = .256$. Furthermore, the two-way interaction between previous congruency and current task was significant, $F(1, 43) = 4.35$, $p = .043$, $\eta_p^2 = .092$. The three-way interaction between current congruency, previous congruency, and current task reached significance, $F(1, 44) = 9.34$, $p = .004$, $\eta_p^2 = .179$. In the univalent Simon task a robust Gratton effect was found (24 ms), but not in the bivalent flanker task (1 ms).

***Error rates.*** An analogous analysis of the error rates corroborated the results of the RT analyses. The main effects of current congruency, $F(1, 43) = 14.64$, $p < .001$, $\eta_p^2 = .254$, and current task, $F(1, 43) = 26.42$, $p < .001$, $\eta_p^2 = .381$, were significant. There were less errors in congruent trials ($M = 8.7\%$) than in incongruent trials ($M = 10.8\%$), and responses were more accurate in the bivalent flanker task ($M = 7.7\%$) than in the univalent Simon task ($M = 11.8\%$). A Gratton effect was observed in the error rates as indicated by a significant two-way interaction between the factors current congruency and *previous congruency*, $F(1, 43) = 8.31$, $p = .006$, $\eta_p^2 = .162$ (see Table 1 for descriptive statistics).

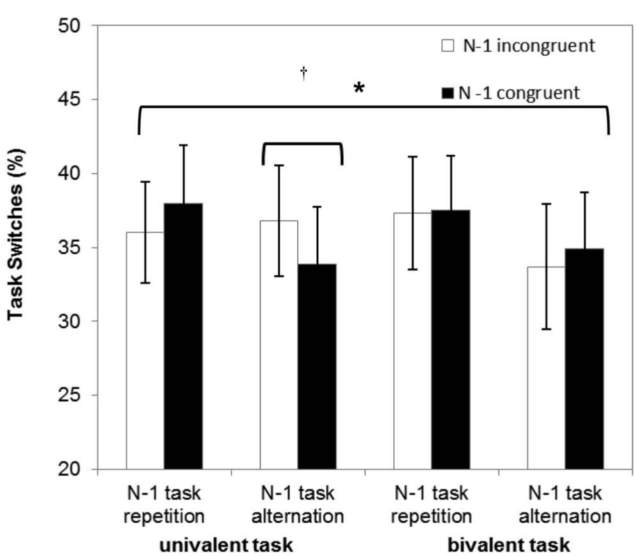


*Figure 3.* Switch rates in Experiment 3 as a function of task bivalence, previous congruency (*N*–1), and previous task repetition. Error bars show standard errors of the mean. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

## Discussion

Experiment 3 tested the assumption that tasks with univalent but not bivalent stimuli reveal avoidance of conflict. Participants switched between a univalent Simon task and a bivalent flanker task. Conflict in the univalent Simon task was unrelated to the bivalent flanker task, whereas a conflict in a bivalent flanker task resulted from stimuli that were relevant for the Simon task. Switch rates were more frequent after conflict in the univalent Simon task. Again, conflict avoidance became only apparent after a previous task alternation, possibly because task-set priming masked effects of conflict avoidance after previous task repetition trials. However unexpectedly, switch rates were not altered by previous conflict or nonconflict trials in the bivalent flanker task. In short, the pattern of results confirms that tasks must not involve bivalent stimuli for a sensitive test for the conflict avoidance strategy, while conflict adjustment effects (Gratton effects) are observed in error rates with univalent and bivalent stimulus sets.

# General Discussion

This research examined how people adapt their behavior to the detection of conflict. As an index for a conflict-adjustment strategy, we measured the Gratton effect in task performance (RTs, errors). In three experiments, we observed an enhanced recruitment of cognitive control following conflict trials: Detection of conflict caused a strengthening of the relevant task dimension and thus facilitated conflict resolution in trials that follow a conflict, as suggested by the conflict monitoring account. As an indicator for a conflict-avoidance strategy, we measured task choices and observed a bias to switch tasks after conflict, yet only when univalent stimulus sets were used. It should be noted that the present finding of reactive conflict avoidance differs in an important aspect from the demand avoidance effect reported by Botvinick and colleagues (Kool et al., 2010; Botvinick & Rosen, 2009). In their research, demand avoidance is reflected in a bias for the less demanding response option. Crucially, this bias develops gradually over longer series of trials and is a result of a proactive conflict management strategy that is learned over time (cf. Botvinick, 2007). In contrast, the conflict avoidance effect observed in the present study is the outcome of a short lived, reactive escape from aversive situations associated with conflict. Because both tasks involved an equal proportion of conflict trials in our experiments, participants could not learn to associate one task with more or less conflict. Thus, Experiment 1 and the univalent condition in Experiment 3 established a new marker for reactive conflict avoidance behavior that calls for an integrative account of both conflict avoidance and conflict adjustment. In the remainder of the discussion, we first address the role of univalent and bivalent stimuli in more detail, before we lay out a process model of flexible conflict management as an account for the presented data. Finally, we discuss briefly how the present research relates to recent advances in theorizing on the stability–flexibility trade-off in cognitive control.

## Between-Task Interference for Bivalent But Not for Univalent Stimuli

In Experiment 1 and in the univalent task in Experiment 3, observation of conflict avoidance was restricted to trials that followed a task alternation, presumably because conflict avoidance that followed a task repetition was overshadowed by task-set priming (Monsell, Sumner, & Waters, 2003). Initially, this may seem surprising because research on backward inhibition suggests that switch costs are increased when participants shift to a task they had previously just disengaged from (Mayr, 2002; Mayr & Keele, 2000). It is assumed that the increase in switch costs is because of inhibition of the previously abandoned task (see also Lien & Ruthruff, 2008). Sumner and Ahmed (2006) suggested that the crucial difference between studies that observed task-set priming effects and studies that observed backward inhibition is due to the characteristics of the stimuli used. Whereas bivalent stimuli call for control to ensure that the correct task is performed and cause backward inhibition, univalent stimuli cause accumulation of task-set priming with increasing repetitions.

For bivalent stimuli, Yeung (2010) reported an asymmetrical bias in task choice when switching between easy and difficult tasks, which was explained with elevated control of the more demanding task that increases the activation level of that task. As a consequence, disengagement from the task should be more difficult (but see the null effect of task difficulty on switch rates for bivalent stimuli in our Experiment 2). An interesting hypothesis is whether different processing characteristics for uni- and bivalent stimuli could explain the absence of an effect of task difficulty on task choice in the present study. With bivalent stimulus sets, strong activation of one task typically goes along with relatively weaker activation of the alternative task (Yeung, 2010). The resulting between-task interference makes it more demanding to disengage from the dominant task. With univalent stimuli, by contrast, activation of a task does not necessarily influence the activation level of the alternative task.

## The Scope of Conflict Adjustment

A key question for cognitive control is whether similar mechanisms and representations guide behavior across different situations (task- general control) or whether different situations call for distinct control mechanisms (task- specific control) (for a recent review, see Braem, Abrahamse, Duthoo, & Notebaert, 2014). For conflict adjustment effects, this question attracted quite a bit of attention, with some studies providing evidence in favor for a task-general control mode (e.g., Freitas, Bahar, Yang, & Banai, 2007; Kleiman, Hassin & Trope, 2014;Kunde & Wühr, 2006; Notebaert & Verguts, 2008;), whereas others found evidence in favor for a task- specific control mode (Verbruggen, Liefooghe, Notebaert, & Vandierendonck, 2005; Kiesel, Kunde & Hoffmann, 2006; Wendt, Kluwe, & Peters, 2006; Funes, Lupiañez, & Hymphreys, 2010). Although the present study was not designed to distinguish between the two accounts, a better understanding of the generalizability of control is important for a flexible conflict management account. Therefore, we reanalysed the performance data of Experiment 1 separately for task alternations (see Notebaert & Verguts, 2008 for a similar approach) and observed a Gratton effect as a marker for conflict adjustment the error data, $F(1, 25) = 8.92$, $p = .006$, $\eta_p^2 = .263$, but not in the RTs, $F < 1$.[4] The task- general conflict adjustment effect for the error data provides some evidence that conflict adjustment and conflict avoidance not only occur in the same paradigm but also in the very same trials. Further research has to establish whether conflict avoidance and conflict adjustment are different manifestations of a same underlying control mechanism or whether they are better characterized as independent conflict-management strategies.

## A Process Model of Conflict Avoidance

According to several theories of task switching, situations like the present experimental paradigm can be distinguished between processes of task selection and task performance (e.g., Logan & Gordon, 2001; Mayr & Kliegl, 2003; Rubinstein, Meyer, & Evans, 2001). For instance, the executive control theory of visual attention (Logan & Gordon, 2001) assumes that task sets are represented on two different levels, the task level and the parameter level. The task level representation consists of the instructions and rules that guide a specific task. In our paradigm this would be equivalent to the task choice. The parameter level representation specifies the *S–R* association that leads to task completion which would be equivalent to task performance in our paradigm. Such a hierarchical view of task representations is well in line with recent empirical work on task switching (e.g., Lien & Ruthruff, 2004; Schneider & Logan, 2006; Weaver & Arrington, 2013). For instance, Arrington and coworkers (Arrington & Yates, 2009; Butler, Arrington & Weywadt, 2011; see also Arrington, Reiman, & Weaver, in press) used a correlation approach to dissociate task choice and task performance. The authors combined the VTS paradigm with an assessment of executive functions and found a correlation between executive function and task performance but not between executive function and task choice.

On the basis of this distinction between representations at a task-choice level and at a task-performance level, a process model of conflict management is developed that can account for flexibility in the avoidance and adjustment to conflict (Figure 4 shows a graphical sketch of the model; see supplementary material for an animation of the model). The model extends and integrates the conflict-monitoring model that can account for conflict adjustment (Botvinick et al., 2001) with Botvinick's (2007) model that can account for conflict avoidance. Although some models already addressed conflict adjustment in a task switching context (Brown et al., 2007; Verguts & Notebaert, 2008), these studies focused on cued task switching and not voluntary task switching. We briefly

[4] Analyzing only task alternations resulted in empty cells for some conditions, leaving a much smaller dataset for analyses.

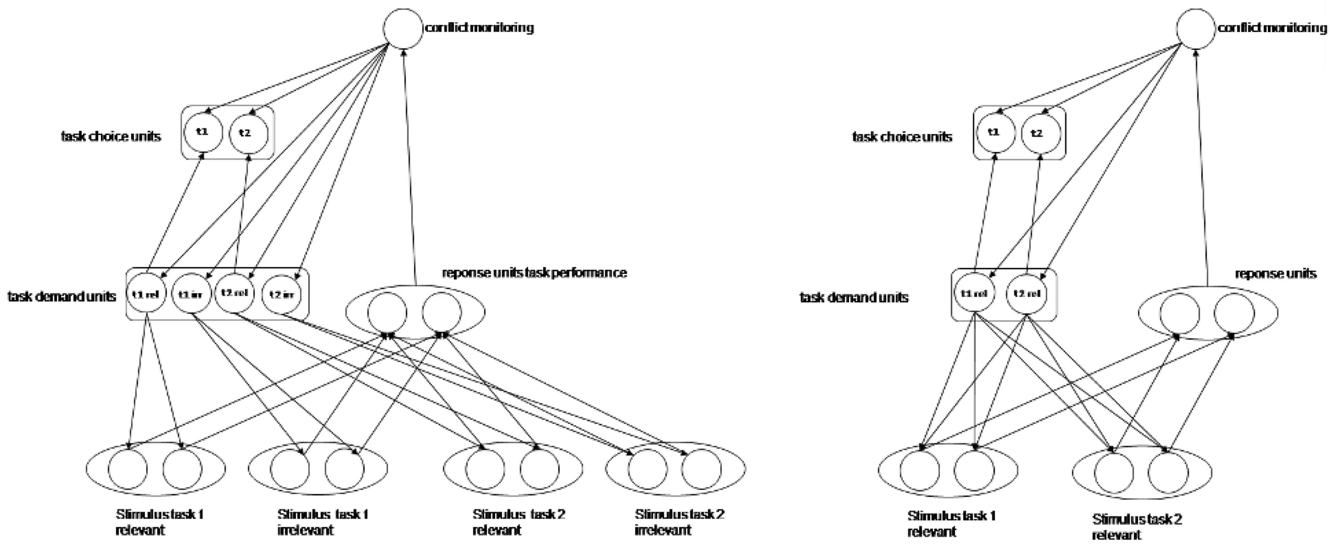


*Figure 4.* Structure of the conflict-management model. The left panel sketches the model for two tasks with univalent stimuli, the right panel for two tasks with bivalent stimuli. For an easier accessible animation of the model, we would like to draw the reader´s attention to the supplementary material available in the online version of the article.

sketch the conflict monitoring account and the Botvinick (2007) model separately before we explain in more detail how we integrated them to account for the reported results.

The conflict monitoring model (Botvinick et al., 2001) is based on previous models of Stroop performance (e.g., Cohen, Dunbar, & McClelland, 1990) that assume separate input (i.e., stimulus representation) and response layers. The input layer is influenced by a task-demand unit, which is responsible for the implementation of the appropriate task goals. Critically, Botvinick and colleagues added a new element to previous models, the so called conflict monitor. This unit receives input from the response layer in case of response competition. The conflict monitor detects this conflict signal and passes it on to the task-demand unit to bias information processing toward the goal-relevant dimension. It has been shown in empirical and simulation studies that activity of the conflict monitor (or its neurophysiological correlate, the ACC) of the preceding trial determines the degree of controlled (goal-directed) responses in the actual trial.

Botvinick (2007) proposed a model to account for the finding that participants gradually learned to avoid a response option that was frequently associated with a high level of conflict (see also Kool et al., 2010). The detected conflict signal propagates to the connection weights that are interposed between an input unit and a response unit that codes for the selection of a response option and biases in this way choice behavior.

Following Logan and Gordon (2001), we assume that with separated task-choice and task-performance processes, both models make predictions regarding different levels of representation. More precisely, we conjecture that conflict monitoring can account well for taskperformance level, whereas the Botvinick (2007) model can account well for task-choice level. Because of the task-switching situation in our VTS paradigm, there are four task-demand units, each of which represents a relevant and an irrelevant aspect of the two tasks. Task-demand units have connections to two different levels of representations: On the one hand, task demand units propagate to the input layer at the task-performance level and bias information processing according to the currently relevant task set. On the other hand, task-demand units propagate to task-choice units at the task-choice level. In line with the conflict-monitoring model, we assume that conflict is the result of a parallel activation of the response unit. This is recognized by a conflict monitor that passes this information to the task demands units and in addition also to the task-choice units. With this architecture in mind, in the following we address several points concerning the model's operating characteristics.

**How can the model explain the simultaneous implementation of conflict adjustment and conflict avoidance?** According to the model, the conflict signal has various effects on the different hierarchies of task representations. At the task-choice level, weights of each task are altered by a conflict signal (cf. Botvinick, 2007) and the last active task-choice unit is weakened. Consequently, the selection of tasks is biased away from the previously active task representation, explaining conflict avoidance. Now, at the task-performance level, conflict causes a strengthening of the relevant dimension and a weakening of the irrelevant dimension, giving rise to conflict adjustment. Thus, conflict has opposing effects on the task-choice and task-performance level, respectively, allowing for a simultaneous implementation of conflict avoidance and conflict adjustment at different levels of representation.

**How can the model explain the diverging results for univalent and bivalent stimuli?** The model was described for a situation with two univalent tasks (Experiment 1). Here, weakening of the irrelevant dimension of a Task 1does not affect an alternative Task 2. If conflict at the task-choice level reduces the strength of Task 1, Task 2 will be favored over Task 1. Now consider a situation with two bivalent tasks (e.g., Experiment 2; for a graphical sketch, see Figure 4, lower panel; see also the online supplementary material). Here, weakening of the irrelevant dimension of Task 1 affects the alternative Task 2, because the irrelevant dimension of one task is also the relevant dimension of the other task. We assume that the propagation from the task demand units is stronger than the signal that arrives from the conflict monitor unit. Thus, even if conflict at the task-choice level reduces the strength of Task 1, Task 2 is still not favored over Task 1. This is because weakening of the irrelevant dimension of Task 1 also reduces activation of the relevant dimension of Task 2, resulting in a stronger activation of Task 1 over Task 2. Thus, conflict avoidance is not observed with bivalent stimuli, and task switching is observed only following nonconflict trials.

**How can the model explain the reactive conflict avoidance effect?** A core assumption of an integrated account of conflict avoidance and conflict adjustment is that conflict is registered as an aversive signal. In line with Botvinick (2007), we assume that conflict biases task choice away from the task associated with conflict. In the Botvinick model, an association between conflict and a task accumulates gradually over time. However, Botvinick also assumed that more recent conflict has a stronger impact on learning than conflict several trials back. Thus, we speculate that by adjusting the learning parameter, the model can not only account for sustained control effects like demand avoidance but also for more transient control effects like conflict avoidance (Experiments 1 and 3). Another, not mutually exclusive explanation for a reactive avoidance of conflict is that the aversive quality of conflict triggers an automatic motivational tendency to avoid the source of the conflict. For example, research on motivational avoidance-avoidance conflicts showed that animals and humans start to oscillate behaviorally between two aversive situations when avoidance of one aversive situation results in the exposure to the other aversive situation (see, e.g., Boyd, Robinson, & Fetterman, 2011; Hovland & Sears, 1938; Miller, 1944). An avoidance–avoidance conflict may also apply to the present task setup in which avoidance of one conflict task resulted in being exposed to another conflict task without viable exit strategy for the participant (except for quitting the experiment). Thus, the aversive experience of a conflict trial may have triggered a transient tendency to avoid the perceived source of the conflict, even when this behavior produced no benefits in the long run.

**How can the model relate to other theoretical account of voluntary task choice?** In the present form, the model focuses selectively on the influence of conflict on task choice. However, several other factors have been identified that affect task choice as well (see, e.g., Arrington, 2008; Arrington & Logan, 2005; Mayr & Bell, 2006). A recent attempt to account for top-down and bottom-up influences and to formalize the process of voluntary task selection has been put forward by Vandierendonck, Demanet, Liefooghe, and Verbruggen (2012). According to their chain-retrieval model, short sequences of task alternations and repetitions are acquired at the start of an experiment and subsequently retrieved from long-term memory for guidance of a task choice. Top-down influences are implemented leading to a bias for easy-to-perform task repetitions, whereas bottom-up influences are assumed that can overrule the currently selected task. As already discussed by Vandierendonck and colleagues, a bias that favors specific task alternations over others must be based on some form of performance monitoring. As the present results suggest, avoidance of conflict is perhaps one factor that promotes task transitions. Alternatively, conflict might function as a bottom-up factor that overrides voluntary task selection.

**How does the model relate both conflict management strategies to each other?** According to the present model, there are three possibilities how both strategies may relate to each other. First, it is possible that both strategies are mutually exclusive: Participants respond either with adjustment or with avoidance to a conflict, but they cannot do both at the same time. Alternatively, it is possible that both strategies are used at the same time but independently of each other, so that participants use one strategy to control performance and the other to control choice behavior. A third possibility is that both strategies rely on a common cognitive mechanism so that participants who are efficient in one strategy are also efficient in the use of the other one. Evidence that speaks against the latter possibility comes from a recent study by Schouppe et al. (2014). The authors tested whether proactive, sustained conflict adjustment is related to proactive, sustained conflict avoidance; however, no correlation was observed between both effects. Clearly, more research is necessary to examine these possibilities.

## Implications for the Stability–Flexibility Trade-Off in Cognitive Control

A recent model of cognitive control proposed that the conflict signal corresponds with an arousal response of the locus coeruleus-norepinephrine (LC-NE) system (Verguts & Noetbaert, 2009). Arousal has been identified as an important neuromodulator for the stability–flexibility trade-off (Aston-Jones and Cohen, 2005; Cohen, McClure & Yu, 2007). According to adaptive gain theory (Aston-Jones and Cohen, 2005), the phasic mode of the LC-NE arousal response is considered to be responsible for maintaining stability within a task, for instance, when performance spontaneously deteriorates. In contrast, the tonic mode is considered to implement flexibility in switching between different tasks, for instance, when the utility of a task decreases. This distinction between phasic arousal in the service for stable task performance and tonic arousal in the service for flexible task choice corresponds with our distinction between conflict avoidance on a task-choice level and conflict adjustment on a task-performance level.

## Summary

This research examined how people manage a conflict situation that allows for two different conflict-management strategies: Recruitment of cognitive control is used to cause performance adjustments and to avoid the source of conflict. Although integrative accounts have been proposed on theoretical grounds that explain how cognitive control maintains a balance between stability and flexibility, this study is the first that put this notion to an experimental test. Supporting integrative theories of cognitive control (e.g., Botvinick, 2007) results show that people use both conflict-management strategies in confrontation with difficult conflict situations.

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