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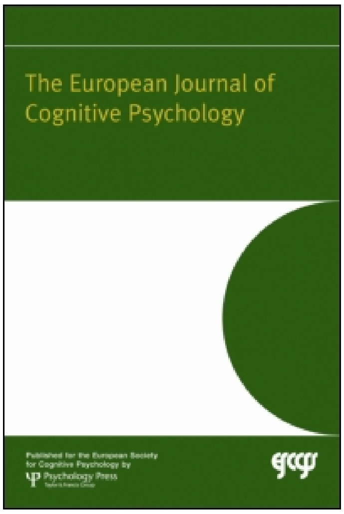

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Task switches under Go/NoGo conditions and the decomposition of switch costs

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Task switches under Go/NoGo conditions and the decomposition of switch costs

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Alternating switches between two simple S–R tasks are combined with Go/NoGo tasks. Non-switches after Go trials are assumed to selectively profit from stimulus driven repetition benefits, whereas switches after NoGo trials are assumed to be selectively delayed by stimulus driven negative priming. Intentionally driven reconfiguration costs are assessed by RT differences between switches after Go trials (no negative priming) and non-switches after NoGo trials (no repetition benefits). Experiment 1 indicates that with short preparation time repetition benefits, negative priming costs, and intentional components contribute approximately additively to switch costs. Experiment 2 confirms that the delay of switches after NoGo trials is indeed due to negative priming. Experiments 3 and 4 show that repetition benefits and intentional components of switch costs are properly assessed only if the settings assure that participants reconfigure the required task set in NoGo as well as Go trials.

INTRODUCTION

Human behaviour is almost always intentionally determined. People mostly do not react to situations but instead act in order to attain certain goals. In contrast to this dominance of intentionally determined behaviour little is known about how intentions control behaviour. For decades, psychology focused on investigating stimulus processing and stimulus-driven behaviour. Nowadays, however, interest on ''top down'' control is increasing, evidenced by numerous concepts of ''executive control'' (e.g., Allport, 1993; Baddeley, 1986; Goschke, 1997; Johnson-Laird, 1988; Kluwe, 1996; Logan, 1985; Monsell, 1996; Norman & Shallice, 1986; Shallice, 1992) and by a revival of the ideo-motor principle (e.g., Hoffmann, 1993; Hoffmann & Stock, 2000; Hommel, 1998b; Kunde, 2001; Prinz, 1998; see also Greenwald, 1970).

A preferred paradigm with which to examine executive control is task switching. In a standard task switch experiment participants are required to

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perform one of two different tasks in each individual trial. For example, in an experiment by Rogers and Monsell (1995), participants were presented a letter and a digit each. One task was to determine whether the letter was a consonant or a vowel. The other task was to determine whether the digit was even or odd. In each trial a cue signalled which of the two tasks was to be performed. In non-switch trials the same task as in the previous trial was to be accomplished, whereas in switch trials participants were required to perform the alternate task. Increase of reaction times (RTs) and decrease of accuracy in switch trials in comparison to non-switch trials (switch costs) are considered as indicating the cognitive effort that is taken to voluntarily switch from the readiness to perform the one task to the readiness to perform the other task, i.e., to switch between task sets.

Numerous studies have indeed shown substantial switch costs (e.g., Allport, Styles, & Hsieh, 1994; De Jong, 2000; Fagot, 1994; Gopher, Armony, & Greenshpan, 2000; Kluwe, 1997; Meiran, 1996; Rogers & Monsell, 1995). Moreover, the data revealed various factors affecting switch costs, which has led to a variety of speculations about the processes switch costs may result from, as discussed in the following sections.

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Task set inertia or proactive interference

Allport et al. (1994, p. 436) argued that switch costs are mainly due to ‘‘a kind of proactive interference from competing S–R mappings with the same stimuli’’. They assumed that in switch trials the task set of the previous trial remains activated despite not actually being required (task set inertia). If the previous task set interferes with the actual required task set, RTs increase. Wylie and Allport (2000, p. 212) specified this account by claiming that interference is based ‘‘on the stimulus-triggered retrieval of competing stimulus-response (S–R) associations’’. Thus, in terms of the task set inertia hypotheses, top-down control contributes, if at all, only marginally to switch costs, as interferences are assumed to originate from stimulus-driven processes.

The ‘‘stimulus cued completion hypothesis’’

Rogers and Monsell (1995; cf., also Monsell, Yeung, & Azuma, 2000) distinguished between exogenous and endogenous control. Endogenous components refer to voluntary processes resulting in the readiness to perform a new task. The authors did not specify these processes, however: ‘‘Although the endogenous component of task-set undoubtedly exists, we refrain from making any such assumptions about it’’ (Rogers & Monsell, 1995, p. 208). Exogenous components refer to stimulus driven processes, especially to the activation of established S–R mappings. According to Rogers and Monsell (1995, p. 224), a task set can be voluntarily reconfigured only partly as: ‘‘Completion of the reconfiguration is triggered only by, and must wait upon, the presentation of a task-associated stimulus''. Thus, two components of switch costs are distinguished. First, costs that are due to voluntary processes that can, if time permits it, be carried out before the stimulus arrives. Second, costs that are due to processes exclusively released by the presentation of the imperative stimulus, the so-called residual switch costs (however, see Hübner, Futterer, & Steinhauser, 2001, for data suggesting that residual switch costs may reflect voluntary processes also).

Backward inhibition

Mayr and Keele (2000) assumed, like Allport et al. (1994), that task sets remain sustained after their use. Moreover, they assumed that the establishment of a new task set requires the deactivation of competing task sets. ''Selecting against a just-executed set could be accomplished by deactivating it, thus, providing the necessary 'room to move' for selecting the new task set.'' The mechanism that deactivates competing task sets is called ''backward inhibition''. Corresponding to these considerations, switch costs do not result from passive interferences between ''new'' and ''old'' task sets but rather from the effort it takes to voluntarily inhibit ''old'' task sets.

Negative priming

Negative priming is an ubiquitous phenomenon that occurs if in a present trial participants have to respond to a stimulus that was to be ignored in the previous trial. Generally, responses to previously to be ignored stimuli are delayed (e.g., Chiappe & MacLeod, 1995; Fox, 1995; Neill & Valdes, 1992; Tipper, 2001; Tipper & Cranston, 1985). Within the task set shift paradigm negative priming at the level of individual stimuli has often been avoided as stimulus repetitions in consecutive trials were excluded (for an exception, see Koch, 2001; Mayr & Keele, 2000; or Meiran, 1996). However negative priming may also occur at the level of stimulus categories or stimulus dimensions. For example, consider the conditions in the previously mentioned experiments by Rogers and Monsell (1995): If in a switch trial the pair *G*7 is presented with the requirement to classify the letter (consonant or vowel) and in the previous trial the pair R*3* was presented with the requirement to classify the digit (odd or even), participants have to respond to a stimulus category (letters) to which responding was just to be suppressed. Rogers and Monsell (1995) indeed reported that switch costs are reduced if the distractor stimuli always belong to a third category that was never response relevant (e.g., %*3*–*G*#) that is consistent with negative priming effects at the level of stimulus categories if the distractor stimuli are potentially response relevant. Likewise, Mayr and Keele (2000) reported evidence for negative priming at the level of stimulus dimensions. Switch RTs increased if in the current trial participants had to respond to a stimulus dimension (e.g., colour)

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to which responding was to be suppressed in the preceding trial. Thus, there is evidence that negative priming contributes to switch costs even if repetitions of concrete stimuli are avoided (cf., also Allport & Wylie, 2000; Goschke, 2000; Monsell et al., 2000).

Repetition benefits

It is somewhat surprising that RT differences between switch and non-switch trials are almost always considered as indicating switch costs although they may likewise indicate repetition benefits: If in a choice reaction task either stimuli and responses or only responses are repeated in successive trials, repetitions are performed faster than non-repetitions (at least within certain time constraints, cf., Soetens, 1998, for a recent overview). Moreover, Marcel and Forrin (1974) reported that sheer repetitions of the relevant stimulus category are sufficient for benefits to occur. Participants had to name letters and digits. Letters are faster named than digits if in the previous trial also a letter was to be named and *vice versa*.

In the task switch paradigm the task relevant stimulus category is always repeated in non-switch trials (as has already been mentioned, repetitions of concrete stimuli are often excluded). Furthermore, in non-switch trials RTs were found to be substantially reduced when the same response was repeatedly required. In contrast, in switch trials there was either no facilitation or even inhibition when the same response was required as in the previous trial (Kleinsorge, 1999; Mayr & Keele, 2000; Meiran, 2000; Rogers & Monsell, 1995). Thus, repetitions of the task relevant stimulus category as well as of responses tend to decrease RTs in non-switch trials and repetitions of responses tend to increase RTs in switch trials, resulting in higher switch costs.

In sum, the available evidence so far clearly indicates that the RT (and accuracy) differences between switch and non-switch trials (the switch costs) are by no means exclusively caused by voluntarily driven, intentional processes of task set reconfiguration. Rather, switch costs are also caused by stimulus driven factors (cf., also Pashler, Johnston, & Ruthruff, 2001). Correspondingly, Mayr and Keele (2000, p. 16/17) admitted, ''that the actual size of true shift costs is difficult to establish in the absence of an agreed-upon neutral baseline that allows us to separate out set or response repetition benefits from costs''. And Wylie and Allport (2000, p. 231) likewise came to the conclusion that experiments ''have shown that switch costs, on their own, cannot be used as an index of the extent to which control processes are active in the alternating runs paradigm''. Thus, an appropriate investigation of executive control processes by the task switch paradigm requires to assess the contributions of stimulus driven processes on the total switch costs independently of the switch costs that are due to intentionally driven reconfigurations of task sets. The present experiments contribute to this issue by combining the task switch paradigm with Go/NoGo requirements. As the foregoing discussion led us to the conclusion that repetition benefits and negative priming costs are important stimulus driven components of switch costs, we especially aim at a separate assessment of these components.

GENERAL METHOD: TASK SWITCHES UNDER GO/NOGO CONDITIONS

In the present experiments two simple tasks are to be performed, let's say ''A'' and ''E''. Each task requires responding to mutually exclusive task relevant stimuli (A and E). Each trial starts with a cue that signals which of the two tasks is to be performed (''A'' or ''E''). After a cue-stimulus interval (CSI) a stimulus is presented that is either relevant for the actually required task or not. If it is relevant, participants are required to respond as fast as possible with a certain response (Go). If the stimulus is not task relevant (e.g., if task ''A'' is cued but stimulus E is presented), participants are required not to respond at all (NoGo) and to wait for the next trial. Additionally to the Go/NoGo variation, there are switch and non-switch trials. With regard to Go trials (only these provide performance data) four cases in relation to the previous trial are to be distinguished (see Figure 1). Case I: The same task is required and in the previous trial the task-relevant stimulus was presented and responded to (non-switch, repetitions of stimulus and response); case II: No task switch but in the previous trial the task-irrelevant stimulus was presented and no response was executed (non-switch, no repetitions—neither of the stimulus nor of the response); case III: The task is switched and in the previous trial a task-relevant stimulus was presented and responded to (switch, the response is to be repeated but now following the other stimulus); and finally case IV: The task is switched and in the previous

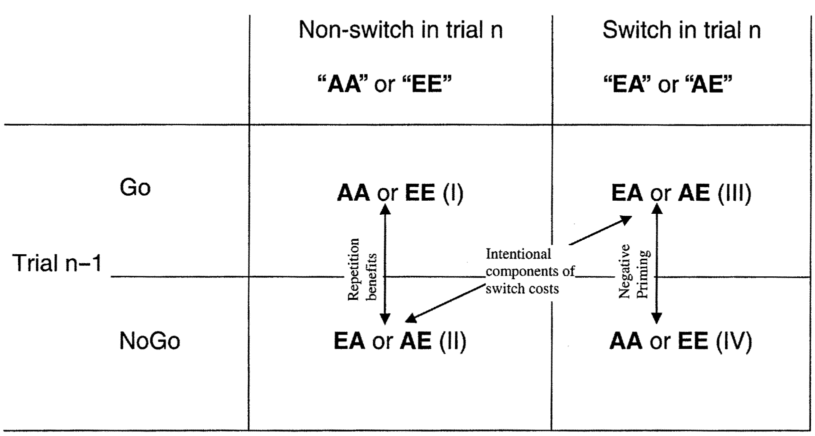

Figure 1. Possible combinations of non-switch and switch Go trials in trial n with Go or NoGo conditions in the previous trial.

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trial a task-irrelevant stimulus was presented and no response was executed (switch, the response is to be executed to the stimulus to which it was to be withheld in the trial before).

If one tentatively assumes that intentional control processes and stimulus-driven benefits and costs contribute approximately independently of each other to RTs, the design should allow a separate assessment of their contributions to the total switch costs.

Repetition benefits

Repetition benefits can be assessed by comparing RTs in cases I and II. In both cases participants do not have to switch the task set. In case I they are required to stay ready to do the same task they have just performed and in case II they are required to stay ready to do the same task they were instructed to prepare in the previous trial without having to perform it. Thus, one can assume that in both cases not much voluntary reconfiguration of task sets takes place. However, in case I repetition benefits are to be expected because performance of the same S–R mapping is repeated. In contrast, in case II repetition benefits are excluded, as there is neither a stimulus nor a response repetition. Thus, RT differences between cases I and II can be assumed to be mainly due to repetition benefits.

Negative priming

Let us now consider cases III and IV. In both cases participants have to switch the task set. In case III they are required to prepare for the alternative task they have performed in the previous trial and in case IV they are required to prepare for the alternative task they were prepared for in the previous trial without having to perform it. Thus, one can assume that in both cases task sets are likewise voluntarily reconfigured. Additionally, in case IV negative priming is expected to occur as participants have to respond to a stimulus to which the response was to be withheld in the previous trial. In contrast, in case III no negative priming is to be expected as in the previous trial the response was executed to the alternative stimulus. Thus, RT differences between cases III and IV are assumed to be mainly due to negative priming.

Note that although the current setting does not fit the ordinary settings of negative priming studies, the same mechanisms might be addressed. For example, Neill and Valdes (1992) (see also Fox, 1995; Neill, Valdes, Terry, & Gorfein, 1992) argued that negative priming is due to the retrieval of an episode in which the current stimulus had to be ignored, i.e., was associated with do-not-respond. As this stimulus has to be associated with a response in the current trial, there is a conflict that produces the delay in responding. This is equivalent to case IV: The stimulus that requires a response in the current trial was associated with do-not-respond in the previous trial.

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Intentional components of switch costs

Finally, a separate assessment of components of switch costs that are due to voluntary reconfiguration of task sets can be accomplished by the differences between RTs in non-switch trials that do not profit from repetitions (case II) and RTs in switch trials that do not suffer from negative priming (case III).

One potential problem of the present approach could be that the proposed assessments of the different components are always based on differences between Go trials that are either preceded by a Go or a NoGo trial. Consequently, emerging differences might not only be due to the described components but also due to unspecific influences of the transitions between withholding and executing the required response. Thus, in order to show that the various differences between the distinguished cases indeed indicate different components of task switching costs it has to be shown that the costs of transitions between NoGo trials and Go trials are specifically modulated by whether they are accompanied by a task switch or a task repetition. Moreover, a selective modulation of the RT differences by conditions specific to the respective component that is assumed to be assessed would provide additional support for the notion that performance in the four distinguished cases is selectively influenced by stimulus-driven and intentionally driven components of task switches.[1]

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EXPERIMENT 1

Experiment 1 was designed in order to examine whether the proposed combination of the task shift paradigm with a Go/NoGo paradigm is indeed appropriate to disentangle the impact of stimulus-driven processes on switch costs from the impact intentionally driven processes may have. Two simple Go/NoGo tasks were used: In task ''A'', participants were required to press a response button if the letter A was presented (Go) and to withhold responding if the letter E was presented (NoGo). In task ''E'', participants were required to press the same button if the letter E was presented (Go) and to withhold responding if the letter A was presented. Each trial started with the presentation of a cue, indicating which letter (task) actually is relevant (''A'' or ''E''). After a variable CSI either the relevant stimulus (''A''–A or ''E''–E) or the irrelevant stimulus (''A''–E or ''E''–A) was presented. Participants were required to respond as fast as possible to the respective task-relevant stimulus, or not to respond and to wait for the next trial if the respective task-irrelevant stimulus was presented.

[1] As the measurements for repetition benefits, negative priming, and intentional components of switch costs are computed as differences of reaction times from a 2 × 2 variation between task shift and Go/NoGo in the previous trial, their assessment is not statistically independent. Therefore, showing that the components can be influenced selectively serves an external validation of the assessments.

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Under the present conditions, task sets refer simply to the readiness to execute a fixed response to a certain imperative stimulus and not to execute the response to another stimulus. (A–Go/E–NoGo versus E–Go/A–NoGo). A switch between the two S–R-mappings presumably entails disengaging attention as well as response readiness from the current task-irrelevant stimulus and directing attention and response readiness to the current task-relevant stimulus. In non-switch trials in which the concrete stimulus and the response from the previous trial are repeated (e.g., ''A''–A, ''A''–A) repetition benefits are to be expected. Finally, negative priming is to be expected in switch trials, in which participants are required to activate a response to a stimulus to which responding was to be suppressed in the previous trial (e.g., ''A''–E, ''E''–E).[2]

Method

Participants. Twelve students of the University of Wuerzburg (age 19–32) participated in an individual session of approximately 45 min in fulfilment of course requirement. They reported having normal or corrected-to-normal vision.

Apparatus and stimuli. The experiment was controlled by a standard PC (Pentium 133 MHz) with a 15-inch monitor. Acoustic signals were presented via Typhon loudspeakers (10 W, 4 Ohm). Visual stimuli were the letters A and E, displayed in uppercase Times New Roman (1.8° × 1.9°). They were presented in black on a white background at the centre of the monitor. The viewing distance was approximately 50 cm. Response button was the b-key on the computer keyboard that was marked with a blue sticker. Participants were free to choose their preferred hand and finger to press the button.

Design and procedure. Each trial started with a verbal cue indicating the current task, i.e., the relevant stimulus: A male voice pronounced either the letter ''A'' or the letter ''E''. The duration of the cue was 150 ms. After a variable CSI (0, 50, 100, 200, 400, and 800 ms from the onset of the cue until the onset of the letter) either the uppercase letter A or the uppercase letter E was presented. In half of all cases the relevant letter (Go) and in the other half of cases the irrelevant letter (NoGo) was presented. The relevant letter remained on-screen

[2] The simplicity of the task sets we used ensures that switches refer only to the concrete stimuli to which the response is to be released and to withhold. By this we intended to avoid that participants have to switch between several settings (stimulus categories, decision criteria, locations, response sets; cf., Monsell et al., 2000). On the other hand, the simplicity of the task sets holds the risk that participants may exchange from switching between two task sets to responding to cue–stimulus compounds (respond if the cue and the stimulus correspond, do not respond if they do not correspond). However, the risk—that participants may redefine required task switches into choice reactions to cue–stimulus compounds—the present experiments share with all task-switching experiments in which tasks are cued. Whether or not participants ''redefine'' task sets is an empirical question, we will discuss against the data.

until the onset of the response. The irrelevant letter remained onscreen for 1000 ms. In each case the next trial started 2000 ms after the onset of the stimulus with the presentation of the next cue. By this, the time structure in the succession of tasks was kept constant irrespective of whether the current trial was a Go or a NoGo trial.

The cued task was switched according to the ''alternating runs'' paradigm introduced by Rogers and Monsell (1995), i.e., the task was switched on every second trial (''AAEEAAEE . . .''). The alternation of task repetitions was explicitly mentioned in the instruction, to make sure that participants were aware of it from the beginning. Stimuli were randomly assigned to each individual task with the restriction that each possible combination of Go/NoGo in trial n–1 (2) $\times$ Go/NoGo in trial n (2) $\times$ CSI (6) was realised four times per block ($2 \times 2 \times 6 \times 4 = 96$). Another four warm up trials were presented at the beginning of each block resulting in 100 trials per block. Six blocks were performed.

RT data from Go trials and error data from all trials were collected. RTs were measured from the onset of the task-relevant stimulus to the onset of the response. In Go trials an error was indicated by an acoustic signal when subjects did not respond within 1000 ms after the onset of the task-relevant stimulus. In NoGo trials an error was indicated when subjects responded to the task-irrelevant stimulus. The design includes three orthogonal within-subject variables: switch versus non-switch trials, a previous Go versus a previous NoGo trial, and a variation of the CSI in six steps.

Results

The relative frequencies of errors were 0.5% for Go trials and 3.9% for NoGo trials, too little for statistical analyses. From the analysis of RTs (only Go trials) all errors as well as all data from trials with an error in the previous trial were excluded (2.9%).

Figure 2 presents the mean RTs for switch and non-switch Go trials in dependence on whether the previous trial was a Go or a NoGo trial, plotted against CSI. An ANOVA with the within subject factors switch/non-switch, Go/NoGo in the previous trial, and CSI revealed a significant effect of the factor switch/non-switch, $F(1, 11) = 18.68$, $p < .001$, $MSe = 30120.19$. Participants responded faster in non-switch trials than in switch trials (349 ms versus 369 ms). There was a significant effect of the factor Go/NoGo, $F(1, 11) = 42.86$, $p < .001$, $MSe = 35265.26$, indicating shorter RTs after Go trials compared to NoGo trials (348 ms versus 371 ms). There was a significant effect of the factor CSI, $F(5, 55) = 56.91$, $p < .001$, $MSe = 57190.23$. RTs decreased with longer CSI (410 ms, 388 ms, 362 ms, 346 ms, 328 ms, and 322 ms). Finally, there were significant interactions between switch/non-switch and CSI, $F(5, 55) = 5.88$, $p < .001$, $MSe = 2858.95$, as well as between switch/non-switch and Go/NoGo, $F(1, 11) = 13.29$, $p < .01$, $MSe = 9271.93$. RTs in switch trials increase with short

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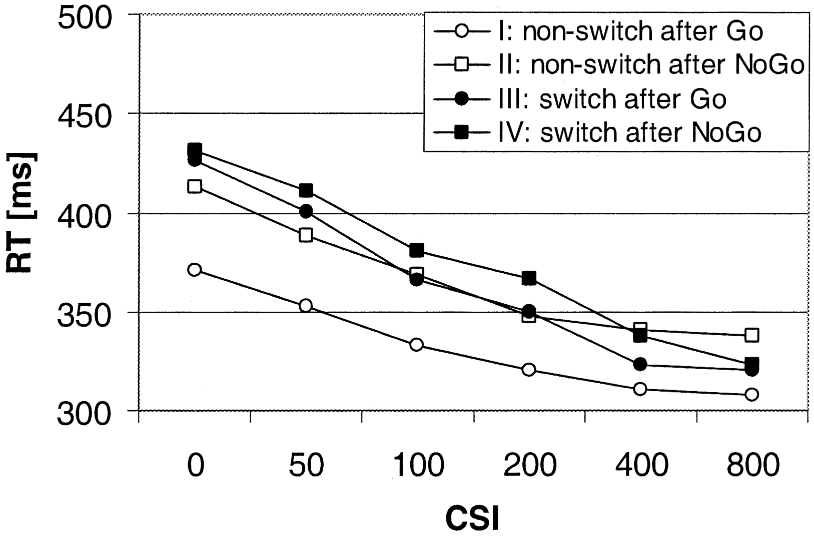

Figure 2. Mean RTs for switch and non-switch Go trials in dependence on whether the previous trial was either a Go or a NoGo trial, plotted against CSI.

CSIs only (cf., Figure 3), and, most important, the impact of the Go/NoGo variation in the previous trial is stronger when the task was repeated (333 ms versus 366 ms) than when it was switched (364 ms versus 375 ms). All other effects were not significant.

Assessment of total switch costs. According to the usual evaluation of task switch experiments (i.e., without considering the Go/NoGo variation, cf., Figure 3), the data show the typical result of switch costs that decrease with the CSI, i.e., the longer participants can voluntarily prepare for the cued task before the stimulus is presented (e.g., Meiran, 1996; Rogers & Monsell, 1995; Vandierendonck & Caessens, 2002).

We turn now to a detailed consideration of the impact of Go and NoGo conditions in the previous trial on RTs in order to disentangle the contributions of repetition benefits, negative priming costs, and intentional components of switch costs, on the total switch costs as described earlier.

Assessment of repetition benefits. Repetition benefits are assessed by calculating for each participant and each CSI the mean difference of RTs between non-switch trials that are either preceded by a Go trial (repetition) or by a NoGo trial (no repetition, see Figure 4). An ANOVA with CSI as the only within-subject factor revealed that repetition benefits are significantly different from zero, $F(1, 11) = 57.01$, $p < .001$, $MSe = 80702.20$ and independent of the

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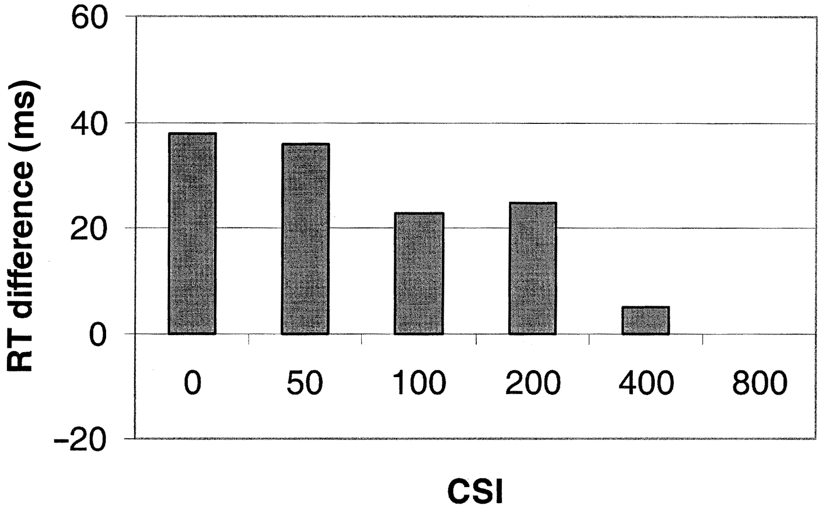

Figure 3. Switch costs (computed RT difference between switch and non-switch trials) plotted against CSI.

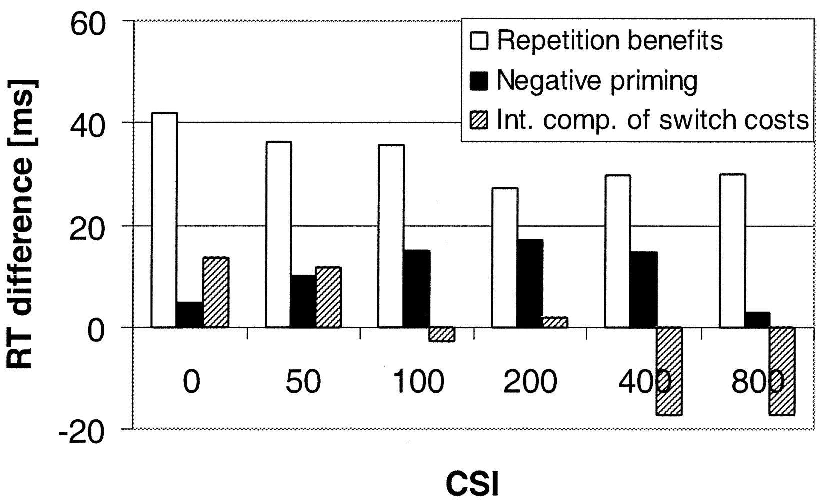

Figure 4. Repetition benefits, negative priming, and intentional components of switch costs plotted against CSI.

CSI, $F(5, 55) < 1$. In non-switch trials, participants responded on average 34 ms faster when they had to respond to the same stimulus in the previous trial than when they did not have to respond in the previous trial.

Assessment of negative priming costs. Negative priming costs were assessed by calculating for each participant and each CSI the mean difference of RTs between switch trials that were either preceded by a Go trial (no negative priming) or by a NoGo trial (negative priming, see Figure 4). An ANOVA with CSI as the only within-subject factor revealed that negative priming costs were significantly different from zero, $F(1, 11) = 5.15$, $p < .05$, $MSe = 8372.18$, and independent of the CSI, $F(5, 55) < 1$.

In switch trials, participants responded on average 11 ms slower when they had to withhold responding to the actual stimulus in the previous trial than when they had to respond to another stimulus in the previous trial.

Assessment of intentional components of switch costs. Intentional components of switch costs were assessed by calculating for each participant and each CSI the mean difference of RTs between switch trials that were preceded by a Go trial (no negative priming) and non-switch trials that were preceded by a NoGo trial (no repetition, see Figure 4). An ANOVA with CSI as the only within-subject factor revealed that intentional components of switch costs were on average not significantly different from zero, $F(1, 11) < 1$, but were marginally significantly influenced by the variation of the CSI, $F(5, 55) = 2.31$, $p < .06$, $MSe = 2191.46$. Intentional components of switch costs decrease and even become negative as the CSI increases.

Discussion

The primary innovation of the present experiment was the combination of a task switch paradigm with a Go/NoGo paradigm, so that repetitions as well as switches of tasks were required after previous Go as well as NoGo trials. First, it is to be noted that the impact of the Go/NoGo variation in the previous trial significantly differs in dependence on whether the task was switched or not switched. Thus, responses are not simply likewise delayed after NoGo trials. The different increases of RTs after NoGo trials rather point to different components, which is consistent with our assumption that in non-switch trials the RT differences are due to repetition benefits, whereas in switch trials they are due to negative priming costs. Moreover, with the exception of long CSIs, the data are also consistent with the tentative assumption that repetition benefits, negative priming costs, and intentional components of switch costs contribute approximately additively to RTs: The mean RTs continuously increase from case I to case IV (cf., Figure 1). Finally, separate assessments of the three components show that under the present conditions of switches between two simple con-

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tradictory S–R mappings, switch costs are mainly caused by stimulus-driven components, i.e., by repetition benefits and negative priming costs. Intentionally driven processes of task set reconfiguration seem to contribute only marginally to switch costs, if at all.

The missing contribution of intentional components of switch costs gives reason for several speculations: First, it seems approximate to assume that under the present conditions intentionally driven reconfigurations are marginal because participants may have adopted the strategy to release the response to a correspondence between the verbal cue and the visual stimulus (‘‘A’’–A/‘‘E’’–E→Go), and to withhold the response in case of a non-correspondence (‘‘A’’–E/‘‘E’’–A→NoGo), so that intentionally driven task set reconfigurations did not take place at all. However, RTs clearly depend on whether in the previous trial the same task or the other task was required (case I versus case III, and case II versus case IV, cf., Figure 2), which is hardly consistent with the assumption that participants simply respond to correspondences between cue and stimulus.[3]

Second, it may be argued that under the used alternating runs paradigm participants have complete foreknowledge about the next-to-be-expected switch, so that they may have finished the required task set reconfiguration before the cue appears. However, it is questionable whether participants really make use of such foreknowledge, especially as participants would therefore have to keep track of the runs. Moreover, the possibility of anticipating the next task has been shown to reduce RTs in general but not the RT differences between switches and non-switches (Koch, 2001; Sohn & Carlson, 2000). Furthermore, the assessments of intentional components of switch costs by the RT differences between cases III and II were the only measure that showed a tendency to decrease with increasing CSI, which is consistent with the assumption that these differences depend at least partly on intentionally driven task reconfigurations.

Third, it has to be questioned whether the RT differences between cases III and II provide a valid assessment of intentional components of switch costs. The assessment is based on the assumption that the required task set is likewise reconfigured in Go as well as in NoGo trials. This, however, might not be the case. It might well be that in NoGo trials participants tend to stop task set

[3] One reviewer argued that the RT differences between cases I and III as well as between cases II and IV might be due to interactions of repetitions of stimuli and responses: If participants would respond to the correspondence between cue and stimulus, in case I stimulus and response of the previous trial are repeated, whereas in case III the stimulus is changed but the response is repeated. Likewise, in case II stimulus and response of the previous trial are changed, whereas in case IV the stimulus of the previous trial is repeated but the response is changed. As changes in both stimulus and response are faster accomplished than changing only the stimulus or the response (Hommel, 1998a), the fact that RTs in case II are shorter than in cases III and IV might result from these sequential effects instead of being caused by different task switching components. However, Experiment 3 will show that pure sequential effects of this kind are too small to account for the RT differences we found here.

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reconfiguration as soon as the task-irrelevant stimulus is presented, so that, especially in NoGo trials with a short CSI, task set reconfigurations may often remain uncompleted. Consequently, task repetitions after NoGo trials (case II) would still require some completion of the previously not yet fully configured task set, resulting in an increase of RTs. An increase of RTs in task repetitions after NoGo trials (case II) reduces in turn the RT differences to task switches after Go trials (case III). In other words, intentional components of switch costs might have been underestimated by their assessment through the calculated RT differences between cases III and II.

The suspicion that RTs in task repetitions after NoGo trials (case II) may partly reflect the effort it takes to fully complete the configuration of the current (previously not yet fully completed) task set is insofar crucial for our approach as it also affects the assessments of repetition benefits. As repetition benefits are assessed by the RT differences between case II and case I, an increase of RTs in case II, due to some task set reconfiguration, results in an overestimation of purely stimulus-driven repetition benefits.

In summary: The explored combination of the task switch paradigm with Go/NoGo requirements seems to be a useful approach to disentangle the contributions of repetition benefits and negative priming to the total switch costs from intentional components of switch costs. The outcomes of Experiment 1 likewise call for further experiments in order to validate the separate assessments of repetition benefits and negative priming costs and to specify the conditions that allow a valid assessment of intentionally caused components of switch costs. The following experiments were designed in order to serve these purposes.

Experiment 2 investigates whether the assessment of negative priming can be selectively influenced by conditions that remove the causes for negative priming to appear. Experiment 3 was conducted in order to compare the present assessment of repetition benefits with comparable repetition benefits in a choice reaction time task with Go and NoGo trials. Finally, Experiment 4 explores the conditions under which task set reconfigurations in NoGo trials are fully completed or not.

EXPERIMENT 2

In Experiment 1 the increase of RTs in switch trials after NoGo trials (case IV, e.g., responding to letter A after suppressing responding to letter A in the previous trial) in comparison to switch trials after Go trials (case III, e.g., responding to letter A after responding to letter E in the previous trial) was considered as caused by negative priming costs. Alternatively, one may argue that the increase of RTs might be an unspecific effect of the previous NoGo trial. It might take longer to initiate a response after one had to withhold it than to initiate a response that one has just executed (response repetition). Experiment 2

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was designed in order to decide between these two accounts: In NoGo trials the respective target letters for the alternate task were replaced by distractor letters. Consequently, participants never had to respond to a letter to which responding was to be suppressed in the previous trial, so that no negative priming should occur. If however, the RT differences between cases IV and III are due to an unspecific effect of the previous NoGo trial, they should remain untouched by this manipulation.

Method

Participants. Twelve students of the University of Wuerzburg (age 19–32) participated in individual sessions of approximately 45 min in fulfilment of course requirement. They reported having normal or corrected-to-normal vision.

Apparatus and stimuli. The equipment, the stimuli, and the computer program to control the experiment were the same as in Experiment 1, except that in NoGo trials in which the task ''A'' was cued the distractor K (or U) instead of the target E, and in NoGo trials in which task ''E'' was cued the distractor letter U (or K) instead of the target A were presented.

Design and procedure. The procedure was the same as in Experiment 1. For half of the participants the distractor in task ''A'' was the uppercase letter K and for task ''E'' it was the uppercase letter U. For the other half of the participants the assignment was reversed.

Results

Mean error rate was 0.2% for Go trials and 2.6% for NoGo trials. From the analysis of RTs (only Go trials) all errors as well as all data from trials with an error in the previous trial were excluded (1.9%). As in Experiment 1, we calculated for each participant first the mean RTs for each of the four cases in each CSI.

An ANOVA with the within-subject factors switch/non-switch, Go/NoGo in the previous trial, and CSI revealed a significant effect of the factor switch/non-switch, $F(1, 11) = 36.03$, $p < .001$, $MSe = 44443.73$. Participants responded faster in non-switch trials than in switch trials (345 ms versus 369 ms). There was a significant effect of the factor Go/NoGo, $F(1, 11) = 7.28$, $p < .05$, $MSe = 11973.78$, indicating shorter RTs after Go trials compared to NoGo trials (351 ms versus 363 ms). There was a significant effect of the factor CSI, $F(5, 55) = 14.22$, $p < .001$, $MSe = 14025.93$. RTs decreased with longer CSI (383 ms, 370 ms, 360 ms, 344 ms, 345 ms, and 339 ms). Finally, there were significant interactions between switch/non-switch and CSI, $F(5, 55) = 3.79$, $p < .01$, $MSe = 1933.11$, as well as between switch/non-switch and Go/NoGo, $F(1, 11) = 17.57$, $p < .01$, $MSe = 17566.25$. RTs in switch trials increased more with short CSIs,

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resulting in an overall difference between switch and non-switch trials of 30 ms, 35 ms, 31 ms, 33 ms, 17 ms, and 2 ms. The main effect of the Go/NoGo factor was restricted to task repetitions (330 ms versus 359 ms) and did not exist when tasks were switched (371 ms versus 368 ms). All other effects were not significant.

The assessments of the amount of repetition benefits, intentional components of switch costs, and negative priming costs plotted against the CSIs are shown in Figure 5.

Separate ANOVAs revealed, as in Experiment 1, that repetition benefits are significantly different from zero, $F(1, 11) = 18.06$, $p < .001$, $MSe = 58545.86$ and independent of the CSI, $F(5, 55) < 1$. Likewise, there are, as in Experiment 1, no significant intentional components of switch costs $F(1, 11) = 3.00$, $p > .1$, $MSe = 10280.35$ and no interaction with the CSI as well, $F(5, 55) = 1.45$, $p > .2$, $MSe = 1618.54$. However, in contrast to Experiment 1, there are no longer significant differences between cases IV and III, $F(1, 11) < 1$, and no interaction of these differences with the CSI, $F(5, 55) < 1$.

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Discussion

In the NoGo trials of Experiment 2 distractor letters were presented instead of the respective alternatively relevant target letters used in Experiment 1. Accordingly, participants never had to respond to a letter to which they had to suppress responding in the previous NoGo trial, i.e., negative priming conditions were excluded. As a result of this manipulation, the RT differences between case

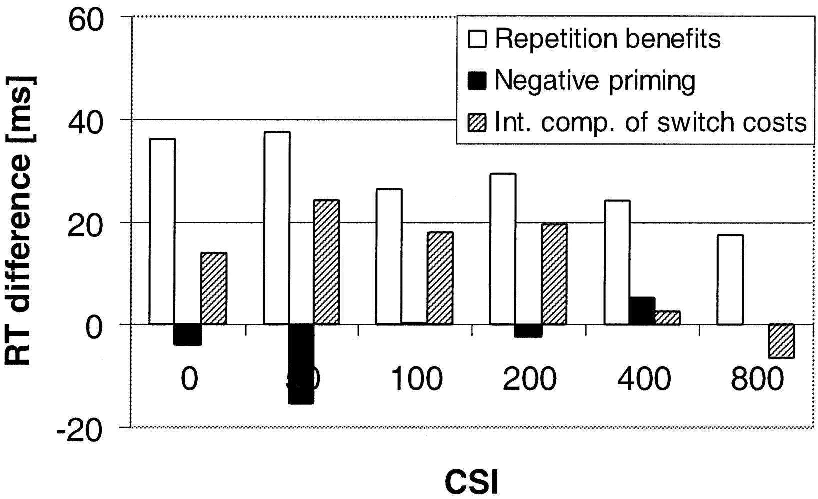

Figure 5. Repetition benefits, negative priming, and intentional components of switch costs plotted against CSI for non-overlapping S–R mappings.

III (switch after Go) and case IV (switch after NoGo), found in Experiment 1, vanish. The finding is consistent with the notion that the RT differences between cases III and IV in Experiment 1 were indeed due to negative priming, instead of being due to an unspecific delay effect of the previous NoGo trial.

EXPERIMENT 3

Results of Experiment 1 led to the suspicion that task sets may not always be completely reconfigured within NoGo trials. Consequently, in non-switch trials after NoGo trials participants might still need to complete the configuration of the required task set despite it is repeated. If this suspicion is correct, the RT differences between task repetitions after Go trials (case I) and task repetitions after NoGo trials (case II) would not only indicate purely stimulus driven repetition benefits (reducing RTs in case I) but also some intentional effort of task set completion (increasing RTs in case II).

In order to gain a separate assessment of the amount to which RT differences between task repetitions after Go trials and task repetitions after NoGo trials are based on purely stimulus-driven repetition benefits, Experiment 1 was replicated with distractor letters and a standard choice reaction instruction: Participants were instructed to respond when either target A or target E was presented but to withhold responding when either of the distractors K or U was presented. Thus, participants were to be ready to respond either to A or to E throughout the whole experimental session instead of switching between the readiness to respond to A and not to E or to respond to E and not to A. Consequently, all possible influences of intentional task reconfigurations, as well as of negative priming should be excluded. On the other hand, RTs from repetitions of S–R mappings likewise can be compared to RTs after NoGo trials, as has been done in Experiment 1, allowing an assessment of the portion to which RT differences between cases II and I are purely due to stimulus-driven repetition benefits.

Method

Participants. Twelve students of the University of Wuerzburg (age 19–47) participated in an individual session of approximately 45 min in fulfilment of course requirement. They reported having normal or corrected-to-normal vision.

Apparatus and stimuli. The equipment, the stimuli, and the computer program to control stimulus presentations were the same as in Experiment 1, except that in NoGo trials distractor letters (K and U) were presented (as in Experiment 2) and the task cues (the spoken letter ''A'' or ''E'') were replaced by a neutral ready signal. Remember that in NoGo trials the targets (A and E) were replaced by the distractors (K and U) according to a fixed schedule: Letter A was always replaced by letter K (or U), and letter E was always replaced by

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letter U (or K). Consequently, the alternating presentation of targets or their respective distractors was the same as in Experiment 1.

Design and procedure. The procedure was equal to that in Experiments 1 and 2, except for the instruction: Participants were now required to respond as fast as possible when an A or an E appeared and not to respond when a K or a U appeared. Letters were randomly assigned to each individual trial in the same way as in Experiment 1, with the exception that in NoGo trials the respective irrelevant target was replaced by a distractor. Again, each possible combination of Go/NoGo in trial n–1 (2) × Go/NoGo in trial n (2) × CSI (6) was realised four times per block.

Results

Mean error rate was 0.1% for Go trials and 0.9% for NoGo trials. Only correct Go-trials with correct predecessors were further analysed (0.6% of Go trials were excluded).

Repetition benefits were assessed by calculating for each participant and each CSI the mean difference of RTs between Go trials that were either preceded by a Go trial with the same target letter (repetitions) or by a NoGo trial (cf., Figure 6). An ANOVA with CSI as the only within subject factor revealed that repetition benefits were significantly different from zero, $F(1, 11) = 14.68$, $p < .01$, $MSe = 22029.01$, and depended on the CSI, $F(5, 55) = 4.27$, $p < .01$, $MSe = 1663.08$.

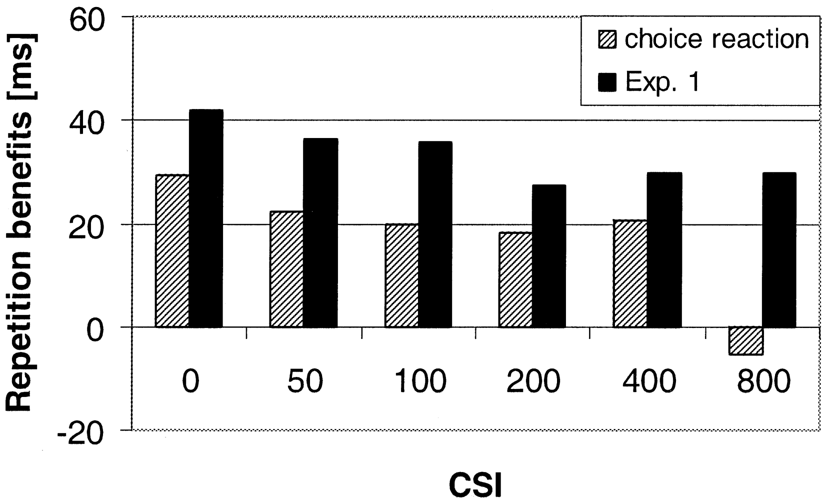

Figure 6. Repetition benefits plotted against CSI for the choice reaction time task in comparison to repetition benefits of Experiment 1.

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Participants responded on average 18 ms faster in repetition trials than after a NoGo trial, and the repetition benefit significantly drops after a CSI of 800 ms. In comparison to Experiment 1, repetition benefits were significantly reduced, $F(1, 22) = 6.31$, $p < .05$, $MSe = 9201.77$ (18 ms vs. 34 ms).

Discussion

Experiment 3 was performed in order to assess the portion to which the RT differences between cases I and II in Experiment 1 are due to purely stimulus-driven repetition benefits. Participants were required to respond to two target letters (Go trials) and to withhold responding to two distractor letters (NoGo trials). The succession of Go and NoGo trials as well as the succession of the two target letters in Go trials were controlled in the same way as in Experiment 1, in which participants switched between the readiness to respond to either one or the other target letter on every second trial. Likewise, as in Experiment 1, repetition benefits were assessed by calculating the RT differences between trials in which participants responded to the same letter as in the previous trial and trials in which participants responded to a target letter after a previous NoGo trial. The experiment yielded two main results: First, there were significant repetition benefits. Second, repetition benefits were significantly smaller than in Experiment 1. The reduction of repetition benefits in comparison to Experiment 1 is consistent with the suspicion that in Experiment 1 the RT differences between cases II and I are not exclusively due to stimulus-driven repetition benefits but may be additionally affected by costs for the completion of task set reconfiguration after NoGo trials.[4]

EXPERIMENT 4

Experiment 4 explicitly examines the suspicion that in NoGo trials task sets may be not completely reconfigured. Terminations of task set reconfiguration are especially to be expected when the stimulus signals immediately after the cue that the cued task is not to be performed. Thus, we suspect that participants tend to stop task set reconfiguration particularly in NoGo trials with short CSIs, whereas in NoGo trials with long CSIs task set reconfigurations may be mostly completed. Accordingly, task repetitions after NoGo trials with short CSIs would often still require a reconfiguration of the task set, despite it being repeated. In contrast, task repetitions after NoGo trials with long CSIs mostly

[4] Moreover, it is notable that in succeeding Go trials a change of the target stimulus (A–E, E–A) leads to costs of only 6 ms in comparison to stimulus repetitions (A–A, E–E), $F(1, 11) = 3.15$, $p > .10$, $MSe = 1335.84$. So, in comparison to repeating both the stimulus and the response, changing the stimulus and repeating the response delays responses only marginally. In contrast, changing both the stimulus and the response (i.e., Go after NoGo) causes a significant delay of about 18 ms. Against these findings it appears to be improbable that the differences between the four cases in Experiment 1 result from interactions between stimulus and response repetitions (cf., Footnote 3).

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would not require a reconfiguration of the task set as it has been already reconfigured.

The effort of voluntarily driven reconfigurations can be assessed through RTs from short CSI trials only, as in long CSI trials reconfiguration may be finished before the stimulus is presented. Thus, the foregoing speculations led us to a rather detailed expectation concerning RTs in non-switch trials with short CSIs in dependence on whether the previous NoGo trial had a short versus a long CSI: Only in the former case we expect a relative increase of RTs, resulting from the additional effort it takes to complete a previously uncompleted task set. In order to examine this expectation, short and long CSIs in the current and the respective previous trial were orthogonally varied under otherwise the same conditions as in Experiment 1.

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Method

Participants. Twelve students of the University of Wuerzburg (age 19–30) participated in individual sessions of approximately 55 min in fulfilment of course requirement. They reported having normal or corrected-to-normal vision.

Apparatus and stimuli. The equipment, the stimuli, and the computer program to control the experiment were the same as in Experiment 1.

Design and procedure. The procedure was basically the same as in Experiment 1. However, instead of six different CSIs only a short (100 ms) and a long CSI (800 ms) were used. Moreover, the successions of CSIs and Go/NoGo conditions in consecutive trials were orthogonally varied, i.e., all 16 combinations of the four possible successions of Go/NoGo trials with the four possible successions of the two CSIs were presented four times in each block. Again, alternating runs of the required tasks were realised, so that each of the 16 combinations of the Go/NoGo and CSI trials was assigned to the four possible task sequences ‘‘AA’’, ‘‘EE’’, ‘‘AE’’, and ‘‘EA’’ once. At the beginning of each block four warm-up trials were presented, resulting in 68 trials per block. The experiment was run with 12 blocks. Finally, the time structure was slightly changed: In NoGo trials the letters remained present only for 800 ms instead of 1000 ms as in Experiment 1, so that in Go trials only responses within 800 ms after stimulus presentation were recorded as being correct. Like in Experiment 1 the next trial started in each case 2000 ms after the onset of the stimulus.

Results

Mean error rate was 1.0% for Go trials and 2.6% for NoGo trials. All errors as well as all data from trials with an error in the previous trial were excluded from the further analysis of the RTs of the Go trials (2.6%).

Table 1 presents mean RTs and standard deviations for switch and non-switch Go trials in dependence on whether the previous trial was a Go or a NoGo trial, whether the CSI of the current trial was short or long, and whether the CSI in the previous trial was short or long.

Over the corresponding individual data an ANOVA with the within-participants factors switch/non-switch, Go/NoGo in the previous trial, CSI in the current trial, and CSI in the previous trial was performed. The ANOVA revealed significant effects of the factor switch/non-switch, $F(1, 11) = 74.33$, $p < .001$, $MSe = 33511.66$. RTs were delayed in switch trials (373 ms vs. 346 ms). There was a significant effect of the factor Go/NoGo, $F(1, 11) = 27.01$, $p < .001$, $MSe = 20092.95$, indicating delayed RTs after NoGo trials (370 ms vs. 349 ms). Further, there was a significant effect of the current CSI, $F(1, 11) = 56.80$, $p < .001$, $MSe = 202468.34$. RTs decreased with longer CSI (392 ms vs. 327 ms). Moreover, there were significant two way interactions between switch/non-switch and CSI in the current trial, $F(1, 11) = 15.05$, $p < .01$, $MSe = 8224.45$, and switch/non-switch and Go/NoGo in the previous trial, $F(1, 11) = 13.78$, $p < .01$, $MSe = 3052.03$. RTs in switch trials increased more if the CSI was short (412 ms vs. 372 ms) than if it was long (334 ms vs. 320 ms), and the increase of RTs after a NoGo compared to a Go trial was stronger in non-switch trials (361 ms vs. 332 ms) than in switch trials (379 ms vs. 367 ms). Additionally, there was a significant three-way interaction between switch/non-switch, Go/NoGo in the previous trial, and CSI in the current trial, $F(1, 11) = 12.02$, $p < .01$, $MSe = 3419.38$. Note that by the switch/non-switch and Go/NoGo variation trials are assigned to the four cases according to Table 1. The three-way interaction indicated that RTs decreased less with a long CSI in case I (354 ms vs. 310 ms), more in case II (390 ms vs. 331 ms) and case IV (413 ms vs. 345 ms), and most in case III (410 ms vs. 323 ms).

TABLE 1
Mean RTs (in ms) and standard deviations for switch and non-switch Go trials in dependence on whether the previous trial was a Go or a NoGo trial, plotted against CSI of the current trial separated for short and long CSIs in the previous trial

		Non-switch		*Switch*	
		Go in n–1	*NoGo in n–1*	*Go in n–1*	*NoGo in n–1*
100 ms CSI	100 ms CSI in n–1	339 (54.98)	384 (59.81)	391 (58.30)	400 (50.12)
100 ms CSI	800 ms CSI in n–1	369 (59.14)	397 (52.88)	429 (65.15)	427 (70.57)
800 ms CSI	100 ms CSI in n–1	307 (42.87)	324 (52.22)	316 (53.68)	338 (67.08)
800 ms CSI	800 ms CSI in n–1	313 (38.81)	338 (59.80)	330 (53.07)	351 (50.22)

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We turn now to a closer inspection of the effects of the CSI in the previous trial. First, RTs are generally increased with a long CSI in the previous trial, $F(1, 11) = 32.49$, $p < .001$, $MSe = 17813.19$ (369 ms vs. 350 ms). Second, there was an interaction between CSI in the current and the previous trial, $F(1, 11) = 7.51$, $p < .05$, $MSe = 2785.87$. RTs increased more with a long previous CSI when the current CSI was short (405 ms vs. 379 ms) than when it was long (333 ms vs. 321 ms). Finally, the increase of RTs after short CSIs was significantly modified in dependence on whether the previous trial was a Go or a NoGo trial, $F(1, 11) = 10.40$, $p < .01$, $MSe = 911.76$ for the three-way interaction. RTs increased more strongly after previous Go trials (399 ms vs. 365 ms) than after previous NoGo trials (412 ms vs. 392 ms). In contrast, when the current CSI was long, the (reduced) impact of the previous CSI did not differ in dependence on whether the previous trial was a Go trial (322 ms vs. 311 ms) or a NoGo trial (344 ms vs. 331 ms). All other effects were not significant.

To further survey the detailed expectation that RTs in non-switch trials with a short CSI after a previous NoGo trial (case II) should be relatively delayed when the previous CSI was short compared to long, we examined the corresponding RTs of case II in comparison to RTs of case I (non-switch—Go in n–1) and case III (switch—Go in n–1, cf., Figure 7). A separate ANOVA with the within-participant factors case (case I, case II, and case III) and CSI in the previous trial revealed significant effects for the factor case, $F(2, 22) = 36.00$, $p < .001$, $MSe = 19297.97$, as well as for the factor CSI, $F(1, 11) = 17.62$, $p < .001$,

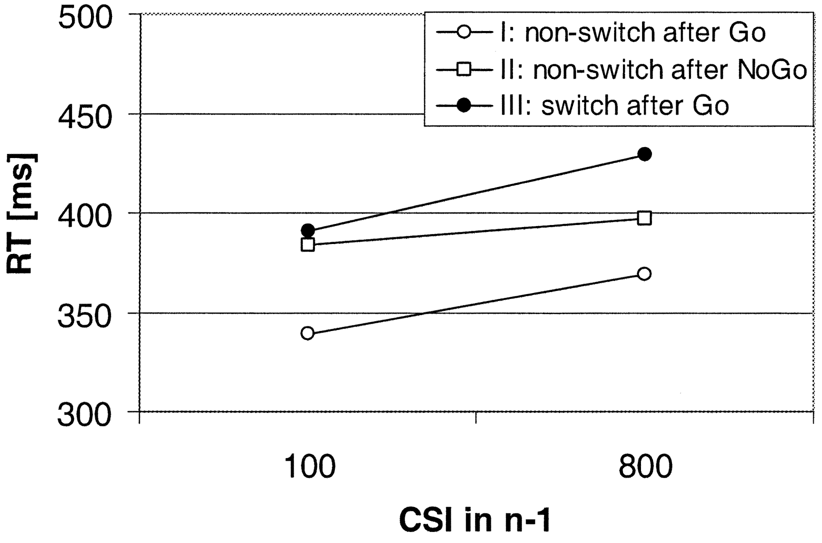

Figure 7. Mean RT for cases I–III for short CSI (100 ms) plotted against CSI in the previous trial.

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MSe = 13235.65. RTs increased from case I to case III (354ms, 390ms, and 410ms) and RTs decreased when the CSI in the previous trial was short (371 ms) compared to long (398 ms). Most important, there was a significant interaction between both factors, $F(2, 22) = 4.32$, $p < .05$, $MSe = 970.38$. The decrease of RTs for short CSIs in the previous trial was significantly less pronounced for case II (384 ms vs. 397 ms) than for case I (339 ms vs. 369 ms) and case III (391 ms vs. 429 ms).

Discussion

Experiment 4 replicated all main findings of Experiment 1. There are significant switch costs that decline with a long CSI, i.e., the more time is available to prepare the currently cued task set before the stimulus is presented. Furthermore, switch costs in general as well as their decline with a long CSI are modified in dependence on whether the previous trial was a Go or a NoGo trial, which supports the appropriateness of the distinction of the four cases (see Figure 1). Thus, despite the few procedural changes, the same components of task switches, namely repetition benefits, negative priming, and intentional components of switch costs as in Experiment 1, seem to be addressed.

Experiment 4 was especially designed in order to examine the suspicion that in NoGo trials with short CSIs the configuration of the required task set often might be terminated before completion, so that in a subsequent non-switch trial the task set is still to be fully configured despite that the task is repeated. Consequently, due to the additional effort for task set completion, RTs in non-switch trials with short CSIs are expected to be increased after NoGo trials with a short CSI compared to NoGo trials with a long CSI. The data, however, reveal that contrarily to this expectation RTs generally decrease if the previous CSI was short (cf., Figure 7).

A comparable phenomenon is known from the ''foreperiod paradigm'', i.e., choice reaction time studies in which the imperative stimulus is presented at variable intervals after a warning signal (foreperiod): RTs generally decrease when the foreperiod of the previous trial is short compared to long (e.g., Alegria & Delhaye-Rembaux, 1975; Los, Knol, & Boers, 2001). Presumably, participants tend to expect a repetition of the previous foreperiod, so that responses are accelerated if a short foreperiod is expectedly repeated but delayed if after a long foreperiod an unexpected short foreperiod appears (Alegria & Delhaye-Rembaux, 1975). Thus, the expected relative increase of RTs after NoGo trials with short CSIs is to be assessed against the oppositely directed general foreperiod effect.

Figure 7 illustrates the foreperiod effect for Case II (non-switch after NoGo) in comparison to the foreperiod effect if the previous trial was a Go trial, i.e., case I (non-switch after Go) and case III (switch after Go). The foreperiod effect is significantly reduced for case II (13 ms) compared to case I (30 ms), and case III (38 ms). The reduction in case II is mainly due to a relative increase of RTs if the CSI in the previous NoGo trial was short. This is consistent with our suspicion that exactly under these conditions a relative increase of RTs is to be expected because of a still necessary completion of a previously not completed task set reconfiguration.

The *relative* increase of RTs in case II after short previous CSIs can be further illustrated if one assesses repetition benefits (case II–case I) and intentional components of switch costs (case III–case II) in dependence on whether the CSI in the previous trial was short or long. Repetition effects are significantly higher if the previous CSI is short compared to long (44 ms vs. 28 ms), $t(11) = 2.17$, $p < .05$, which is consistent with our suspicion that after short previous CSIs repetition benefits may be overestimated because they also contain costs of a completion of task set reconfiguration. In contrast, intentional components of switch costs are significantly reduced under short previous CSIs (7 ms vs. 32 ms), $t(11) = 2.89$, $p < .01$, which is consistent with our suspicion that after short previous CSIs intentional efforts may be underestimated because they are assessed in comparison to non-switch trials that still require a completion of task set reconfiguration.

To conclude: A ''clean'' assessment of repetition benefits and intentional components of switch costs is only assured when task set reconfiguration was completed in the previous trial, i.e., when the CSI in the previous trial was long. In this case significant intentional components of switch costs (32 ms), $t(11) = 2.98$, $p < .05$, reveal when the current CSI is short.

GENERAL DISCUSSION

The present experiments were designed in order to explore whether stimulus-driven components of switch costs can be properly disentangled from intentionally driven components by combining a task switch paradigm with a Go/NoGo paradigm. It was argued that non-switches after Go trials should selectively profit from stimulus-driven repetition benefits, whereas switches after NoGo trials should selectively suffer from stimulus-driven negative priming. Finally, intentional components of switch costs should be assessable by RT differences between switches after Go trials, which do not suffer from negative priming, and non-switches after NoGo trials, which do not profit from repetitions. Four experiments confirm that the proposed combination of a task switch and a Go/NoGo paradigm may indeed be a useful approach to gain separate assessments of repetition benefits, negative priming costs, and intentional components of switch costs, if certain conditions are met.

Experiment 1 showed that participants smoothly adapt to a task switch experiment with Go and NoGo trials. Furthermore, the data reveal that task repetitions after Go trials are in general accomplished faster than task repetitions after NoGo trials, indicating separate repetition benefits. Likewise, task switches after NoGo trials are accomplished more slowly than after Go trials, indicating

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separate negative priming costs. Experiment 2 confirmed that negative priming costs selectively reduced to zero if the causes for the appearance of stimulus-driven negative priming are removed. Experiment 3 provided data of stimulus-driven repetition benefits in a choice reaction task under Go/NoGo requirements. A comparison with the otherwise identical task switch conditions suggests that the repetition benefits in Experiment 1 have been overestimated. Finally, Experiment 4 confirmed that the overestimation of repetition benefits as well as a suspected underestimation of intentional components of switch costs are presumably due to a tendency of participants to cancel the task set reconfiguration in NoGo trials if immediately after the task cue the presentation of a task-irrelevant stimulus signals that the cued task is not to be performed.

The findings let it appear worthwhile to further adopt combinations of task switches and Go/NoGo requirements in order to disentangle the impact of repetitions, negative priming, and intentionally driven task set reconfigurations on total switch costs. The data additionally reveal that an appropriate application of the approach for this purpose requires settings that ensures that also in NoGo trials participants fully reconfigure the cued task sets. According to the findings of Experiment 4 this seems to be achievable by using long CSIs.

In the present experiments participants had to switch between the mapping of two stimuli to Go and NoGo responses only. The data reveal that even within this restricted setting switch costs entail exogenous as well as endogenous components as proposed by Rogers and Monsell (1995).

The exogenous components are attributed to sequential effects in the succession of the four possible S–R mappings (A–Go, E–Go, A–NoGo, and E–NoGo). Repetitions of the same S–R mapping cause RT benefits additionally to the ‘‘benefit’’ of task repetition. Transitions from suppressing the response to a certain stimulus to responding to it (e.g., A–NoGo, A–Go), cause negative priming costs in addition to the costs of task switching. These results accord well with the consideration that realised S–R couplings tend to sustain so that it is easy to repeat them; in contrast, it is difficult to respond to a stimulus to which one has not just responded to (Allport & Wylie, 2000; Waszak, Hommel, & Allport, 2002; Wylie & Allport, 2000).

The endogenous components are only reflected in RTs after short CSIs. They are attributed to the intentional effort it takes to attend to the currently relevant stimulus and to be ready to respond to it. Additionally, intentional effort may be required in order to disengage attention and response readiness from the irrelevant stimulus. To what extent intentional components of switch costs reflect an adjustment of the stimulus set (Meiran, 2000) and an inhibition of the previous task set (Mayr & Keele, 2000) is not resolvable by the present data.

In order to prove the principal practicability of the new paradigm we decided to explore switches between two extremely simple task sets for the first step. As the majority of task switching studies examined more complex switches between stimulus dimensions (Mayr & Keele, 2000; Meiran, 1996, 2000) or cognitive operations (Rogers & Monsell, 1995), further research is needed to prove the general applicability of our approach. Indeed the paradigm is easily adaptable to more complex conditions. The insertion of NoGo trials only requires to use a task-irrelevant stimulus set besides the task-relevant sets. Let us consider for example the experiment by Rogers and Monsell (1995), in which either letters or numbers were to be classified. If one additionally uses, let's say, currency signs as a task-irrelevant stimulus set, an imperative stimulus like ''M€'' would represent a Go stimulus for letter classification but a NoGo stimulus for the number classifications task, because there is no number to be classified. Likewise, a stimulus like ''£3'' would represent a Go stimulus for the number classification but a NoGo stimulus for the letter classification task, etc.

By proper combinations of tasks and stimuli the same variations of switch and non-switch trials after Go and NoGo trials as in the present experiments can be accomplished. The insertion of NoGo trials now offers an even more detailed analysis of repetition benefits and negative priming costs. If one considers the underlined stimuli as the actual task relevant target, trial sequences like ***M***$–***M***3, ***G***$–***M***3, and ***A***3–***M***€ allow repetition benefits for stimulus repetitions, response repetitions, and stimulus set repetitions to be distinguished. Likewise, trial sequences like *M****£–M***€, ***G£–M***€, and *A****£–M***€ allow negative priming costs for ignoring the same stimulus, the same response, or the same stimulus set to be assessed. Furthermore, the distinction between successions of Go-Go trials without (e.g., £*7*–***M***€) or with negative priming (e.g., A*7*–***M***€) can be explored. Finally, it is possible to investigate the impact of presenting bivalent stimuli in the previous and/or in the present trials by comparing sequences like $***M***–$***M***, 3***M***–$***M*****,** $***M***–3***M***, or 3***M***–3***M***.

It is beyond the scope of the present paper to elaborate in detail these different possibilities. The present experiments were restricted to demonstrate that the combination of the task switch paradigm with a Go/NoGo approach opens new possibilities for a more detailed analysis of the various components that contribute to switch costs. The exploration of these possibilities remains open to further exploration.

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