

# Differential Effects of Cue Changes and Task Changes on Task-Set Selection Costs

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A task-switching paradigm with a 2:1 mapping between cues and tasks was used to separate cue-switching processes (indexed through pure cue-switch costs) from actual task-switching processes (indexed through additional costs in case of cue and task changes). A large portion of total switch costs was due to cue changes (Experiments 1 and 2), and cue-switch costs but not task-switch costs were sensitive to effects of practice (Experiment 1) and preparation (Experiment 2). In contrast, task-switch costs were particularly sensitive to response-priming effects (Experiments 1 and 2) and task-set inhibition (Experiment 3). Results suggest two processing stages relevant during task-set selection: cue-driven retrieval of task rules from long-term memory and the automatic application of rules to a particular stimulus situation.

The ability to intentionally change an implemented course of action is not only one of the most important but probably also most exclusively human skills. It allows us to respond flexibly to changing circumstances, and it also allows us to abandon old routines in favor of new solutions. However, changes in the course of action come at a cost in terms of speed and accuracy of performance (e.g., Allport, Styles, & Hsieh, 1994; Jersild, 1927; Meiran, 1996; Rogers & Monsell, 1995; Spector & Biederman, 1976). These so-called switch costs are an indication of the cognitive system's processing limitations relevant during coordination of different tasks or actions across time. Understanding the factors that underlie switch costs is an important step toward the development of a model of intentional control of action.

In the current work we propose that two distinct, serial processing stages are critical during changes of task configurations and thus for the emergence of switch costs. The first stage is associated with cue-driven retrieval of rules for upcoming task demands from long-term memory (LTM) into working memory (in short, *retrieval stage*). The retrieval stage can be triggered through any internal or external signal that indicates an upcoming task, and it can run off in an anticipatory manner (i.e., before the response-relevant stimulus appears). The second stage, which we refer to as the *application stage*, is much more closely tied to the actual

stimulus than to the task cues. During this stage, task rules are applied in a relatively automatic manner once the stimulus is presented (although we do not want to rule out the possibility that an imagined stimulus may be sufficient). This two-stage conceptualization is similar in spirit to several other two-process accounts of task switching (e.g., Meiran, 2000; Rogers & Monsell, 1995; Rubinstein, Meyer, & Evans, 2001).

In order to assess the functional characteristics of processes associated with these two stages, we borrow the so-called information-reduction method. This method has been used in the context of response-repetition-priming research to distinguish between stimulus-based and response-based priming (e.g., Bertelson, 1965; Campbell & Proctor, 1993) and is described in detail in the section Switch Costs and LTM Retrieval. In the context of the task-switching paradigm, this method allows us to divide total switch costs into a cue-switch component, supposedly representing the retrieval stage, and a task-switch component, supposedly representing the application stage. In other words, we can determine the degree to which costs of switching tasks are produced by a change in cue-initiated retrieval and to what degree they are produced by a change in task per se. More important, this method allows us to locate several important set-selection phenomena and processes with regard to the two proposed stages. Specifically, we look at the locus of short-term task-switching practice effects (e.g., Kramer, Hahn, & Gopher, 1999), at task-specific response-priming effects (e.g., Rogers & Monsell, 1995), at intentional preparation (e.g., Mayr & Kliegl, 2000; Meiran, 1996; Rogers & Monsell, 1995), and at inhibition of task sets (Mayr & Keele, 2000).

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## The Task-Switching Paradigm

The task-switching paradigm allows a systematic examination of task-set configuration costs (e.g., Allport et al., 1994; Jersild, 1927; Meiran, 1996; Rogers & Monsell, 1995). Typically, in this paradigm, participants work on two or more simple response-time (RT) tasks within the same block of trials. The currently relevant task is signaled by a task cue or is instructed via a sequential rule

(e.g., “alternate every two tasks”). The contrast between RTs from task-switch trials and RTs from task-repetition or no-switch trials yields the switch cost. Switch costs as assessed in the task-switching paradigm can be quite substantial (on the order of several hundred milliseconds). Further, switch costs can be reduced, though usually not eliminated, through opportunity for preparation (Mayr & Kliegl, 2000; Meiran, 1996; Rogers & Monsell, 1995). The fact that switch costs can be reduced through preparation suggests that at least in part, changes in cognitive configurations are subject to intentional control. At the same time, the fact that residual costs remain even after long preparatory intervals suggests that complete reconfiguration is either impossible or at least difficult to achieve without actually executing the task. Dual-process conceptualizations of switch costs have been triggered specifically by this pattern of both preparation sensitive and seemingly more exogenously driven switch-cost components (e.g., Rogers & Monsell, 1995; Rubinstein et al., 2001).

### Switch Costs and LTM Retrieval

For the preparation-linked switch-cost component, Mayr and Kliegl (2000) recently suggested LTM retrieval of the upcoming task rules as the critical process. Such a proposal is not very surprising when applied to situations in which circumstances require the adoption of a new course of action (i.e., one that has not been applied recently). However, during a typical task-switching experiment, the situation is different in that participants usually need to switch back and forth between a small set of simple tasks (usually two). The proposal that a controlled LTM retrieval is critical even in such a situation implies a model of cognitive control that allows no more than one of several competing sets of task rules to be represented in working memory at a time. Working memory, by this account, functions as the critical set-selection device. Consistent with this view is the finding that disengagement from a no-longer-relevant task set goes along with inhibition of that task set (e.g., Arbutnott & Frank, 2000; Mayr & Keele, 2000; Schuch & Koch, in press).

Obviously, an important consequence of the single-task constraint is that each change of task requires reretrieving the next task set from LTM even if it had been used only two trials earlier. Mayr and Kliegl (2000) presented several pieces of evidence that are consistent with this prediction. For example, they showed that switch costs increase as a function of the LTM-retrieval demand of the switched-to task, as one would expect when two successive retrieval processes interfere with each other. Even more important, this retrieval-demand effect is limited to the preparatory component of switch costs. In other words, LTM retrieval of task rules seems to be a large part (if not everything) of what people can do intentionally to prepare for an upcoming task.

The claim that a simple retrieval process is a crucial part of switch costs leads to an important question: Are switch costs actually due to a trial-to-trial change in the task itself, or can they be attributed to a trial-to-trial change in retrieval path? The typical task-switching paradigm confounds the two critical parameters: Whenever there is a change in cue, there also is a change in task; whenever cues stay the same across trials, tasks also stay the same.<sup>1</sup> As a consequence of this confound, the cue-switch component and the actual task-switch component both contribute to total switch costs in an undifferentiated manner.

To separate these two components, we applied the information-reduction logic used in research on stimulus- or response-repetition priming (e.g., Bertelson, 1965; Campbell & Proctor, 1993) to a task-switching paradigm with trial-by-trial cuing of tasks. The key element of the information-reduction paradigm, as applied to the task-switching situation, is a 2:1 mapping between cues and tasks. When tasks can be accessed through more than one cue, three different types of trial-to-trial transitions are possible: (a) the task set and the cue stay the same (which is the usual no-switch condition); (b) a task switch is accompanied by a cue switch (which is the usual switch condition); or (c) a task set is repeated across successive trials, but the cue changes. For the third situation, which we call the cue-switch condition, we assume that a new cue elicits a new retrieval process. Therefore, we expect a substantial RT cost between the no-switch and the cue-switch condition even though the task set is repeated in each of these two conditions. The size of the RT difference between the no-switch and the cue-switch condition should reflect the switch-cost component that is associated with the task-set retrieval stage. By this logic, the difference between the cue-switch RT and the task-switch RT should reflect the additional cost that arises from whatever processes cannot be accomplished through mere retrieval of task rules. Presumably, this entails the automatic application of given task rules to a particular stimulus situation.

The logic of using the information-reduction method to separate task-set retrieval from the actual task-switch component is based on the critical assumption that a retrieval process and the specific cue by which it was elicited become closely linked to each other. In the case of such a link, a repetition of the immediately preceding cue would lead to reactivation of the most recent retrieval process, whereas a cue change would require activation of a new retrieval process (or the activation of a less recent retrieval instance). On the empirical level, this assumption is in line with findings in the response-priming literature: Priming benefits often have been found to be limited to situations in which stimuli (or at least preexperimentally defined stimulus categories) repeat. In contrast, response repetitions alone are usually not associated with priming benefits (e.g., Campbell & Proctor, 1993; Pashler & Baylis, 1991). On a theoretical level, the assumption of a tight link between a specific cue and a specific retrieval process is in line with an instance view of episodic memory (e.g., Hintzman, 1986; Logan, 1990). By this view, each set-selection episode would produce a memory record of all selection-relevant parameters, including the task cue. Generally, repetition benefits would be expected to be a function of the degree of match between the current-trial selection episode and the previous-trial selection episode (for a somewhat more complex model, see Hommel, 1998).

### Experiment 1: Priming and Practice

Here and in the following experiment, the information-reduction paradigm was applied to a task-switching situation with two 3-choice visual RT tasks, one in which the color and one in which

<sup>1</sup> This is obvious when participants are cued on a trial-to-trial basis. However, even in the case of sequential cues (e.g., “alternate every two trials”), we argue there is an internally generated cue that may either change or stay the same along with the actual task.

the shape of a single object had to be discriminated. Letters served as symbolic cues (*G* and *S* for the color task and *B* and *W* for the shape task). Aside from the primary cue-change and task-change comparisons, two additional factors were considered to provide information regarding the dissociation between the task-set retrieval and the task-set application stage.

The first factor was whether responses repeated across successive trials or not. Past work has shown that the usual, positive repetition-priming effects can be obtained only in the case of no-switch transitions whereas priming effects are either absent or turn negative in the case of a task switch (e.g., Rogers & Monsell, 1995). Obviously, the repetition-priming effects are a signature of actual processing of the previous-trial stimulus, and the fact that these effects are limited to no-switch transitions suggests that they may be tied to the actual task-set configuration as applied to a particular stimulus. This allows for an interesting prediction: If a change in cue actually leads to a change in retrieval but maintenance of the just-applied task configuration, then repetition-priming effects should be qualitatively similar to those in "normal" no-switch trials. Alternatively, a particular retrieval instance may also become integrated with the way the rules were applied to the stimulus so that a change in retrieval path would also lead to a change in applied configuration. In this case, repetition-priming effects in the cue-switch case should behave in the same way as when the actual task changes. In other words, the behavior of response repetitions can serve as an indicator of the degree to which representations associated with the retrieval stage and representations associated with the application stage are dissociated.

The second factor was within-session practice. Specifically, we predicted differential effects of practice concerning the cue-switch cost versus the task-switch cost. This prediction is based on the following rationale. During a switch, participants use the cue to retrieve the task set. Optimally, the task set specifies the necessary stimulus-response (S-R) associations. The stronger the association between the cue and the task set and between the stimuli and responses, the faster this process of loading the adequate information into working memory should be executed. Thus, practice-related strengthening of both the associations from the cue to the task set and the S-R associations (which are part of the task set that is loaded into working memory) should modulate the retrieval-related cost. In contrast, if a relatively automatic application of a given set of rules to the stimulus is assumed, there is much less reason to expect substantial practice effects for the application component.

## Method

**Participants.** A group of 16 students at the University of Potsdam served as participants in exchange for course credits or a payment of DM 10 (about \$6).

**Task and stimuli.** Depending on the task, participants were supposed to discriminate either the color or the shape of an object. The object could be either a circle, a square, or a triangle of about the same size (i.e., the side length of the square was 1 cm), and it could appear in green, blue, or red. The object was presented on a black background within a white frame with a side length of 2.5 cm. The frame was visible throughout the entire block. Responses were entered with the index, middle, or ring finger of the preferred hand using the 1 key, the 2 key, and the 3 key of the numeric keyboard. Circle and green were mapped onto the 1 key, square and blue were mapped onto the 2 key, and triangle and red were mapped onto the 3

key. Stimuli remained on the screen until the correct response was entered. Thus, in the case of an incorrect response, participants could continue only after pressing the correct response.

A task cue indicating the task relevant for the next stimulus was presented 200 ms before the stimulus and 300 ms after the preceding response. Four different capital letters served as cues. They were presented immediately above the stimulus frame and stayed on until the correct response to the stimulus was entered. For all participants, the letters *G* and *S* were used to indicate the color task and the letters *B* and *W* were used to indicate the form task.

**Procedure and design.** Block length was 90 trials. There were three practice blocks. The first two were single-task blocks in which participants could become familiar with each of the two tasks and the cue-task associations. Order of introducing the two different tasks was counterbalanced. The third practice block was identical to the test blocks. Then, six test blocks were presented. Task instructions as well as the S-R mappings were presented prior to each block.

Stimuli, tasks, and cues were selected randomly for each trial with the constraint that each of the three critical condition transitions (cue-task repetitions, cue changes, and task changes) should be equal ( $p = .33$ ). In order not to introduce an imbalance with respect to the probabilities of specific cue transitions in this experiment (arising from the fact that for each task set there is only one type of no-switch and cue-switch transition but there are two types of task-switch transitions), we used only one of the two possible cue transitions in the case of task switches for each participant (e.g., *S* to *W* and *G* to *B* for color-form transitions). The assignment of cue transitions to participants was counterbalanced.

## Results and Discussion

Errors and trials following errors were excluded from further analysis. Also, all RTs larger than 5,000 ms were excluded (leaving 99.5% of the entire RT distribution). Trials were classified in terms of the relationship to their immediately preceding trial into no-switch trials, cue-switch trials, and task-switch trials. Two nonorthogonal contrasts were used to compare the no-switch and the cue-switch condition on the one hand (the cue-switch contrast) and the cue-switch and the task-switch condition on the other (the task-switch contrast).

Figure 1 shows RTs and error scores from the no-switch, the cue-switch, and the task-switch condition across the six test blocks. As can be seen, in the case of response changes, a substantial component of the total switch cost was associated with the cue switch ( $M = 250$  ms,  $SEM = 40$  ms), whereas a smaller component was associated with the actual task switch ( $M = 153$  ms,  $SEM = 37$  ms). It is also apparent from the figure that response repetitions were associated with benefits in the case of no-switch ( $M = 260$  ms,  $SEM = 24$  ms) and cue-switch transitions ( $M = 176$  ms,  $SEM = 43$  ms) but with costs in the case of task-switch transitions ( $M = -134$  ms,  $SEM = 34$  ms). Given the opposing effects of response repetitions for cue-switch and task-switch transitions, cue-switch costs were somewhat smaller than task-switch costs here (cue-switch,  $M = 346$  ms,  $SEM = 39$  ms; task-switch,  $M = 451$  ms,  $SEM = 51$  ms).

Consistent with these observations, both the cue-switch contrast,  $F(1, 15) = 96.1$ ,  $MSE = 89,091.5$ ,  $p < .01$ , and the task-switch contrast,  $F(1, 15) = 96.7$ ,  $MSE = 90,674.2$ ,  $p < .01$ , proved highly reliable. In line with the finding of a moderate reduction of response-repetition benefits when going from the no-switch to the cue-switch condition (see Figure 1), the response-repetition factor produced a tendency toward an interaction with the cue-switch

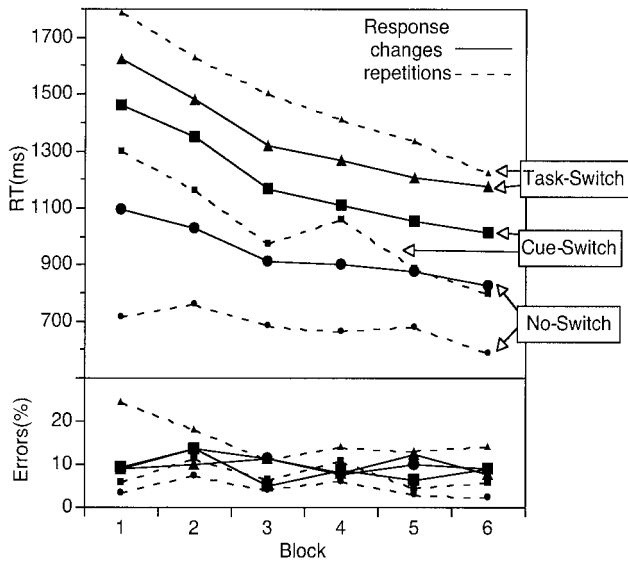


Figure 1. Average response times (RTs) and error percentages across six practice blocks for the three different types of task transitions (no-switch, cue-switch, task-switch) and for response changes versus response repetitions.

contrast,  $F(1, 15) = 3.84$ ,  $MSE = 58,254.7$ ,  $p < .07$ . However, priming benefits were highly significant in each of these two conditions (all  $F$ s  $> 10.0$ ). In contrast, the task-switch contrast produced a highly significant reverse interaction with the response-repetition factor,  $F(1, 15) = 21.1$ ,  $MSE = 100,566.4$ ,  $p < .01$ . This interaction can be attributed to the fact that only in the task-switch condition was a substantial response-repetition cost obtained,  $F(1, 15) = 16.5$ ,  $MSE = 53,302.7$ ,  $p < .01$ .<sup>2</sup>

Regarding the effect of practice, cue-switch costs became smaller across blocks (cost reduction between Blocks 1 and 6 = 52%), which was reflected in an interaction between the cue-switch contrast with a linear, polynomial contrast used for the block factor,  $F(1, 15) = 17.7$ ,  $MSE = 43,491.4$ ,  $p < .01$ . In contrast, the task-switch contrast was relatively constant across practice (cost reduction between Blocks 1 and 6 = 10%),  $F(1, 15) = 0.18$ ,  $MSE = 75,964.3$ ,  $p > .6$ .

There were no significant error effects associated with the cue-switch contrast ( $F$ s  $< 0.3$ ), whereas there was a reliable task-switch error cost,  $F(1, 15) = 18.7$ ,  $MSE = 2,147.0$ ,  $p < .01$ . Errors increased by 5.1% between the cue-switch trials and the task-switch trials,  $F(1, 15) = 18.7$ ,  $MSE = 2,147.0$ ,  $p < .01$ . However, this increase in error rate could be attributed to relatively higher switch costs in the case of response repetitions. When only response changes were included, switch costs dropped to 1.5% ( $p > .2$ ). Finally, there were no critical error effects associated with the block factor.

This experiment produced three novel findings. First, considerable switch costs emerged in a situation in which task sets repeated but task cues changed. We argue that the cue-switch cost represents the retrieval component of the total switch cost. By this reasoning, a major portion of the traditional switch costs can be attributed to LTM retrieval. By the same token, the actual task-switch component—that is, the RT difference between the cue-

switch and the task-switch condition—can be attributed to the application of task rules to the stimulus after they are loaded into working memory.

Second, the fact that response-repetition benefits survived a change in cue but were reversed after a change in task suggests that there is in fact a level of task-set representation (a) that is relatively independent of how it is accessed during retrieval and (b) that seems to reflect the way task rules are applied to an actual stimulus.

Finally, within-session practice modulated the cue-switch cost but not the actual task-switch cost. The differential practice effect is consistent with the retrieval account because strengthening of both cue–task associations and of S–R associations should make it easier to bring the relevant information into working memory. In contrast, there is no a priori reason to expect similar practice benefits for the presumably more automatic task-set application component.

## Experiment 2: Task-Set Preparation

If, as we argue, the task-set retrieval stage is closely associated or even identical with the preparatory switching component, the cue-switch cost demonstrated in Experiment 1 should be sensitive to variations of the cue–stimulus interval (CSI), that is the time available to prepare the upcoming task. In contrast, the actual task-switch cost should be unaffected by the CSI. To test this prediction, we used in this experiment the same information-reduction paradigm as in Experiment 1. In addition, the CSI was varied between 200 and 1,300 ms while keeping the total intertrial interval constant at 1,500 ms (see Meiran, 1996). We expected to find a marked reduction of cue-switch costs for the long preparatory interval but no comparable effect on task-switch costs. As an additional factor, we manipulated the response–cue interval (RCI). The RCI cannot be used for active preparation (Meiran, 1996) and therefore should not interact with retrieval-related processes (Mayr & Kliegl, 2000).

## Method

**Participants.** Eighteen students at the University of Potsdam served as participants in exchange for course credits or a payment of DM 10 (about U.S. \$6).

**Task and stimuli.** The same tasks, cues, and stimuli were used as in Experiment 1. Depending on the condition, both RCI and CSI were 200 ms (the 200–200 condition), RCI was 1,300 ms and CSI was 200 ms

<sup>2</sup> Given that all stimulus parameters were selected randomly, 33% of the response repetitions also implied an exact stimulus repetition. It seems possible that the repetition-priming pattern we observed is driven by these exact repetitions. To assess this possibility, we analyzed the data of Experiments 1 and 2 after excluding cases of exact repetitions. We obtained positive response priming effects for no-switch (Experiment 1,  $M = 260$  ms,  $SEM = 24$  ms; Experiment 2,  $M = 179$  ms,  $SEM = 25$  ms) and cue-switch transitions (Experiment 1,  $M = 128$  ms,  $SEM = 44$  ms; Experiment 2,  $M = 85$  ms,  $SEM = 31$  ms), as well as costs in the case of task-switch transitions (Experiment 1,  $M = -162$  ms,  $SEM = 36$  ms; Experiment 2,  $M = 91$  ms,  $SEM = 23$  ms), all  $p$ s  $< .02$ . Thus, even though priming benefits were generally reduced after excluding exact stimulus repetitions, the general pattern of effects was the same as in the full data set.

(the 1,300–200 condition), or RCI was 200 and CSI was 1,300 ms (the 200–1,300 condition).

**Procedure and design.** The experiment began with two 45-trial single-task practice blocks in which the three possible RCI-CSI constellations were randomly intermixed, followed by a task-switching practice block, again with intermixed RCI-CSI constellations. For the remaining nine 90-trial test blocks, the three CSI-RCI constellations were cycled through in a blockwise manner (e.g., 200–200, 1,300–200, 200–1,300, 200–200, 1,300–200, 200–1,300, 200–200, 1,300–200, 200–1,300). Sequences within each cycle were counterbalanced across participants. Task instructions as well as the S-R mappings were presented prior to each block. Cue–task transition probabilities were the same as in Experiment 1, and cue–task assignments were, again, counterbalanced across participants.

### Results and Discussion

Errors and trials following errors were excluded from further analysis. Also, all RTs larger than 5,000 ms were excluded (leaving 99.3% of the entire RT distribution). Trials were classified in terms of the relationship to their immediately preceding trial into no-switch trials, cue-switch trials, and task-switch trials as well as in terms of response-repetition versus response-change trials. Again, two nonorthogonal contrasts were used to compare the no-switch and the cue-switch condition on the one hand (the cue-switch contrast) and the cue-switch and the task-switch condition on the other (the task-switch contrast). A second set of nonorthogonal contrasts was used to assess the role of passive decay and active preparation. The preparation contrast tested the 1,300–200 against the 200–1,300 constellation (i.e., RCI-CSI). The decay contrast tested the 200–200 against the 1,300–200 constellation.

Figure 2 shows RTs from the no-switch, the cue-switch, and the task-switch condition for the three different RCI-CSI constellations. As is evident from the figure, there were substantial cue-switch costs both for response changes (200–200,  $M = 281$  ms,  $SEM = 41$  ms; 1,300–200,  $M = 169$  ms,  $SEM = 43$  ms) and response repetitions (200–200,  $M = 350$  ms,  $SEM = 51$  ms; 1,300–200,  $M = 338$  ms,  $SEM = 37$  ms) when the preparatory interval was short. However, as predicted, the cue-switch cost was virtually eliminated when the preparatory interval was long in the case of response changes (200–1,300,  $M = 8$  ms,  $SEM = 25$  ms) and it was considerably reduced for response repetitions (200–1,300,  $M = 81$  ms,  $SEM = 24$  ms). The critical interaction between preparation time and the cue-switch contrast was highly significant,  $F(1, 17) = 37.4$ ,  $MSE = 84,144.7$ ,  $p < .01$ . In contrast, an increase in intertrial interval that could not be used for preparation did not reduce the cue-switch cost in a substantial manner; the interaction between the cue-switch and the decay contrast was not reliable,  $F(1, 17) = 2.03$ ,  $MSE = 136,494.1$ ,  $p > .17$ .

As in Experiment 1, there also was a reliable task-switch cost over and above the cue-switch cost (response changes,  $M = 114$  ms,  $SEM = 29$  ms; response repetitions,  $M = 328$  ms,  $SEM = 55$  ms),  $F(1, 17) = 29.6$ ,  $MSE = 992,443.2$ ,  $p < .01$ . This effect interacted neither with the preparation contrast,  $F(1, 17) = 0.01$ , nor the decay contrast,  $F(1, 17) = 1.4$ .

Response-repetition benefits were reduced in the case of a cue switch,  $F(1, 17) = 12.6$ ,  $MSE = 136,578.1$ ,  $p < .01$ . However, there was a response-repetition benefit for both the no-switch ( $M = 228$  ms,  $SEM = 26$  ms) and the cue-switch condition ( $M = 117$  ms,  $SEM = 28$  ms). Also, as in Experiment 1, a substantial

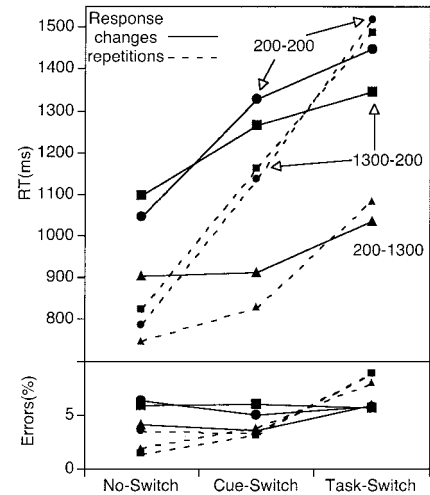


Figure 2. Average response times (RTs) and error percentages as a function of type of task transition (no-switch, cue-switch, task-switch), response–cue interval/cue–stimulus interval constellations (200–200, 200–1,300, 1,300–200 ms), and response changes versus response repetitions.

repetition cost was associated with the actual task switch ( $M = -91$  ms,  $SEM = 23$  ms); the interaction between the task-switch contrast and the repetition-priming factor was highly reliable,  $F(1, 17) = 30.2$ ,  $MSE = 243,732.4$ ,  $p < .01$ .<sup>3</sup>

With regard to errors, there was no cue-switch effect; however, there was a reliable task-switch effect,  $F(1, 17) = 6.4$ ,  $MSE = 93,279.5$ ,  $p < .05$ . As in Experiment 1, task-switch costs were reliable for response repetitions only,  $F(1, 17) = 11.9$ ,  $MSE = 35,805.8$ ,  $p < .01$ , not for response changes,  $F(1, 17) < 0.8$ .

As predicted by the task-set retrieval view, the results of Experiment 2 did indeed show that the cue-switch cost is eliminated (in the case of response changes) or at least substantially reduced (in the case of response repetitions) through a sufficiently large preparatory interval. In contrast, the task-switch cost was not reduced through the opportunity for preparation. The elimination or strong reduction of the cue-switch component after opportunity for preparation, again, suggests that task-set retrieval and preparatory configuration of task sets are strongly associated, if not identical, processes. In contrast to the preparation effect, the effect of passive decay was not associated with reliable effects on either the cue-switch or the task-switch component.

As in Experiment 1, the response-repetition effect was more strongly associated with the actual task set than with the task cue. Only in the case of a task change was the repetition-priming benefit observed both for task switches and cue switches reversed. Thus, again, it seems that response-priming effects are predominantly tied to the task-set application stage. At the same time the reliable reduction of response-priming effects in the case of cue switches obtained in this experiment suggests some integration between cue-related representations and S-R related representations.

<sup>3</sup> See Footnote 2.

The findings that intentional effects on task-set configuration are tied to the retrieval stage whereas the reversal of response-priming effects is tied to the application stage are important because they lend credibility to the basic two-stage view of task-set configuration. They also suggest that the information-reduction paradigm can in fact be used to separate these two stages. In the final experiment, we made use of this procedure to locate one additional important set-selection process with regard to the two task-switch stages: task-set inhibition.

### Experiment 3: Task-Set Inhibition

Suppression of the no-longer relevant representations has been assumed to play a major role during task-set changes. In theory, such suppression of the no-longer-relevant configuration may be critical to allow a new configuration to replace the representation that had full control of action fractions of a second earlier. Empirical evidence for such set-level inhibition has recently been presented in the form of the so-called backward-inhibition effect by Mayr and Keele (2000; see also Arbuthnott & Frank, 2000; Mayr, 2001, 2002). These authors reported that switching back to a task set that recently had to be abandoned (e.g., Task A to Task B to Task A) and therefore may have been suppressed is associated with an additional RT cost when compared with a situation in which the switch is to a less recently abandoned task (e.g., Task A to Task B to Task C).

An open question is at what level of representation or processing backward inhibition has its effect. One possibility is that inhibition affects encoding of the cue or of processes that lead from the cue to a task-set representation in working memory. The alternative scenario would hold that backward inhibition affects the application of a task set to the stimulus after it has been loaded into working memory. Again, the use of 2:1 mappings between cues and tasks should make it possible to distinguish between these two theoretical options. To see how, consider the situation in a critical inhibition sequence of the kind  $A_1-B_x-A_1$  where the subscript indexes whether each task is addressed through Cue 1 or Cue 2. If inhibition during the switch from A to B affects Cue 1 leading to Task A (or cue-associated processes), then a return to Task A should lead to an RT increase only when, as in this example, Cue 1 has to be used again. In this case, no backward inhibition would be observed when Task A can be accessed via alternative Cue 2 (e.g.,  $A_1-B_x-A_2$ ). However, if inhibition targets representations associated with the cue-independent application stage, then it should be obtained even when task cues change across the critical Lag-2 repetition of tasks (e.g.,  $A_1-B_x-A_2$ ).

Implementing both task-alteration sequences and the necessary control sequences here requires three different tasks. Thus, six different letter cues and three different tasks (color, form, size) were used. To compensate for the overall higher demands imposed through the use of three different tasks, we used two-choice instead of three-choice tasks in this experiment.

### Method

*Participants.* Fifteen students at the University of Oregon served as participants in exchange for course credits.

*Task and stimuli.* Three different tasks were used in this experiment. Participants had to judge an object's color (red vs. blue), shape (circle vs. square), or size (small vs. large). Stimuli appeared centrally on a black

screen within a 20- × 20-mm white frame. The width and height of small stimuli were 5 mm; those of large stimuli were 10 mm. Participants responded with the left (depending on tasks for blue objects, circles, or small objects) or right (depending on tasks for red objects, squares, or large objects) arrow keys on a Macintosh keyboard. Task cues were letters (i.e., *D* and *R* for the color task, *M* and *V* for the shape task, and *T* and *K* for the size task). Task cues were presented 5 mm above the stimulus frame in 18-point Geneva type.

*Procedure and design.* The experiment consisted of fifteen 80-trial blocks. Blocks were increased by 1 trial for each error trial. In the first three blocks, each of the three different tasks was practiced alone. Task order was counterbalanced across participants for these practice blocks. In Block 4, all three tasks were practiced together. Actual testing occurred in Blocks 5 to 15. In Blocks 4 to 15 tasks and cues were selected randomly but with the constraint of no immediate task repetitions. This was done to maximize the number of trial triplets with either A-B-A or C-B-A trial sequences, which are critical to compute the backward inhibition effect. With this procedure, the probability of each of the two types of sequences is 50%.

For the entire experiment, the RCI was 100 ms and the CSI was 800 ms. In past work, a CSI of 800 ms has proven sufficient for task-set preparation to occur.

### Results and Discussion

Errors and trials following errors in the preceding two trials were excluded. Also, all RTs that were larger than 5,000 ms were excluded (leaving 97.8% of the entire RT distribution). Trials were classified in terms of the relationship to their preceding two trials into control sequences (C-B-A), inhibition sequences with Lag-2 repetition of cues (e.g.,  $A_1-B_x-A_1$ ), and inhibition sequences with Lag-2 cue changes (e.g.,  $A_1-B_x-A_2$ ).

Mean RT for control sequences was 1,181 ms ( $SEM = 71$  ms), for inhibition sequences with Lag-2 repetition of cues it was 1,163 ms ( $SEM = 70$  ms), and for inhibition sequences without Lag-2 repetition of cues it was 1,232 ms ( $SEM = 77$  ms). The comparison between control and inhibition sequences with Lag-2 repetition of cues was not reliable,  $t(14) = 0.67$ ,  $p > .6$ . However, the 51-ms difference between control and inhibition sequences without Lag-2 repetition of cues was reliable,  $t(14) = 2.53$ ,  $p < .03$ . Accuracy for the three critical conditions was 93.3%, 92.9%, and 93.1%, respectively, with no reliable differences between conditions (all  $ts < 0.8$ ).

The finding of backward inhibition in the absence of a Lag-2 cue repetition is consistent with the hypothesis that backward inhibition affects the task-set application stage rather than the retrieval stage. Surprising is the complete absence, even numerical reversal, of backward inhibition in the case of a Lag-2 cue repetition. One possibility is that backward inhibition is in fact present in the case of both Lag-2 cue changes and repetitions. However, in the case of a Lag-2 cue repetition the inhibitory effect is counteracted through positive priming affecting cue-related processing.

To test this idea, we computed both for RTs and errors the partial correlation between the backward inhibition scores for the two critical conditions (i.e., Lag-2 cue changes vs. repetitions) while statistically controlling for the control-condition RT (which is common to both inhibition scores). If inhibition is present in both cases, then we should expect a positive covariation between the two backward inhibition scores (e.g., individuals with high backward inhibition in the case of cue changes should also have a relatively high or at least less negative backward inhibition score

in the case of a Lag-2 cue repetition). The relevant partial correlation was .58 ( $p < .03$ ) for RTs and .53 ( $p = .06$ ) for errors. Without the 2 individuals with the largest backward inhibition scores (greater than 2 standard deviations from the group means), the correlation for RTs increased to .82 ( $p < .01$ ). This result suggests that even though not apparent on the level of means, a common influence is present in both backward inhibition scores. Likely this common influence is the effect of inhibition, and that is occluded by positive priming in the case of Lag-2 cue repetitions.

The question remains why the inhibition effect may have been occluded in the case of Lag-2 cue repetitions. After all, in earlier experiments in which backward inhibition was found, there was always a 1:1 mapping between tasks and cues, so that each Lag-2 repetition of a task went along with a Lag-2 repetition of a cue (e.g., Mayr & Keele, 2000). However, a 2:1 mapping between cues and tasks results in a critical change: With six instead of the usual three cues, each cue creates a more distinctive memory trace. The more distinct a memory trace, the larger the to-be-expected benefits from repetition priming (e.g., Logan, 1998). Therefore, we suggest that a 2:1 mapping situation increases the relative prominence of cue-specific, positive priming effects. The substantial positive correlation between the two backward inhibition scores is no proof of a common inhibitory component, but it is consistent with the claim that inhibition is present for both cases but occluded in the case of Lag-2 cue repetitions.

In summary, in this experiment a backward inhibition effect similar in size to that in other recent reports (e.g., Mayr, 2001, 2002; Mayr & Keele, 2000) was obtained, but only when cues changed between the alternating repetitions of the same task set. This result suggests that backward inhibition is not tied to the task-set retrieval stage. Rather, inhibition seems to affect the representation associated with the task-set application. At the same time, some caution with regard to this conclusion is in order until our interpretation of the absence of backward inhibition in the case of cue repetitions can be confirmed.

### General Discussion

In this work we introduced a way of distinguishing two stages of processing related to changes in cognitive configurations. At the first stage, the currently relevant task rules are retrieved from LTM into an active representation. We indexed processing on this level through the cue-switch contrast: a comparison between a condition in which neither task cues nor tasks change across successive trials and one in which cues change but tasks stay constant. During the second stage, the retrieved task rules are applied to the stimulus. This application stage is indexed through the actual task-switch contrast: a comparison between a condition in which cues change but tasks stay invariant and one in which both cues and tasks change.

An important conclusion from Experiments 1 and 2 is that much of the total switch costs observed is not actually due to a change in task per se but rather is due to a change in cue-associated processes.<sup>4</sup> To the degree to which this finding can be generalized to other task-switching studies, it implies that a large component of switch costs does not directly reflect the time necessary to configure the cognitive system for upcoming task demands. Rather, this component reflects a necessary step for subsequent configuration,

namely, loading task rules from LTM into working memory, but one that is necessary even when the actual configuration turns out to remain the same. Beyond the cue-related component there was an additional component of around 100 ms (in the case of response changes) that could be attributed to applying a loaded task set to the stimulus.

Before we turn to the additional, substantive findings obtained with this paradigm, we need to discuss some potential limitations and qualifications. One potential qualification concerns our selection of cues. We used letter cues that neither had preexperimental associations to the tasks used nor could be grouped according to their task associations by some additional feature. In particular, the latter factor has proven critical in research on repetition priming in the context of RT tasks. For example, Campbell and Proctor (1993) found that only if stimuli associated with a single response belonged to a preexperimentally defined category (e.g., digits vs. numbers) were substantial priming effects obtained when stimuli changed but responses stayed constant across trials. Apparently, in this case S-R associations are formed on the level of the category rather than on the level of single stimuli. By analogy, one might expect that with categorizable cues (e.g., vowels as cues for Task A and consonants as cues for Task B) cue-switch costs would be reduced or even eliminated. Although this is certainly an issue worth addressing in future research, the focus in the current work was on the costs associated with a change in the retrieval path leading to a task set. Arguably, with categorizable cues, a cue switch may imply only a superficial change in stimuli that, once interpreted in terms of the critical category, allows convergence on a common retrieval path.

There is another issue with regard to which caution dictates some moderation in interpreting the present results, in particular those of Experiment 2. In the extreme, these results could be used to suggest that there are no cue-independent intentional or preparatory processes involved in task-set reconfiguration. However, this strong conclusion rests on the assumption that the present results can be generalized unconditionally to other variants of the task-switching paradigm. This is not necessarily the case. In particular, it is possible that the use of four different cues itself changes the task-switching situation, simply by introducing a particularly large retrieval burden. This retrieval burden may have prevented the recruitment of preparatory processes that otherwise may be observable, such as a shift of attentional bias to task-relevant perceptual dimensions (e.g., Meiran, 1996). Alternatively, however, such processes may also be an immediate consequence of loading the critical task rules into working memory and therefore may be functionally indistinguishable from task-set retrieval. In its current version, this paradigm simply does not allow the necessary finer grained analyses. Also, the precise duration of the

<sup>4</sup> A result that at least at first sight seems similar to the finding of large cue-switch cost reported here is the reconsideration cost recently reported by Gopher, Armony, and Greenspan (2000). This cost arises when a regularly paced sequence of trials is interrupted, even when after the interruption the task does not change. However, different than the cue-switch cost, the reconsideration cost survives a long preparatory interval. It probably reflects the effects of realigning one's performance with a regularly paced rhythm rather than the retrieval of upcoming task rules.

cue-switch stage probably depends on a number of factors such as levels of practice (e.g., Experiment 1) or types of cues.

An additional complicating aspect that must be considered when evaluating our estimates of cue-switch and task-switch costs is the status of no-switch trials. From the LTM-retrieval perspective, there is no qualitative difference between no-switch transitions, on the one hand, and cue-switch or task-switch transitions on the other. Retrieval is necessary in each case, but in the case of no-switch transitions, positive priming from the immediately preceding retrieval instance will reduce retrieval demands. The degree to which participants profit from cue repetitions in no-switch trials is probably moderated through the probability of such repetitions. In the present experiment, the probability of a cue repetition was smaller than that of a cue change (i.e.,  $p = .33$  vs.  $p = .66$ ), which may have worked against participants' tendency to rely on past retrieval instances (e.g., Kane, May, Hasher, & Rahal, 1997). This could explain why no-switch RTs were relatively large in Experiments 1 and 2 (which, in turn, should lead to an underestimation of cue-switch costs). Future experiments in which cue-repetition probabilities are manipulated should be useful in determining to what degree the observed data pattern is subject to expectancy-strategic settings.

Despite these qualifications, the current results do allow the conclusion that cue-based retrieval constitutes a major component of overall switch costs. In addition, the exact duration of the retrieval and the application stage are less important than the possibility that they can be functionally dissociated within this paradigm. In principle, cue-switch costs and the actual task-switch costs could simply reflect identical processing demands, only to different degrees. In order to determine the degree to which the cue switches and the task switches can be functionally dissociated, we looked at the effects of four different task-switching factors on the two components: priming, practice, intentional preparation, and inhibition.

### *Response-Repetition Priming*

In the task-switching paradigm, positive response priming can be found for task repetitions, whereas repetition costs are often obtained for task switches (e.g., Mayr, 2002; Quinlan, 1999; Rogers & Monsell, 1995). This pattern suggests that traces of task-specific processing of a particular stimulus can be carried over across trials, but only to the degree to which the same actual task configuration can be reused. If a change in task cue in the case of a task repetition would lead not only to a new retrieval process but also to a newly applied configuration, then we would expect eliminated or even negative response-repetition effects. However, if cue-driven retrieval and the task-set configuration as applied to the stimulus are associated with distinct representations, then we should find the normal response-repetition effect in the case of a cue switch, but repetition costs in the case of a task switch. The dominant finding across Experiments 1 and 2 was that the qualitative pattern of repetition-priming effects was much more similar between cue-switch and no-switch transitions than between cue-switch and task-switch transitions. Only in the latter case were response-repetition costs observed. At the very least, this suggests that retrieval-related representations and representations associated with applying a task-set to a stimulus are distinguishable entities. It is a different question whether these representations will be

dissociated under all circumstances. In fact, there was evidence of some integration across stages: Response repetitions in the case of a cue switch were somewhat smaller than in the case of a task repetition (in particular, in Experiment 2). Thus, the distinction between representations may be a matter of degree rather than a qualitative one. There may very well be additional boundary conditions that modulate the across-stages integration, such as task complexity or the consistency of across-stages mappings. Exploring such boundary conditions should be informative with regard to the question of how continuous action is parsed into distinct selection episodes.

### *Practice*

In Experiment 1, we found that reduction of switch costs with practice could be attributed mainly to the cue-switch component whereas the task-switch component was relatively invariant across blocks of trials. The cue-task associations and the S-R associations used in these experiments were arbitrary, thus leaving room for practice-related strengthening. The task-switch component should reflect the application of rules to the stimulus, once they are loaded into working memory. We submit that practice has little effect here, simply because implementation of a given working memory content into the configuration required for a particular stimulus is an automatic process that requires no, or only very little, tuning.

### *Preparation*

Recently, Mayr and Kliegl (2000) claimed that retrieval of task rules is an important component of the switching process (see also Rubinstein et al., 2001). This hypothesis is based on the general view that a key principle of working memory is a representational coherence constraint that essentially allows only one of several competing task sets to be loaded at any point in time (e.g., Dehaene, Kerszberg, & Changeux, 1998; Mayr, 2003). As a consequence, every switch necessarily implies the elimination of the no-longer-relevant set from working memory and the reactivation of the now-relevant set from LTM. Consistent with this view, Mayr and Kliegl reported that switch costs were affected by the retrieval demands of the switched-to primary task, supposedly because of mutual interference between retrieval to a task and retrieval within a task. Even more important, this retrieval-demand effect on switch costs was eliminated after sufficient time for preparation (i.e., a long CSI), suggesting that task-set retrieval is exactly what happens during the preparatory interval.

On the basis of these results, we had expected that the cue-switch component—which supposedly reflects task-switch retrieval—should be affected by the CSI, whereas the task-switch component—which supposedly reflects stimulus-specific application of rules loaded into working memory—should remain invariant. This is exactly what we found. The cue-switch component was eliminated through the long preparatory interval for response changes, and it was much reduced for response repetitions. In contrast, the task-switch component was not affected by the preparatory interval. The mere passage of time (as manipulated through variations of the RCI) had no comparable effects. Thus, these results are consistent with the idea that retrieval of task rules and intentional task-set preparation are largely identical processes.

Although we can be relatively confident that the cue-switch cost reflects retrieval of task-relevant instructions or rules into working memory, the precise nature of what we referred to as the *application stage* is less clear. In particular, the question of why these costs occur only after the appearance of the stimulus requires an answer. One speculation is that preparation through retrieval allows specification of the “inclusionary” aspects of the upcoming task set, that is, the specification of the relevant stimulus dimension and how to respond to it. However, it may be difficult, or even impossible, to prepare the “exclusionary” aspects of task sets, that is, the prescription of what information not to attend to. For example, there is evidence that the verbal instruction not to think of something actually has the ironic effect of making the “forbidden” content particularly salient (Wentzlaff & Wegner, 2000). Maybe the exclusionary aspects of a task set can be established only during the process of actually dealing with stimulus-elicited conflict (see also Schuch & Koch, in press).

### *Inhibition*

A final important result of this work regards the level of representation affected by task-set inhibition. Task-set inhibition was assessed through the backward-inhibition paradigm proposed by Mayr and Keele (2000; see also Mayr, 2001, 2002). It involves a comparison between switches to a task set that had been abandoned only two trials earlier—and therefore may still suffer from residual inhibition—and switches to a task set that had been abandoned less recently. Larger RTs in the former than in the latter type of switches suggest the need to overcome inhibition of the most recently abandoned task set. In principle, this type of inhibition may either affect the actual task-set configuration or the access to the configuration, given a particular retrieval cue. The use of a 2:1 mapping between cues and tasks allowed resolution of this issue. The critical question is whether backward inhibition in the case of Lag-2 repetitions of tasks (e.g., color–form–color) is obtained only when it is accompanied by a Lag-2 repetition of cues or whether it can be found even when cues change. Substantial backward inhibition was found in the case of a cue change. Thus, inhibition affects the configuration stage and not the cue-based access to the configuration. In fact, in the case of a Lag-2 repetition of cues, the backward-inhibition effect was actually eliminated, even slightly reversed. As suggested in the discussion of Experiment 3, this likely is the result of a cue-specific, positive priming effect that occludes the otherwise observable inhibition effect.

The fact that inhibition affects the actual configuration and not the retrieval stage is consistent with the speculations in the preceding section regarding exclusionary aspects of task sets as well as with other recent results in the literature. For example, in past research, opportunity for preparation typically had no effect on the size of the inhibition effect (e.g., Mayr, 2002; Mayr & Keele, 2000). Also, inhibition seems to be found only after a particular task is actually executed, not when task execution was prevented through a no-go signal (Schuch & Koch, in press). Another result that is in general agreement with the notion that inhibition affects postretrieval stages of task-switching was recently reported by Arbutnot and Woodward (2000). These authors observed that a manipulation of pre-experimental cue–task associations affected

task-switch costs (i.e., presumably the retrieval stage), but not the backward-inhibition effect.

Finally, it is noteworthy that the procedure used here bears some resemblance to the so-called independent-probe technique introduced by Anderson and Spellman (1995) to study inhibition in the context of episodic memory retrieval. Specifically, this technique has been used to determine whether retrieval-induced inhibition affects the representation of to-be-retrieved information or the cue-based access to the representation. Of interest, both the work on retrieval-induced forgetting and the current results on task-set inhibition converge on the same conclusion, namely, that it is the representation that is suppressed and not just the cue-based access. It is tempting to speculate that task-set inhibition and suppression of competitors during episodic memory retrieval may be identical or at least highly related processes.

### *Neurocognitive Implications*

Brain imaging of task switching has revealed activations in a multitude of areas, possibly with some overrepresentation of prefrontal as well as frontal and parietal motor areas. One important result is that often switch and no-switch conditions differ less in terms of qualitative pattern of activation than in terms of degree of activation with, typically, more activation in the switch condition (e.g., Dove, Schubert, Wiggins, & von Cramon, 2000; Kimberg, Aguirre, & D’Esposito, 2000). This result is consistent with our general view that at least in cuing paradigms the difference between the switch and the no-switch condition may be in the degree of retrieval demands rather than in some discrete processing difference.

With regard to the neurocognitive localization of different switch components, there is some evidence that frontal, in particular prefrontal, activations seem to be particularly associated with cue-related, preparatory processing. For example, MacDonald, Cohen, Stenger, and Carter (2000) reported left-dorsolateral activation associated with cue-based preparation (see also Sohn, Ursu, Anderson, Stenger, & Carter, 2000). Also, patients with frontal damage seem to have switching deficits, in particular when retrieval demands are high (e.g., Mayr, Diedrichsen, Ivry, & Keele, 2002; Rogers et al., 1998). Further, most of the cited brain-imaging and patient work seems to suggest a particular role of left-frontal areas for task switching (but see Sohn et al., 2000). A left-prefrontal locus would be compatible with recent suggestions that left-frontal areas may be particularly involved in resolving conflict during difficult retrieval (e.g., Ranaganath, Johnson, & D’Esposito, 2000).

The role of parietal areas is less clear. There is evidence from work with attention-cuing paradigms that posterior parietal regions are generally involved in preparation (e.g., Corbetta, Kincade, Ollinger, McAvo, & Shulman, 2000). In addition, the study by Sohn et al. (2000) showed that also for a task-switching paradigm parietal regions are sensitive to preparation effects. However, these effects seemed smaller and later in time than the corresponding frontal effects, and large parietal effects were also found for stimulus-related components. This pattern may be consistent with the view that parietal areas receive “instructions” from prefrontal areas that are then translated into effective configurations once the stimulus appears. However, even though tempting, the distinction between frontal = retrieval stage and parietal = application stage

is probably overly simplistic. For example, frontal premotor areas have also been implied in the stimulus-based switch component (e.g., Sohn et al., 2000). Along with other paradigms (e.g., Brass & von Cramon, 2002), the contrast between cue switches and task switches within an imaging protocol should be helpful in further discerning the neural basis of different task-switch components.

### Conclusion

In this research we merged the information-reduction method (as used in research on repetition priming) with the task-switching paradigm to distinguish two processing stages associated with executive changes of tasks. The first, cue-based retrieval of task rules, is indexed by the cost associated with trial-to-trial changes in task cues without accompanying changes in tasks. The second, the actual application of active task rules to a stimulus, is indexed by the additional cost observed when not only cues but also tasks change. An important result was that cue changes alone produced the lion's share of the total switch cost (at least in the case of response changes). Moreover, the cue-switch cost made up nearly all of the cost that could be associated with intentional preparation, and it was selectively affected by practice. In contrast, the task-set application component was associated with trial-to-trial response-repetition benefits and task-set inhibition as indexed by the backward-inhibition effect. Together, these results provide supporting evidence for a two-stage conception of task switching (e.g., Mayr & Kliegl, 2000; Rogers & Monsell, 1995; Rubinstein et al., 2001; Sohn et al., 2000). Further research using 2:1 mappings between cues and tasks should provide additional information about the neurocognitive underpinnings of the two distinct stages of task reconfiguration.

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### **Members of Underrepresented Groups: Reviewers for Journal Manuscripts Wanted**

If you are interested in reviewing manuscripts for APA journals, the APA Publications and Communications Board would like to invite your participation. Manuscript reviewers are vital to the publications process. As a reviewer, you would gain valuable experience in publishing. The P&C Board is particularly interested in encouraging members of underrepresented groups to participate more in this process.

If you are interested in reviewing manuscripts, please write to Demarie Jackson at the address below. Please note the following important points:

- To be selected as a reviewer, you must have published articles in peer-reviewed journals. The experience of publishing provides a reviewer with the basis for preparing a thorough, objective review.
- To be selected, it is critical to be a regular reader of the five to six empirical journals that are most central to the area or journal for which you would like to review. Current knowledge of recently published research provides a reviewer with the knowledge base to evaluate a new submission within the context of existing research.
- To select the appropriate reviewers for each manuscript, the editor needs detailed information. Please include with your letter your vita. In your letter, please identify which APA journal(s) you are interested in, and describe your area of expertise. Be as specific as possible. For example, "social psychology" is not sufficient—you would need to specify "social cognition" or "attitude change" as well.
- Reviewing a manuscript takes time (1–4 hours per manuscript reviewed). If you are selected to review a manuscript, be prepared to invest the necessary time to evaluate the manuscript thoroughly.

Write to Demarie Jackson, Journals Office, American Psychological Association, 750 First Street, NE, Washington, DC 20002-4242.