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Cognitive Control Under Stress

How Stress Affects Strategies of Task-Set Reconfiguration

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ABSTRACT—***This study investigated the effect of stress on cognitive control in task shifting. Subjects shifted between two tasks in an explicit cuing paradigm. Shift costs (i.e., performance decrements on task shifts relative to task repetitions) were measured for a long and a short cue-stimulus interval (CSI). Stress was varied by administering low-stress and high-stress IQ scales to two groups of subjects. In the low-stress group, shift costs were reduced with an increased CSI, a result that typically indicates anticipatory and shift-specific task-set reconfiguration. In the high-stress group, however, shift costs were independent of the CSI. This result is consistent with the idea that stress induces a change in the reconfiguration strategy, possibly to adapt to depleted resources.***

A crucial prerequisite for goal-directed behavior is the ability to establish new task sets. It is widely assumed that this is achieved by an endogenous reconfiguration process that adjusts attention (Meiran, 2000), retrieves task rules from memory (Mayr & Kliegl, 2000), and sets new goals (Rubinstein, Meyer, & Evans, 2001). Although these mechanisms have been investigated intensively, only a few studies have addressed the role of motivational and affective states in task-set reconfiguration (e.g., Dreisbach & Goschke, 2004; Heuer, Kleinsorge, Klein, & Kohlisch, 2004), and, as far as we know, no study has examined how reconfiguration is affected by stress. This is surprising, because questions about how cognitive control adapts to stress should be interesting not only to cognitive psychologists, but also to industrial-organizational psychologists concerned with stressful work environments and to clinical psychologists dealing with, for instance, affective disorders.

It could be assumed that stress generally impairs control processes like task-set reconfiguration, because they require central resources, which seem to be reduced under stress. Hockey (1997), for instance, proposed that regulatory processes required for coping with stress consume resources that are then no longer available for other processes (see also Broadbent, 1971; Sanders, 1983). However, the assumption that stress generally impairs cognitive processes might be too simple. It has been suggested that the cognitive system can adapt to depleted resources by adopting less capacity-demanding strategies (Hockey, 1997). A typical example is the reduction in Stroop interference observed under conditions of stress (Chajut & Algom, 2003; Huguet, Dumas, & Monteil, 2004; Huguet, Galvaing, Monteil, & Dumas, 1999). This effect probably occurs because the system increases its selectivity and in this way restricts the amount of input in order to compensate for reduced available resources (Chajut & Algom, 2003).

Such an adaptation to reduced resources is even more likely with respect to task-set reconfiguration. When reconfiguration processes are impaired, behavior depends strongly on stimulus-driven processes, which makes goal-directed behavior difficult. Therefore, maintaining the ability to reconfigure the task set should have a high priority for the cognitive system. Accordingly, we hypothesized that stress changes the reconfiguration strategy in a way that reduces the amount of capacity needed to guarantee goal-directed behavior under these conditions. Before we report our experiment testing this hypothesis, we give a brief introduction to the method we applied, as well as some relevant results from other research on task-set reconfiguration.

TASK SHIFTING AND STRATEGIES OF TASK-SET RECONFIGURATION

A method frequently applied to investigate reconfiguration processes is the explicit cuing procedure (Hübner, Futterer, & Steinhauser, 2001; Meiran, 1996; Sudevan & Taylor, 1987), a specific variant of the task-shifting paradigm (for other variants, see Allport, Styles, & Hsieh, 1994; Rogers & Monsell, 1995). In this procedure, subjects alternate between two or more tasks presented in randomized order, and a cue indicates the relevant task on each trial. Subtracting response times and error rates on task-repetition trials from the same measures on task-shift trials yields what are referred to as *shift costs*. These shift costs are

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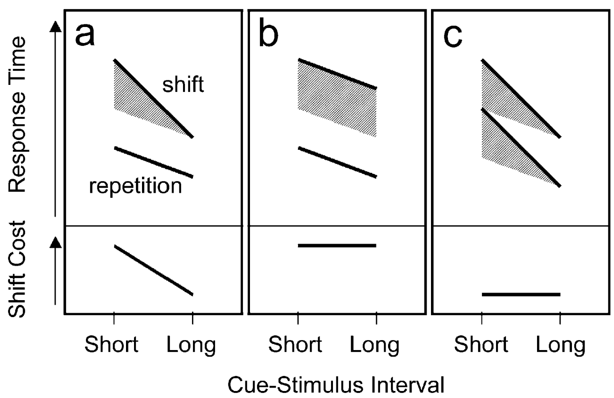

Fig. 1. Possible effects of cue-stimulus interval (CSI) on shift costs. The upper row shows absolute response times, and the lower row shows corresponding shift costs. The gray areas indicate the response time component that is attributable to endogenous reconfiguration. In the typical situation (a), there is an effect of CSI on the shift costs. The effect disappears (b) when reconfiguration does not occur in advance and (c) when reconfiguration takes place not only on task switches, but also on task repetitions.

typically reduced when the interval between the cue and the stimulus (cue-stimulus interval, or CSI) is increased, as illustrated in Figure 1a.

Shift costs are assumed to consist of two components (e.g., Ruthruff, Remington, & Johnston, 2001; Sohn & Anderson, 2001; Sohn & Carlson, 2000). One component is thought to reflect the duration of an endogenous reconfiguration process, which is anticipatory and shift-specific. That is, this process can occur before stimulus onset when the CSI is long, and it is present on task-shift trials only. Accordingly, it is represented in the portion of the shift costs that is reducible with an increasing CSI (gray area in Fig. 1a). A second component, which is present even for long CSIs, is called the residual costs. This component is not related to reconfiguration, but is thought to reflect task priming or associative strengthening (e.g., Schuch & Koch, 2003; Steinhauser & Hübner, 2006). However, even on task-repetition trials, performance is improved with a longer CSI. This effect probably reflects processes that can occur during the CSI and that are present on task-shift trials as well as on task-repetition trials (e.g., cue processing).

The majority of task-shifting studies have yielded a data pattern like that in Figure 1a, which indicates anticipatory and shift-specific reconfiguration (for a review, see Altmann, 2004b). However, there are also exceptions suggesting that reconfiguration is strategic, and that sometimes a different reconfiguration strategy is applied. For instance, Koch (2001) and Altmann (2004a, 2004b) reported a condition in which shift costs do not vary with the CSI. In these studies, the shift costs were unaffected by the CSI when the CSI was manipulated between, rather than within, subjects (i.e., when the CSI was constant for each subject throughout the experiment). Altmann supposed that subjects in the long-CSI condition did not use the long CSI for anticipatory reconfiguration. Accordingly, the shift costs in this condition also contained the time required for the reconfiguration process, as illustrated in Figure 1b. It is important to note that in this case, one would expect the shift costs with a long CSI to be larger than the shift costs in a condition in which anticipatory reconfiguration takes place (cf. Figs. 1a and 1b). Indeed, this was true, for instance, in Altmann's (2004b) Experiments 2 and 3.

This characteristic is important for distinguishing another data pattern. The CSI effect on shift costs can also be absent because the shift costs with a short CSI are decreased, for example, because of an increased CSI effect on task-repetition trials (cf. Figs. 1a and 1c). Such a pattern can be explained by a strategy in which subjects reconfigure their task set not only on task-shift trials, but also on task-repetition trials (see also Koch, 2005). In this case, the reconfiguration process is not captured by the shift costs. Accordingly, the shift costs with a short CSI are smaller in this condition than in a condition in which reconfiguration takes place on task-shift trials only. The remaining costs should reflect processes related to the residual shift costs. A pattern like this is observable in the data of Koch (2001). Shift costs with a short CSI were reduced when he manipulated the CSI between subjects (cf. Experiments 1 and 3), relative to when he manipulated the CSI within subjects (Experiment 4). In most experiments, however, it is difficult to distinguish between the two patterns described in Figures 1b and 1c. This suggests that a mixture of the two strategies was applied. This is possible because the two strategies are not mutually exclusive.

Taken together, these experimental results suggest that under some conditions, subjects adopt a suboptimal reconfiguration strategy that is either not anticipatory or not shift-specific. The question is why such a suboptimal strategy is adopted. Altmann (2004b) proposed that the underlying "mechanism is, by default, lazy" (p. 160) and needs to be stimulated by specific conditions, such as a variable CSI. This is plausible, because anticipatory and shift-specific reconfiguration both need additional control processes. Anticipatory reconfiguration requires that the reconfiguration process is optimally scheduled (for a discussion, see Rogers & Monsell, 1995). If, for instance, reconfiguration is completed too early, the preparation state has to be maintained until the stimulus appears. Similarly, shift-specific reconfiguration requires that the task set is actively maintained after task execution until a task shift becomes necessary. Moreover, it requires a decision on whether or not reconfiguration is necessary (i.e., whether the current trial involves a task shift; Monsell & Mizon, 2006). Thus, abandoning either anticipatory or shift-specific reconfiguration might be a strategy for reducing the mental capacity needed for control.

RATIONALE OF THE PRESENT STUDY

Thus, reconfiguration can occur using either an optimal reconfiguration strategy or suboptimal reconfiguration strategies that require less control. The present study addressed the question of whether stress reduces the amount of capacity available for reconfiguration, and if so, whether the reconfiguration strategy is changed to adapt to this condition. Stress was induced by a procedure previously used by Chajut and Algom (2003). Before the actual task-shifting experiment, in which an explicit cuing procedure with two CSI levels was used, all subjects worked on a short intelligence test. There were two groups of subjects. For the *low-stress* group, the test items were easy to solve, no time limit was given, and the alleged goal of the test was to measure item difficulty. For the *high-stress* group, the test items were difficult, responses had to be made within a time limit, and the alleged goal of the test was to measure the subjects' intelligence.

We expected that the low-stress group would demonstrate the usual CSI effect on shift costs, such that the data pattern would reflect both anticipatory and shift-specific reconfiguration. In contrast, we expected that the high-stress group would not show such an effect, which would indicate that these subjects abandoned either reconfiguration in advance or shift-specific reconfiguration, or even both. Such a result would support the idea that the cognitive system adapts to depleted resources under stress by changing its control strategy.

METHOD

Subjects

Forty subjects were randomly assigned to the low-stress group (12 females, mean age = 23.1) and the high-stress group (11 females, mean age = 22.5). All subjects had normal or corrected-to-normal vision; were recruited at the Universität Konstanz, Germany; and were paid €5.

IQ Scale

Following the procedure of Chajut and Algom (2003), subjects completed three multiple-choice tasks, each containing 10 items, at the beginning of the session. The first task was a word-selection task, in which subjects chose the word that did not fit semantically with the other words listed (e.g., *table*, *chair*, *bird*, *scaffold*, *bed*). In the second task, subjects had to find analogies according to an example (e.g., "*dark* relates to *light* as *wet* relates to . . .," with response options of *rain*, *day*, *humid*, *wind*, and *dry*). The third task consisted of selecting a number that continued a series of numbers according to some rule (e.g., "2 4 6 8 10 12 14 . . .," with response options of *15*, *9*, *16*, *20*, and *8*). The items were presented on a computer screen, and responses were made via the computer keyboard.

The level of stress induced was manipulated by means of task difficulty, time pressure, and threat to the ego. In the low-stress condition, the items were fairly easy and could be solved without much difficulty. No time limit was given, and the subjects were told that the test was designed to evaluate psychometric properties of the tasks and that their individual results would not be evaluated. In the high-stress condition, the items were much more difficult, and, in addition, four items in each task were insoluble. A response was required within 30 s for each item, and the subjects were told that the test was designed to measure their cognitive abilities and that, after the experiment, they could compare their own results against norm data from a representative sample from the local student population.

Task Shifting

We used the stimuli and tasks of Rogers and Monsell (1995). The stimuli consisted of all possible numeral-letter pairs formed by combining the digits from 2 to 9 with the letters *G*, *K*, *M*, *R*, *A*, *E*, *I*, *U* in each possible order (128 pairs; e.g., "6M"), all possible symbol-numeral pairs formed by combining the same digits with the neutral symbols "#," "%," "?," and "*" in each possible order (64 pairs; e.g., "%7"), and all possible symbol-letter pairs formed by combining the letters with the neutral symbols in each possible order (64 pairs; e.g., "A#"). The digits, letters, and neutral symbols were presented in Arial font, and each character was scaled to a width of 1.24° and height of 1.77° visual angle at a viewing distance of 127 cm. The left and right members of each pair were presented at an eccentricity of 0.84° to the left and right of the center, respectively. A circle and a square, both 1.43° in diameter, were used as cues. Cues and stimuli were presented in white on a black background.

At the beginning of each trial, a cue specified the required task. For the *digit* task, indicated by the circle, subjects had to decide whether the digit in the stimulus was odd or even. For the *letter* task, indicated by the square, subjects had to decide whether the letter in the stimulus was a consonant or a vowel. A response was given by pressing one of two response buttons with the index (odd, consonant) or middle (even, vowel) finger of the right hand. Each trial started with the presentation of the cue for 150 ms, followed by a blank screen. Either 200 ms (short-CSI condition) or 1,000 ms (long-CSI condition) after cue onset, the stimulus was presented for 120 ms. The trial ended as soon as the subject made a response. So that the interval between the response and the new stimulus would be constant, a short CSI was paired with a long response-cue interval (1,000 ms), whereas a long CSI was paired with a short response-cue interval (200 ms). An error was signaled by a tone.

Immediately after completing the IQ scale, subjects worked through four practice blocks of 24 trials each. Each of the first two practice blocks contained only one of the tasks. These blocks were followed by two practice blocks with mixed tasks, one with the long CSI and one with the short CSI. Then, eight test blocks, each with 48 trials, were administered. Blocks with the long and short CSIs alternated, and the CSI of the first test block was counterbalanced across subjects. At the beginning of each block, subjects were informed about whether the long or short CSI would be used. The task-shifting part of the session lasted for about 40 min. At the end of the session, subjects rated their level of perceived stress during the session on a 7-point scale.

After this, they were debriefed regarding the true goals of the study.

RESULTS

Subjects in the high-stress group reported higher levels of subjective stress ($M = 4.65$ on a 7-point scale) than those in the low-stress group ($M = 3.45$), $t(38) = 2.18$, $p_{rep} = .90$, $\eta^2 = 0.11$, $p < .05$. Response times for correct responses and error rates were entered into a three-way analysis of variance with the between-subjects factor of group (low stress, high stress) and the within-subjects factors of CSI (short, long) and task transition (task repeat, task shift).

Response Times

Response times showed significant main effects of CSI, $F(1, 38) = 52.1$, $p_{rep} = .999$, $\eta^2 = .58$, $p < .001$, and task transition, $F(1, 38) = 48.7$, $p_{rep} = .99$, $\eta^2 = .56$, $p < .001$, as well as a significant two-way interaction between CSI and task transition, $F(1, 38) = 7.07$, $p_{rep} = .95$, $\eta^2 = .16$, $p < .05$. However, these effects were qualified by a significant three-way interaction of group, CSI, and task transition, $F(1, 38) = 4.90$, $p_{rep} = .90$, $\eta^2 = .11$, $p < .05$ (see Fig. 2). No other effects reached significance. Planned contrasts revealed that the interaction between CSI and task transition was significant only for the low-stress group, $F(1, 19) = 13.3$, $p_{rep} = .99$, $\eta^2 = .41$, $p < .01$, and not for the high-stress group ($F < 1$).

Error Rates

The mean error rate was 9.1%. The analysis of variance revealed significant main effects of CSI, $F(1, 38) = 6.18$, $p_{rep} = .94$, $\eta^2 = .14$, $p < .05$, and task transition, $F(1, 38) = 20.7$, $p_{rep} = .99$, $\eta^2 = .35$, $p < .001$. These main effects were qualified by a significant two-way interaction between task transition and CSI, $F(1, 38) = 4.28$, $p_{rep} = .88$, $\eta^2 = .10$, $p < .05$. The shift costs were larger with a short CSI (repetition: 8.0%; shift: 11.7%) than with a long CSI (repetition: 7.4%; shift 9.2%). No effect involving group reached significance. Most important, the three-way interaction was far from significant ($F < 1$). Therefore, no further analyses were conducted.

DISCUSSION

The present study investigated the effects of stress on task-set reconfiguration. Stress was manipulated by administering differentially stressful intelligence tests to two groups of subjects. As the subjects' self-reports indicate, this method was successful in inducing different stress levels. Moreover, and most important for our objective, although the average response times were similar for the two groups, the different stress levels had a specific effect on subsequent task-shifting performance. Whereas the typical reduction of shift costs with increased CSI

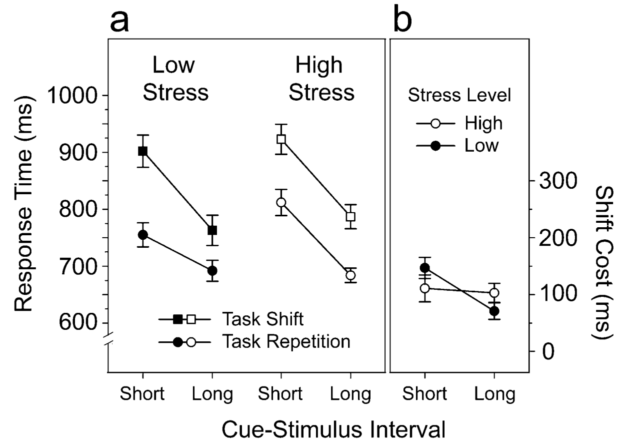

Fig. 2. Experimental results: (a) mean response times as a function of group, cue-stimulus interval, and task transition and (b) shift costs as a function of group and cue-stimulus interval. Error bars represent standard errors of the means.

was observed for the low-stress group, the shift costs did not change with CSI for the high-stress group. This result confirms our hypothesis that stress leads to a change in reconfiguration strategy.

This raises the question of which reconfiguration strategy was applied under high stress. As mentioned, a reduction in shift costs with a long CSI is usually interpreted as a result of anticipatory, shift-specific task-set reconfiguration. The absence of such a reduction, as in our high-stress group, could be due to two strategy changes. First, reconfiguration may not be anticipatory. Such a strategy selectively impairs performance on task-shift trials with a long CSI, leading to increased shift costs for the long CSI (see Fig. 1b). Inspection of Figure 2 shows that there is indeed a trend toward such a pattern in the data. For the long CSI, the shift costs were increased in the high-stress group (103 ms) relative to the low-stress group (71 ms), although this difference was not significant.

Second, the absence of a reduction in shift costs with a long CSI could be due to reconfiguration not being shift-specific (i.e., the task set might be reconfigured on each trial). This strategy selectively impairs performance on task-repetition trials with a short CSI, leading to reduced shift costs for the short CSI (see Fig. 1c). Indeed, there is also a trend in this direction in our data. The shift costs for a short CSI were reduced in the high-stress group (147 ms) relative to the low-stress group (111 ms). But again, this difference was not significant. Thus, our results do not favor an account based on one or the other strategy. Rather, they suggest that a mixture of both strategies was used. Possibly, the CSI effect on shift costs disappeared in the high-stress condition because reconfiguration became less anticipatory, as well as less shift-specific.

Taken together, our results clearly show that high stress induces a change in the reconfiguration strategy. Moreover, irrespective of whether anticipatory reconfiguration was abandoned or the task set was reconfigured on each trial (or even whether both strategy changes occurred), each of these strategies can be characterized as less control demanding than an anticipatory shift-specific reconfiguration. The latter strategy requires not only optimal scheduling of the reconfiguration process within the CSI, but also a decision about whether or not reconfiguration is necessary on each trial, as well as active maintenance of the current task set until a task shift occurs. Thus, when the available resources are scarce because of high stress, it makes sense to apply a still-reliable but less resource-consuming strategy.

Obviously, our results have implications for research on stress, as well as for research on cognitive control. Our results are in line with the notion that the cognitive system adapts to high stress by choosing processing strategies that need fewer resources (e.g., Hockey, 1997). In this way, the system prevents unreliable performance due to not providing enough resources to processes that rely strongly on resources. This adaptation to stress is particularly necessary for crucial processes, such as reconfiguration, that play a fundamental role in goal-directed action. In the present case, this adaptation was probably achieved by adopting a less control-demanding reconfiguration strategy.

The question arises, what exactly underlies the effect obtained with our stress-inducing method? Researchers using a similar method have attributed its effect to a number of sources (e.g., Chajut & Algom, 2003; Keinan, 1987; Keinan, Friedland, Kahneman, & Roth, 1999; Mogg, Mathews, Bird, & Macgregor-Morris, 1990). On the one hand, the difficult, ego-threatening test could have induced a negative affective state (e.g., Mogg et al., 1990), which, in turn, reduced the available resources by triggering self-regulatory processes (e.g., Hockey, 1997). On the other hand, because of its ego-threatening nature, the test could have increased cognitive load directly by eliciting ruminations (for a discussion of this issue in the context of another method, see Dumas, Huguet, Monteil, & Ayme, 2005). In either case, the effect of stress was not merely quantitative (i.e., general performance was only slightly, and nonsignificantly, impaired). Rather, the effect of stress was qualitative in the sense that it changed the pattern of performance across the experimental conditions. This supports the idea that stress induced a strategy change.

With respect to task shifting, our study has identified high stress as an additional condition in which the effect of CSI on shift costs is absent. This raises the question of whether the high variability of results in the task-shifting literature (Altmann, 2004b) could also be due in part to differentially stressful experimental settings. Finally, our study supports the idea that reconfiguration is strategic in the sense that the mode of reconfiguration is optional, at least to some extent. However, it remains unclear whether subjects choose the mode of reconfiguration deliberately (which could be viewed as a critical feature of a strategy). It is possible that the reconfiguration mode applied is a consequence of an automatic optimization process that selects the most optimal mode for a given amount of resources. Further research is needed to investigate this issue in more detail.

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REFERENCES

Allport, A., Styles, E.A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In C. Umilta & M. Moscovitch (Eds.), *Attention and performance 15: Conscious and nonconscious information processing* (pp. 421–452). Cambridge, MA: MIT Press.

Altmann, E.M. (2004a). Advance preparation in task switching: What work is being done? *Psychological Science*, *15*, 616–622.

Altmann, E.M. (2004b). The preparation effect in task switching: Carryover of SOA. *Memory & Cognition*, *32*, 153–163.

Broadbent, D.E. (1971). *Decision and stress*. New York: Academic Press.

Chajut, E., & Algom, D. (2003). Selective attention improves under stress: Implications for theories of social cognition. *Journal of Personality and Social Psychology*, *85*, 231–248.

Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: Reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*, 343–353.

Dumas, F., Huguet, P., Monteil, J.-M., & Ayme, E. (2005). Social context effects in the Stroop task: When knowledge of one's relative standing makes a difference. *Current Psychology Letters: Behaviour, Brain & Cognition*, *16*. Retrieved February 15, 2006, from http://cpl.revues.org/document456.html

Heuer, H., Kleinsorge, T., Klein, W., & Kohlisch, O. (2004). Total sleep deprivation increases the costs of shifting between simple cognitive tasks. *Acta Psychologica*, *117*, 29–64.

Hockey, G.R.J. (1997). Compensatory control in the regulation of human performance under stress and high workload: A cognitive-energetical framework. *Biological Psychology*, *45*, 73–93.

Hübner, R., Futterer, T., & Steinhauser, M. (2001). On attentional control as a source of residual shift costs: Evidence from two-component task shifts. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 640–653.

Huguet, P., Dumas, F., & Monteil, J.-M. (2004). Competing for a desired reward in the Stroop task: When attentional control is unconscious but effective versus conscious but ineffective. *Canadian Journal of Experimental Psychology*, *58*, 153–167.

Huguet, P., Galvaing, M.P., Monteil, J.-M., & Dumas, F. (1999). Social presence effects in the Stroop task: Further evidence for an attentional view of social facilitation. *Journal of Personality and Social Psychology*, *77*, 1011–1025.

Keinan, G. (1987). Decision making under stress: Scanning of alternatives under controllable and uncontrollable threats. *Journal of Personality and Social Psychology*, *52*, 639–644.

Keinan, G., Friedland, N., Kahneman, D., & Roth, D. (1999). The effect of stress on the suppression of erroneous competing responses. *Anxiety, Stress and Coping*, *12*, 455–476.

Koch, I. (2001). Automatic and intentional activation of task sets. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 1474–1486.

Koch, I. (2005). Sequential task predictability in task switching. *Psychonomic Bulletin & Review*, *12*, 107–112.

Mayr, U., & Kliegl, R. (2000). Task-set switching and long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 1124–1140.

Meiran, N. (1996). Reconfiguration of processing mode prior to task performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*, 1423–1442.

Meiran, N. (2000). Reconfiguration of stimulus task sets and response task sets during task switching. In S. Monsell & J. Driver (Eds.), *Control of cognitive processes: Attention and performance XVIII* (pp. 377–400). Cambridge, MA: MIT Press.

Mogg, K., Mathews, A., Bird, C., & Macgregor-Morris, R. (1990). Effects of stress and anxiety on the processing of threat stimuli. *Journal of Personality and Social Psychology*, *59*, 1230–1237.

Monsell, S., & Mizon, G.A. (2006). Can the task-cuing paradigm measure an endogenous task-set reconfiguration process? *Journal of Experimental Psychology: Human Perception and Performance*, *32*, 493–516.

Rogers, R.D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General*, *124*, 207–231.

Rubinstein, J.S., Meyer, D.E., & Evans, J.E. (2001). Executive control of cognitive processes in task switching. *Journal of Experimental Psychology: Human Perception and Performance*, *27*, 763–797.

Ruthruff, E., Remington, R.W., & Johnston, J.C. (2001). Switching between simple cognitive tasks: The interaction of top-down and bottom-up factors. *Journal of Experimental Psychology: Human Perception and Performance*, *27*, 1404–1419.

Sanders, A.F. (1983). Towards a model of stress and human performance. *Acta Psychologica*, *53*, 61–97.

Schuch, S., & Koch, I. (2003). The role of response selection for inhibition of task sets in task shifting. *Journal of Experimental Psychology: Human Perception and Performance*, *29*, 92–105.

Sohn, M.-H., & Anderson, J.R. (2001). Task preparation and task repetition: Two-component model of task switching. *Journal of Experimental Psychology: General*, *130*, 764–778.

Sohn, M.-H., & Carlson, R.A. (2000). Effects of repetition and foreknowledge in task-set reconfiguration. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 1445–1460.

Steinhauser, M., & Hübner, R. (2006). Response-based strengthening in task shifting: Evidence from shift effects produced by errors. *Journal of Experimental Psychology: Human Perception and Performance*, *32*, 517–534.

Sudevan, P., & Taylor, D.A. (1987). The cuing and priming of cognitive operations. *Journal of Experimental Psychology: Human Perception and Performance*, *13*, 89–103.

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