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Task switching promotes switch readiness: Evidence from forced and voluntary task switching

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ABSTRACT

People find it harder to switch from one task to another than to repeat a task. One common explanation is that lingering activation of the just-executed task facilitates repetitions and impairs switching. However, beyond specific task sets, it is also conceivable that switching a task increases more abstract switch readiness, whereas repeating a task reduces switch readiness. To investigate switch readiness independent of task-set activation, we used consecutive chunks, each consisting of two tasks, with self-paced breaks between chunks. This way, the salient task transition happens within a chunk, independent of the task transition between chunks. In four experiments, we applied a (hybrid) task-switching paradigm with a mixture of forced choice (only one task presented) and free choice (participants can decide which task to perform). We expected an increased ability and willingness to switch (i.e., switch readiness) in the current chunk when the previous chunk entailed a task switch rather than a repetition. In line with a switch-readiness account, Experiments 1 and 2 showed reduced switch costs and increased voluntary switch rates (VSR) after a switch within the previous chunk. Furthermore, this effect transferred to new task pairs (only descriptively in Experiment 3, significantly in Experiment 4). Taken together, the present study uncovered a novel property of sequential control during task switching.

1. Introduction

Every day, we face a variety of different tasks and must decide which task to do next, i.e. either continue with the just executed task or switch to a different task. Task switches typically lead to worse performance compared to repeating the same task, so-called switch costs (Koch & Kiesel, 2022). One common explanation for such switch costs assumes that lingering activation of the just-executed task facilitates repetitions and impairs switches (Allport et al., 1994; Goschke, 2000). However, beyond specific task sets, it is also conceivable that a more abstract higher or lower switch readiness following switches or repetitions (partially) modulates the switch costs. In the present study, we investigated whether switching tasks facilitates voluntary and forced task switching independent of specific task-set activation.

In typical task-switching paradigms (for reviews, see Dreisbach & Mendl, 2024; Kiesel et al., 2010; Koch & Kiesel, 2022; Monsell, 2003; Vandierendonck et al., 2010), participants must perform two simple tasks sequentially with the relevant task either repeating or switching from one trial to the next. Typically, participants perform worse on task switches compared to task repetitions due to either persisting activation from the just executed task set (Allport et al., 1994; Allport & Wylie, 2000) and/or due to processes of task-set reconfiguration (Rogers & Monsell, 1995). A variant of the task-switching paradigm, the voluntary task-switching paradigm (Arrington & Logan, 2004), allows to measure a distinct facet of cognitive flexibility beyond the switch costs, namely the motivation to switch tasks voluntarily. Here, participants choose which task to perform on a given trial (free-choice; for a review, see Arrington et al., 2014) and the voluntary switch rate (VSR) can be calculated based on the respective task choice as the percentage of voluntary task switches. All else being equal (e.g., the length of the preparatory interval), lower switch costs and higher VSR indicate greater flexibility, i.e., greater switch readiness (Dreisbach & Mendl, 2024). Taken together, the switch costs and the VSR can thus be used as measures of switch readiness, a subtype of cognitive flexibility.

Here, we aimed to investigate whether task switching would not only activate one or the other task set but whether it also improves switch readiness in general and independent from specific task activations. If this is the case, a task switch should lead to reduced switch costs and increased VSR in the following trial. Studies about sequential adaptations between two-task chunks and (implicit) sequence learning already

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showed that participants can form higher-order representations of the task sequence beyond the task identity (Koch et al., 2006; for a review, see Hirsch & Koch, 2024). Furthermore, in line with our assumptions, Moss et al. (2023) showed that a repetition of an abstract grammar (i.e., the transition between tasks) within a sequence of three tasks facilitated performance. This suggests that the cognitive system encodes not just specific tasks but also the relationship between them. The present study built on this idea by focusing on the ability and motivation to switch. Hence, we tested whether experiencing a task switch activates the abstract representation of switching (switch readiness), thereby influencing subsequent performance beyond immediate task-set activation.

In fact, a previous study by Brown et al. (2007) already found reduced switch costs following task switches. However, using the standard task-switching paradigm to investigate the potential switch readiness poses a problem because sequential switch readiness is perfectly confounded with effects of lingering task-set activation (Allport et al., 1994; Goschke, 2000): Task-set activation may simply be larger the more recently and frequently that task has been executed. Therefore, faster RTs on repetitions following repetitions (e.g., task sequence = AAA) compared to repetitions following switches (e.g., BAA) may simply reflect the accumulated activation advantage of repeating the same task set multiple times. Likewise, faster RTs on switches following switches (e.g., ABA) compared to switches following repetitions (e.g., BBA) may simply reflect the advantage of switching to a recently active task set.[1] However, it is also conceivable that this advantage, if present, stems from sequential switch readiness instead of the repetition of a task set. According to this logic, a repetition is facilitated after consecutive repetitions (AAA vs. BAA), and a switch is facilitated after consecutive switches (ABA vs. BBA).

To investigate the role of sequential switch readiness in task switching independent of task-set activation, we implemented two consecutive tasks (first task, second task) per trial ("chunk" hereafter). This procedure was adapted from previous studies on RT introspection during task switching (Bratzke & Bryce, 2019, 2022). By including a self-paced break between the chunks, task activation should dissipate between chunks (Allport & Wylie, 2000). Therefore, the most salient task transition occurs between the two tasks within a given chunk, whereas the task transition between chunks (between the second task of the previous chunk and the first task of the current chunk) should be less salient for the participants. For example, in the chunk sequence "AB-AA", the task switch within the first chunk and the task repetition within the second chunk are more salient than the task switch between the chunks due to the restart costs in the first task of each chunk (Allport & Wylie, 2000). This idea is supported by studies on sequence learning which demonstrate that chunking creates higher-order representations that organize individual tasks (Koch et al., 2006; Lien & Ruthruff, 2004; Mayr, 2009). Taken together, when analyzing the VSR and switch costs based on the task transition within the previous chunk, task-set activation should be reduced due to the self-paced-break and, therefore, have negligible influence on the potential findings.

Even if some task-set activation remained when switching between chunks, the present method offers a second crucial advantage. Using chunks of two tasks and a self-paced break between chunks allowed us to vary the specific tasks (and thereby potential effects of task-set activation) while keeping the transition (repetition vs. switch) within a chunk constant (e.g., using BB instead of AA or using BA instead of AB). By making all potential task sequences equally likely, the resulting effects allow us to distinguish between task-set activation and sequential switch readiness. The differing predictions of task-set activation (if there is some task activation left after the self-paced break) and switch readiness regarding the switch costs and the VSR in all potential sequences of subsequent chunks are presented Fig. 1 and Fig. 2. A task-set activation account generally assumes better performance the higher the task-set activation depending on the recency and frequency of a certain task. In contrast, the switch-readiness account assumes better performance on switches following switch chunks and on repetitions following repetition chunks. Critically, a sequence of repetition chunks could also include the task sequence BB-AA, where the switch-readiness account would predict faster RTs for the second Task A in the second chunk compared to BA-AA. When only considering task-set activation without sequential switch readiness, the prediction would be reversed because Task A has been activated more frequently in the latter case. Similarly, a sequence of switch chunks could include the task sequence BA-AB, where the switch-readiness account would predict faster RTs for Task B in the second chunk compared to BB-AB. Again, the task-set activation account would predict the opposite because Task B has been activated more recently and frequently in the latter case.[2],[3] In other words, according to the switch-readiness account, after a task switch within the previous chunk, a task switch in the current chunk should be facilitated (increased switch readiness), resulting in reduced switch costs (relatively faster switches and slower repetitions) and higher VSRs (increased willingness to switch voluntarily). Conversely, after a task repetition within the previous chunk, a task repetition should be facilitated in the current chunk (reduced switch readiness), resulting in increased switch costs (relatively faster repetitions and slower switches) and lower VSRs (reduced willingness to switch voluntarily). When only considering task-set activation, there should be no switch-cost difference between chunks following switch chunks and chunks following repetition chunks because we counterbalance the specific task sequence in each chunk (see Fig. 1 and Fig. 2).

To the best of our knowledge, apart from the study by Brown et al. (2007) there were no previous attempts to investigate sequential switch readiness during task switching. Given the outlined shortcomings regarding task-set activation in the study by Brown et al. (2007) we aimed at closing this research gap. Therefore, we conducted four experiments to investigate the potential influence of a task switch (or a task repetition) in the previous chunk on the switch costs and the VSR in the current chunk. Experiment 1 used a hybrid task-switching paradigm (Fröber & Dreisbach, 2017) with a mixture of forced-choice tasks (only one predetermined task is presented) and free-choice tasks (participants can decide which task to perform as the second task). This allows measuring the VSR within the free-choice chunks and switch costs within the forced-choice chunks (see Mendl & Dreisbach, 2022). In Experiment 2, we mainly replicated Experiment 1 while controlling for potential confounds of hand and location repetitions. Experiments 3 and 4 tested the transfer of the potential switch readiness to a different pair of task sets. In Experiment 3, we used only forced choices and focused on switch costs, whereas in Experiment 4, we increased the proportion of voluntary choices and focused on the VSR. In all experiments, we expected reduced switch costs and increased VSRs when there was a task switch within the previous chunk rather than a task repetition. This would provide the first evidence that switching increases switch

[1] The opposite pattern would be expected when considering backward inhibition (Mayr & Keele, 2000) which represents a second potential confound. Switching back to a recently inhibited task may be especially time consuming. To foreshadow, however, backward inhibition can neither explain the findings by Brown et al. (2007) nor the present results.

[2] Note that potential effects of backward inhibition (Mayr & Keele, 2001) on the last B in BB-AB should be negligible for two reasons: First, backward inhibition is mainly present when pre-cues are presented (which is not the case here) and not observed for bottom-up activation of task sets. Second, we doubt that backward inhibition would survive between chunks. To foreshadow, the present results, especially the exploratory chunk sequence analysis, showed no signs of backward inhibition.

[3] Note that the predictions for a task-set activation account may not necessarily change linearly across the four sequences. The account only allows for ordinal predictions, meaning the relative order can be anticipated but not the absolute size of the costs. The AA–AX sequence may for example lead to especially high switch costs while the other sequences may not differ strongly in their switch costs. Collapsed per Transition in the previous chunk, this would result in similar predictions for both accounts. We therefore report additional analyses per sequence to directly compare the resulting pattern with both accounts. In the main analysis, we collapsed across the AA-AX/BB-AX and BA-AX/AB-AX sequences.

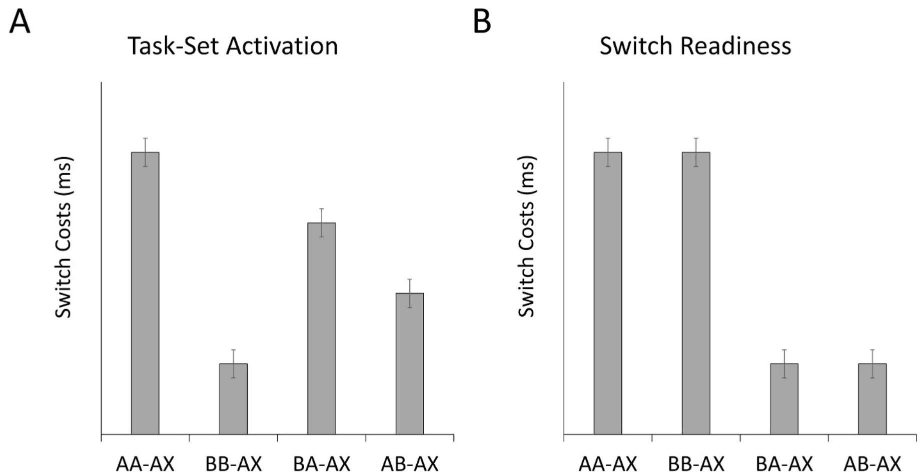

Fig. 1. Hypothetical Switch Costs in the Current Chunk per Chunk Sequence (AA-AX, BB-AX, BA-AX, AB-AX) Predicted by a Task-Set Activation Account (A) and Switch-Readiness Account (B). *Note.* A = Task A, B = Task B, X = Task A or Task B. Interchangeable sequences are not shown, e.g., BB-BX instead of AA-AX. Switch Costs refer to the difference between task switches and task repetitions in the current chunk (e.g. AA-AX refers to switch costs derived from RT on AA-A**B** minus RT on AA-A**A**). The task-set activation depends on the recency and frequency of a certain task set. This assumes that task-set activation carries over between chunks despite the self-paced break. The switch readiness depends on the transition in the previous chunk (task repetition, task switch).

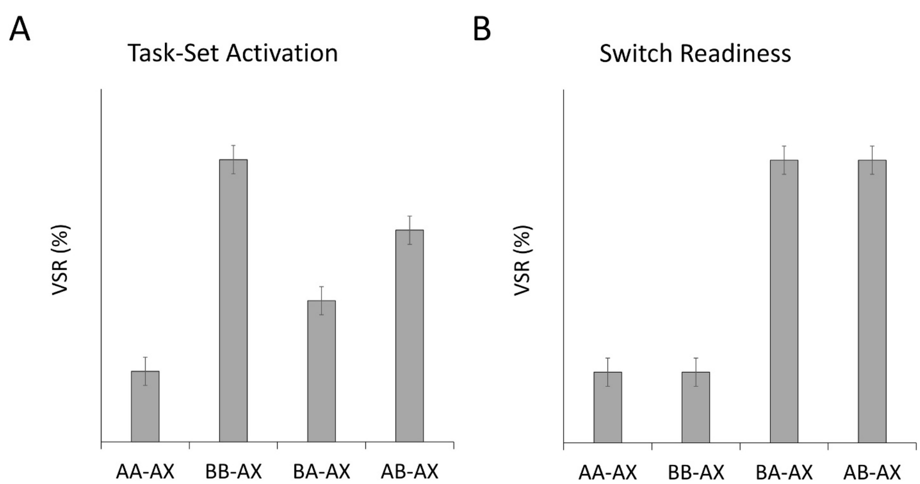

Fig. 2. Hypothetical Voluntary Switch Rate (VSR) in the Current Chunk per Chunk Sequence (AA-AX, BB-AX, BA-AX, AB-AX) Predicted by a Task-Set Activation Account (A) and Switch-Readiness Account (B). *Note.* A = Task A, B = Task B, X = Choice between Task A and Task B. VSR refers to the rate of voluntary switches regarding chunk sequences where participants can choose which task to perform as the second task in the current chunk (e.g. in AA-AX a voluntary switch would be AA-AB whereas a voluntary repetition would be AA-AA). Interchangeable sequences are not shown, e.g., BB-BX instead of AA-AX. Note, that the VSR predictions are the inverse of the switch costs presented in Fig. 1.

readiness and modulates performance during task switching accordingly.

2. Experiment 1

2.1. Method

2.1.1. Participants

Experiment 1 was preregistered (https://aspredicted.org/7vtd-qqch.pdf). In all experiments, data collection and analysis were performed according to the preregistration protocol. A power analysis based on Langenberg et al. (2023), using the effect size of a comparable manipulation on the switch costs (Mendl & Dreisbach, 2022; Exp 2: partial eta squared = 0.31), with a power of 0.80, resulted in a required sample of at least 20 participants. Due to the novelty of the current approach, we aimed for at least 50 participants. Hence, 52 participants completed the experiment. One participant had to be excluded (for exclusion criteria, see Data Preprocessing), resulting in a final sample of $N = 51$. In the final sample, the mean age was 23.24 years ($SD = 3.35$), ranging from 18 to 30 years. Thirty-nine participants were female (12 male) and 45 were right-handed (6 left-handed). All participants provided informed consent following the ethical standards of the national research committee and with the 1964 Helsinki Declaration and its later amendments. Psychology students received course credit for their participation.

2.1.2. Apparatus and stimuli

The experiment was programmed in lab.js (Henninger et al., 2022) and hosted online on Open Lab (Shevchenko, 2022). The stimuli were adopted from the study of Fröber and Dreisbach (2017). In the number task, participants had to categorize numbers (125, 132, 139, 146; 160, 167, 174, 181) as smaller or larger than 153. In the letter task, participants had to categorize letters (B, D, F, H; S, U, W, Y) as closer to A or Z in the alphabet. The stimuli were shown in black ink (5.33% of the screen height in the default sans-serif font) on a white background. One task was consistently presented above the center of the screen while the other task was presented below (shifted by 8.33% of the screen height in the respective direction). Participants had to respond to the upper task with their left hand according to an intuitive mapping (Dehaene et al., 1993), e.g., whether the number was smaller (G key; left middle finger) or larger (H key; left index finger) than 153, and to the lower task with their right hand, e.g., whether the letter was closer to A (K key; right index finger) or closer to Z (L key; right middle finger). The mapping between task and location (and thereby to response hand and keys) was counterbalanced across participants.

2.1.3. Procedure

After providing demographic information, the experiment started with separate practice blocks for each task (8 trials each). Next, participants practiced switching between the two tasks in a forced-choice practice block (only one stimulus presented per trial; 16 trials) and a free-choice practice block (stimuli of both tasks presented in each trial; 16 trials).[4] Each trial of these practice blocks contained a fixation cross in the center of the screen for 500 ms, followed by the stimulus/stimuli (until response), feedback in the form of the German words for correct ("Richtig!") and error ("Fehler") for 1000 ms, and an inter-trial interval for 500 ms.

In the next practice block (4 trials), participants were familiarized with the trial structure of the test phase, where each trial (hereafter referred to as a chunk) consisted of two consecutive tasks. Each chunk comprised a fixation cross for 500 ms, the first task (until response), a blank screen for 500 ms, another fixation cross for 500 ms, the second task (until response), a pre-feedback interval for 200 ms, feedback (until the spacebar is pressed), and an inter-chunk interval for 500 ms (see Fig. 3). The feedback informed participants whether they responded correctly ("Richtig!") or made an error in the first task ("Fehler bei erstem Reiz!"), the second task ("Fehler bei zweitem Reiz!"), or both ("Fehler bei erstem Reiz! Fehler bei zweitem Reiz!"). The feedback served as a self-paced break between chunks because participants had to press the spacebar to continue.

The test phase consisted of eight blocks with 32 chunks each. In every fourth chunk, the second task was presented in the free-choice format, while all other tasks were presented in the forced-choice format. In each block, all eight potential *sequences* of transitions in four consecutive chunks appeared in random order (RRRF, RRSF, RSRF, RSSF, SRRF, SRSF, SSRF, SSSF; R = Repetition chunk, S = Switch chunk, F = Free choice in the second task). Across the eight blocks, each task appeared equally often in each position of each sequence of four chunks. The stimuli were presented in randomized order, avoiding direct stimulus repetitions. One session lasted approximately 35 min.

2.1.4. Design

The VSR (in %) was analyzed as a function of the within-subjects factor Previous Transition (repetition chunk, switch chunk), referring to the transition within the previous chunk. For the mean RT (in ms) and error rate (in %) in forced-choice chunks, we used a 2 (Previous Transition) x 2 (Current Transition: repetition chunk, switch chunk) repeated measures design. Current Transition refers to the transition within the current chunk.[5] We additionally report exploratory analyses of the VSRs and RTs with the factor chunk sequence (AA-AX, BB-AX, BA-AX, AB-AX; Fig. 1 and Fig. 2) instead of Previous Transition to support the interpretation of the present findings as switch readiness. We thank an anonymous reviewer for suggesting this analysis.

[4] Note that using a hybrid task switching procedure with free and forced choices intermixed makes it superfluous to restrict task choices via instructions (see Fröber & Dreisbach, 2017). That means, participants were truly free to choose either task on free choice trials meaning that they could have always chosen a task repetition.

[5] For Experiment 1, we also preregistered explorative linear mixed effects model analyses to investigate the influence of the RT level in the previous chunk as an adaptation signal on the RT and VSR in the current chunk. In both cases, the resulting pattern provided no clear indication of such effects. Therefore, we did not preregister these analyses in Experiments 2–4.

In the Supplemental Material we report comparisons of the switch costs within and between chunks for all experiments to show that the most salient transition happened within chunks rather than between chunks. We also report analyses of the error rate in voluntary chunks per Previous Transition and Current Transition to rule out careless and random responding following switches. Last, we analyzed the duration of the self-paced break following a chunk per Current Transition. All raw data files associated with this article are available online under the following link: http://doi.org/10.5283/epub.78517. Additional study materials of all experiments (lab.js experiment files, SPSS analysis scripts) will be shared upon request.

2.2. Results

2.2.1. Data preprocessing

In all analyses, only the second task of each chunk was of interest. We excluded the first chunk of each block from all analyses (3.13% of all chunks). Additionally, for the RT and VSR analyses, we excluded chunks with errors in the current (10.16%) or previous chunk (9.16%), and chunks with RTs in the first or the second task faster than 150 ms or slower than 3000 ms (see Miller, 2023) in the current (0.58%) or previous chunk (0.56%). The VSR was calculated on the remaining free-choice tasks. The task choice was derived from the response hand. RTs and error rates were analyzed on forced-choice tasks only. One participant had to be excluded prior to the final analyses due to an extreme mean RT (1343 ms) more than 3 interquartile ranges above the third quartile. No participant displayed an extreme error rate according to the same criterion.

2.2.2. VSR

The paired-sample *t*-test of the VSR was significant, $t(50) = 6.43$, $p < .001$, $d = 0.91$. In line with the switch-readiness account, participants switched tasks more often following a switch chunk than following a repetition chunk (see Table 1).

2.2.3. RT

The 2 (Previous Transition) x 2 (Current Transition) repeated-measures ANOVA of the RT revealed a significant main effect of Current Transition, $F(1, 50) = 105.41$, $p < .001$, $\eta_p^2 = 0.68$. Participants showed typical switch costs by responding slower on task switches ($M = 739$ ms, $SE = 19$) compared to repetitions ($M = 628$ ms, $SE = 12$). Critically, the interaction between Previous Transition and Current Transition was significant, $F(1, 50) = 11.25$, $p = .002$, $\eta_p^2 = 0.18$ (see Fig. 4). In accordance with the switch-readiness account, the switch costs (RT_{switch} minus $RT_{repetition}$) were lower following a switch chunk ($M = 88$ ms, $SE = 13$) than following a repetition chunk ($M = 134$ ms, $SE = 12$). The main effect of Previous Transition was not significant, $F(1, 50) = 0.15$, $p = .702$, $\eta_p^2 < 0.01$.

2.2.4. Error rate

In the 2 (Previous Transition) x 2 (Current Transition) repeated-measures ANOVA of the error rates there was a significant main effect of Current Transition, $F(1, 50) = 6.41$, $p = .015$, $\eta_p^2 = 0.11$. Participants made more errors on task switches ($M = 5.86\%$, $SE = 0.59$) than on task repetitions ($M = 4.34\%$, $SE = 0.42$). The main effect of Previous Transition and the interaction were not significant (all *F*s < 0.61, all *p*s $> .438$).

2.2.5. Exploratory chunk sequence analysis

We ran additional exploratory analyses regarding the sequence (AA-AX, BB-AX, BA-AX, AB-AX) in two consecutive chunks as presented in Fig. 1 and Fig. 2. This way, we can compare the resulting pattern with predictions of a task-set activation account and a switch-readiness account. Note that we collapsed across interchangeable sequences. For example, AA-AX is treated as equivalent to BB-BX. In the analysis of the VSR the X stands for the choice of the participants. In the analysis of the

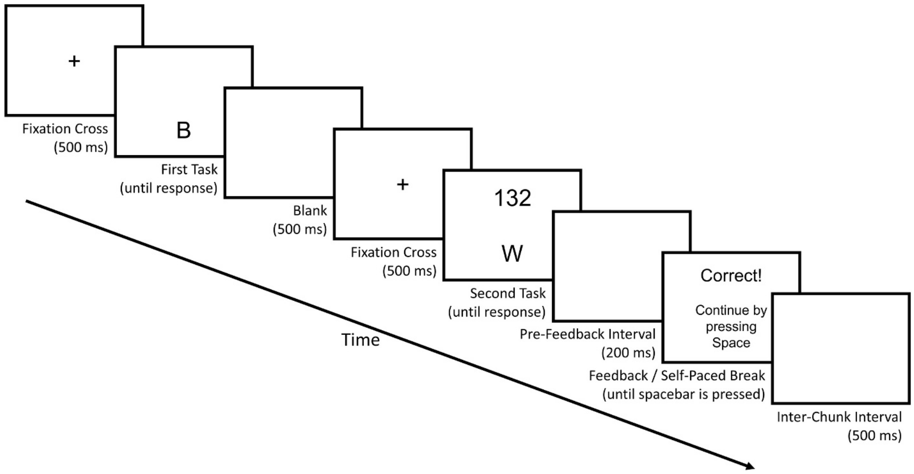

Fig. 3. Schematic Depiction of a Single Chunk with Free Choice in the Second Task in Experiment 1.

Table 1
Mean VSR (in %) as a Function of Previous Transition (Repetition Chunk, Switch Chunk) and, Only for Experiment 4, Task-Pair Transition (Task-Pair Repetition, Task-Pair Switch).

Previous Transition	Task-Pair Repetition		Task-Pair Switch	
	Repetition Chunk	Switch Chunk	Repetition Chunk	Switch Chunk
Experiment 1	18.29% (1.90)	29.33% (2.31)	–	–
Experiment 2	33.64% (1.72)	43.77% (1.86)	–	–
Experiment 4	26.06% (1.83)	33.86% (1.94)	24.86% (1.79)	27.97% (2.01)

Note. The values in parentheses represent the SE of the mean.

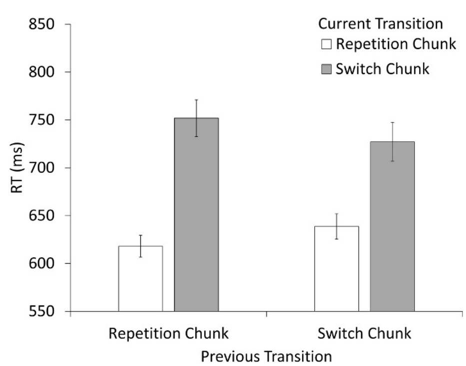

Fig. 4. RT (in ms) as a Function of Previous Transition (Repetition Chunk, Switch Chunk) and Current Transition (Repetition Chunk, Switch Chunk) in Experiment 1. *Note.* Error bars represent ± one standard error of the mean.

RTs the X stands for both potential task transitions in the specific chunk sequence (e.g., for AA-AX: repetition AA-AA, and switch AA-AB).

The one-way repeated-measures ANOVA of the VSR using the independent variable Chunk Sequence (AA-AX, BB-AX, BA-AX, AB-AX) resulted in a significant main effect of Chunk Sequence, $F(3, 150) = 17.25$, $p < .001$, $\eta_p^2 = 0.26$. According to pairwise comparisons, the highest VSR was evident for the AB-AX sequence, followed by BA-AX. The two sequences with repetitions in the previous chunk (AA-AX, BB-AX) showed the lowest VSR (all $ps < .036$; see Fig. 5). There was no significant difference between AA-AX and BB-AX ($p = .807$). This pattern is more in line with a switch-readiness account because the task-set activation account would have predicted the highest VSR for BB-AX.

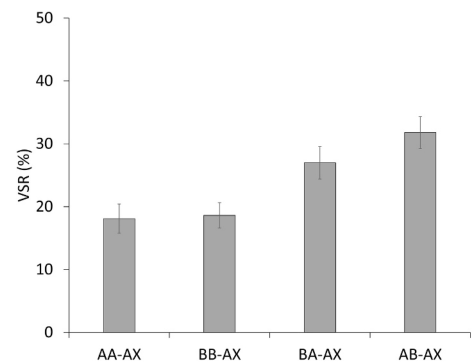

Fig. 5. VSR (in %) as a Function of Chunk Sequence (AA-AX, BB-AX, BA-AX, AB-AX) in Experiment 1. *Note.* Error bars represent ± one standard error of the mean.

The 4 (Chunk Sequence: AA-AX, BB-AX, BA-AX, AB-AX) x 2 (Current Transition: repetition chunk, switch chunk) repeated-measures ANOVA of the RT resulted in a significant main effect of Current Transition, $F(1, 50) = 104.84$, $p < .001$, $\eta_p^2 = 0.68$. The main effect of Chunk Sequence was not significant, $F(3, 150) = 0.62$, $p = .601$, $\eta_p^2 = 0.01$. There was a significant interaction of Chunk Sequence and Current Transition, $F(3, 150) = 8.00$, $p < .001$, $\eta_p^2 = 0.14$. Follow up analyses showed that the switch costs were highest in AA-AX followed by BB-BX and BA-AX, and lowest in AB-AX. All pairwise comparisons were significant (all $ps < .023$) except for the difference between AA-AX and BB-AX ($p = .055$) and

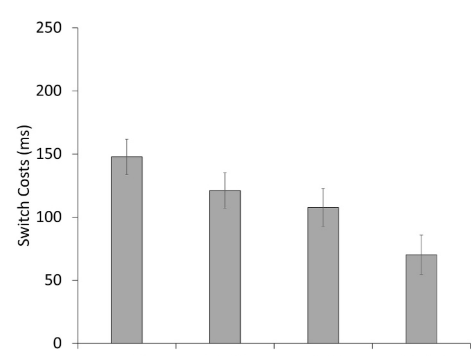

Fig. 6. Switch Costs (in ms) as a Function of Chunk Sequence (AA-AX, BB-AX, BA-AX, AB-AX) in Experiment 1. *Note.* Error bars represent ± one standard error of the mean.

between BB-AX and BA-AX (p = .414; see Fig. 6). Again, this pattern is more in line with a switch-readiness account. A task-set activation account would have predicted the lowest switch costs in BB-AX. Please note, that the pattern of the BB-AX sequence was not driven by backward inhibition because the higher switch costs (compared to AB-AX) not only resulted from slower switches but also from faster repetitions (p = .014).

2.3. Discussion

The results of Experiment 1 are in line with the predictions of the switch-readiness account. After a switch chunk, participants were more inclined to switch voluntarily and showed reduced switch costs in RTs. Critically, the pattern of the exploratory chunk sequence analyses can only be explained by considering switch readiness whereas task-set activation cannot account for the findings. This suggests that, independent of task-set activation, switch readiness influences task choice and task processing in the current chunk. The results thus provide first evidence for the role of sequential switch readiness in task switching.

3. Experiment 2

In Experiment 2, we aimed to replicate the results of Experiment 1 while avoiding potential influences of task location and hand repetitions. Note that in Experiment 1, tasks were consistently tied to a response hand and a location on the screen. Therefore, participants may have been biased to repeat the response hand after a response-hand repetition or to attend to the same location twice after a location repetition. To circumvent this problem in Experiment 2, we mapped one task to the two middle fingers and the other task to the two index fingers while presenting the stimuli centrally for forced-choice tasks and randomly slightly above and below the center for free-choice tasks. This way, we avoided systematic influences of location and hand repetitions.

3.1. Method

3.1.1. Participants

Experiment 2 was preregistered (https://aspredicted.org/tbcf-y2zj.pdf). A power analysis according to Langenberg et al. (2023), using the effect size of the RT interaction in Experiment 1 (partial eta squared = 0.18), with a power of 0.80, resulted in a required sample of at least 38 participants. To be on the safe side, we aimed for a minimum of 50 participants. We collected 54 participants. One participant had to be excluded (for exclusion criteria, see Data Preprocessing), resulting in a final sample of N = 53. The mean age was 20.87 years (SD = 2.08), ranging from 18 to 28 years. Forty-five participants were female (8 male) and 48 were right-handed (5 left-handed). All participants provided informed consent in accordance with the ethical standards of the national research committee and with the 1964 Helsinki Declaration and its later amendments. Psychology students received course credit for their participation.

3.1.2. Apparatus, procedure, and design

The procedure of Experiment 2 was very similar to that of Experiment 1. The same tasks and stimuli were used. As a main difference, one task was mapped to the two middle fingers while the other task was mapped to the two index fingers of both hands. We again used an intuitive response mapping (Dehaene et al., 1993). That means, participants had to respond to numbers smaller than 153 with the left middle finger (G key) and to numbers larger than 153 with the right middle finger (L key). Likewise, letters closer to A required a response with the left index finger (H key), and letters closer to Z required a response with the right index finger (K key). The task-to-finger mapping was counterbalanced across participants.

The second difference was that forced-choice tasks were always presented in the center of the screen. On free-choice tasks, the two stimuli were *randomly* presented slightly above or below the center of the screen (vertical offset = 3.33% of the screen height). Thereby, tasks were no longer associated with distinct hands or locations. The entire procedure and design remained the same as in Experiment 1.

3.2. Results

3.2.1. Data preprocessing

As in Experiment 1, the first chunk of each block was excluded from all analyses (3.13% of all chunks). Additionally, for the RT and VSR analyses, we excluded chunks with errors in the current (10.52%) or previous chunk (9.22%), and chunks with RTs in the first or the second task faster than 150 ms or slower than 3000 ms in the current (1.22%) or previous chunk (1.10%). One participant had to be excluded prior to the final analyses due to an extreme mean RT (1791 ms) which was more than 3 interquartile ranges above the third quartile. No participant displayed an extreme error rate according to the same criterion.

3.2.2. VSR

The paired-sample t-test of the VSR was significant, $t(52) = 6.14$, $p < .001$, $d = 0.84$. Participants again switched tasks more often after switch chunks than after repetition chunks (see Table 1).

3.2.3. RT

The 2 (Previous Transition) x 2 (Current Transition) repeated-measures ANOVA of the RT revealed significant main effects of Previous Transition, $F(1, 52) = 7.03$, $p = .011$, $\eta_p^2 = 0.12$, and Current Transition, $F(1, 52) = 45.43$, $p < .001$, $\eta_p^2 = 0.47$. Responses were slower after switch chunks (M = 747 ms, SE = 17) than after repetition chunks (M = 733 ms, SE = 16). Similarly, responses were slower when the task switched in the current chunks (M = 776 ms, SE = 19) compared to when the task repeated (M = 704 ms, SE = 15). Furthermore, the interaction between Previous Transition and Current Transition was significant, $F(1, 52) = 39.96$, $p < .001$, $\eta_p^2 = 0.44$ (see Fig. 7). The switch costs were reduced after a switch chunk (M = 30 ms, SE = 11) compared to a repetition chunk (M = 115 ms, SE = 14).

3.2.4. Error rate

In the 2 (Previous Transition) x 2 (Current Transition) repeated-measures ANOVA of the error rates there was a significant main effect of Current Transition, $F(1, 52) = 4.63$, $p = .036$, $\eta_p^2 = 0.08$. Participants made more errors on task switches (M = 5.72%, SE = 0.55) than on task repetitions (M = 4.84%, SE = 0.45). The main effect of Previous Transition and the interaction were not significant (all Fs < 2.96, all ps > .091).

3.2.5. Exploratory chunk sequence analysis

The one-way repeated-measures ANOVA of the VSR resulted in a significant main effect of Chunk Sequence, $F(3, 156) = 15.91$, $p < .001$,

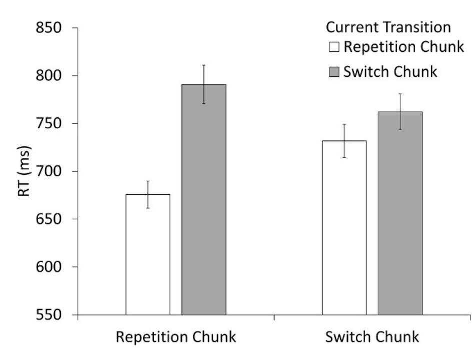

Fig. 7. RT (in ms) as a Function of Previous Transition (Repetition Chunk, Switch Chunk) and Current Transition (Repetition Chunk, Switch Chunk) in Experiment 2. *Note.* Error bars represent ± one standard error of the mean.

$\eta_p^2 = 0.23$. The highest VSR was evident for the AB-AX and BA-AX sequences, followed by AA-AX, and last BB-AX (all $ps < .048$; see Fig. 8). There was no significant difference between AB-AX and BA-AX ($p = .154$). This pattern is again more in line with a switch-readiness account because a task-set activation account would have predicted the highest VSR for BB-AX.

The 4 (Chunk Sequence: AA-AX, BB-AX, BA-AX, AB-AX) x 2 (Current Transition: repetition chunk, switch chunk) repeated-measures ANOVA of the RT resulted in a significant main effect of Current Transition, $F(1, 52) = 45.43$, $p < .001$, $\eta_p^2 = 0.47$. The main effect of Chunk Sequence was not significant, $F(3, 156) = 2.24$, $p = .085$, $\eta_p^2 = 0.04$. There was a significant interaction of Chunk Sequence and Current Transition, $F(3, 156) = 17.43$, $p < .001$, $\eta_p^2 = 0.25$. Follow up analyses showed that the switch costs were highest in BB-AX and AA-AX followed by BA-AX, and lowest in AB-AX. All pairwise comparisons were significant (all $ps < .022$) except for the difference between BB-AX and AA-AX ($p = .663$, see Fig. 9). This pattern is more in line with a switch-readiness account because a task-set activation account would have predicted the lowest switch costs in BB-AX. Again, the pattern of the BB-AX sequence was not driven by backward inhibition because the higher switch costs (compared to BA-AX and AB-AX) not only resulted from slower switches but also from faster repetitions (all $ps < .001$).

3.2.6. Between-experiment analysis

Additionally, we ran a preregistered between-experiment analysis on the VSR to investigate whether hand or location transitions influenced the findings of Experiment 1. If this were the case, an interaction between Experiment and Previous Transition should indicate a reduced influence of Previous Transition on the VSR in Experiment 1. The mixed 2 (Experiment: 1, 2; between-subjects) x 2 (Previous Transition: repetition, switch; within-subjects) ANOVA revealed significant main effects of Previous Transition, $F(1,101) = 79.77$, $p < .001$, $\eta_p^2 = 0.44$, and Experiment, $F(1, 101) = 38.06$, $p < .001$, $\eta_p^2 = 0.27$. Participants switched more often voluntarily after a switch chunk ($M = 36.39\%$, $SE = 1.48$) compared to a repetition chunk ($M = 25.71\%$, $SE = 1.27$). In Experiment 2, participants generally switched more often ($M = 38.71\%$, $SE = 1.73$) compared to Experiment 1 ($M = 23.39\%$, $SE = 1.78$). The interaction was not significant, $F(1, 101) = 0.21$, $p = .650$, $\eta_p^2 < 0.01$. Hence, there was no significant difference regarding the effect of Previous Transition on the VSR between experiments. The overall larger VSR in Experiment 2 compared to Experiment 1 may be driven by the used finger-mapping and random task locations. Participants may have been less biased to use certain hands or respond to certain locations in Experiment 2.

3.3. Discussion

The results of Experiment 2 closely replicated those of Experiment 1.

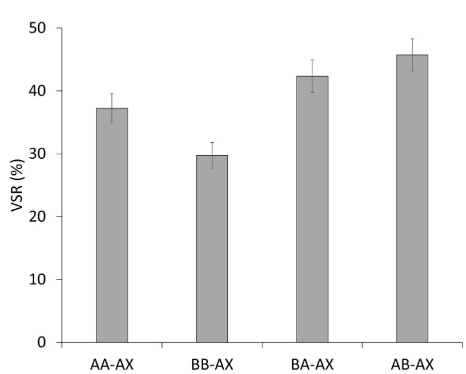

Fig. 8. VSR (in %) as a Function of Chunk Sequence (AA-AX, BB-AX, BA-AX, AB-AX) in Experiment 2. *Note.* Error bars represent ± one standard error of the mean.

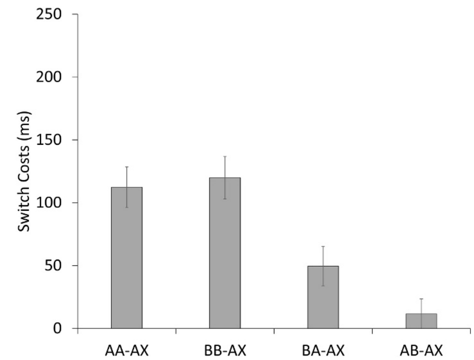

Fig. 9. Switch Costs (in ms) as a Function of Chunk Sequence (AA-AX, BB-AX, BA-AX, AB-AX) in Experiment 2. Note. Error bars represent ± one standard error of the mean.

Even when controlling for potential influences of location and response repetitions, behavior was modulated by the transition within the previous chunk. After a switch chunk, participants were again more inclined to switch voluntarily and showed reduced switch costs in RTs. Again, the pattern of the exploratory chunk sequence analyses can only be explained by switch readiness. The effects were similar in size to those of Experiment 1, suggesting that location and hand repetitions had negligible influence on the present results. Hence, the present results can be interpreted as evidence for sequential switch readiness during forced and voluntary task switching.

4. Experiment 3

So far, it is not clear what exactly constitutes sequential switch readiness. It could be task-specific in the sense that the switch readiness after a switch chunk is restricted to the specific tasks that were presented in the previous chunk. More precisely, this would mean that having switched between Task A and B in the previous chunk (irrespective of the direction of switching) would facilitate switching between these two tasks again. However, it is also possible that having switched between Task A and B in the previous chunk would increase the switch readiness between a different pair of Tasks C and D (see Fröber et al., 2021 for a related discussion). To investigate whether sequential switch readiness is specific to the recently executed task pair or transfers to a different pair of tasks, Experiment 3 included two task pairs, A-B and C-D. This means that between chunks, the task pair could either repeat or switch. In Experiment 3, we primarily focused on modulations of the switch costs by only using forced-choice tasks, whereas Experiment 4 primarily examined modulations of the VSR by increasing the frequency of voluntary choices.

4.1. Method

4.1.1. Participants

Experiment 3 was preregistered (https://aspredicted.org/v4ty-krdz.pdf). A power analysis according to Langenberg et al. (2023), using the effect size of the RT interaction in Experiment 1 (partial eta squared = 0.18), with a power of 0.80, resulted in a required sample of at least 38 participants. We again aimed for at least 50 participants. The initial sample consisted of 52 participants. Two participants had to be excluded (for exclusion criteria, see Data Preprocessing), resulting in a final sample of $N = 50$. The mean age was 26.12 years ($SD = 5.35$), ranging from 18 to 41 years. Thirty-seven participants were female (11 male, 1 diverse, 1 N/A) and 47 were right-handed (2 left-handed, 1 ambidextrous). All participants provided informed consent in accordance with the ethical standards of the national research committee and with the 1964 Helsinki Declaration and its later amendments. Psychology students received course credit for their participation.

4.1.2. Apparatus, procedure, and design

The procedure of Experiment 3 was very similar to that of Experiment 1. In addition to the first task pair consisting of the number and the letter task, we implemented a second task pair consisting of a shape and character task, adopted from Fröber and Dreisbach (2021). This allowed us to examine the transfer of flexibility across task pairs. In the shape task, participants had to categorize shapes (♠, ♣, ♥, ◆; ■, ⬤, ⬟, ▲) as playing card symbols or basic geometrical shapes. In the character task, participants had to categorize characters (ل,ج ,ي,گ; Σ, Φ, Ψ, Ω) as Arabic or Greek letters. Because Experiment 2 showed that location and hand repetitions did not influence the results, we again mapped the tasks to a response hand and a location on the screen. One task of each pair was mapped to the left hand (G and H Key; presented above the center of the screen) while the other task of each pair was mapped to the right hand (K and L Key; presented below the center of the screen). The Hand-to-Task assignment in each task pair was counterbalanced across participants.

Participants first practiced each task (16 tasks each). Next, participants were familiarized with the trial structure of the test phase, consisting of chunks with two consecutive tasks each. This practice entailed 16 chunks. Then, eight test blocks of 32 chunks each followed. We only used forced-choice tasks. In each block, every potential chunk (NN, LL, NL, LN, SS, CC, SC, CS; N=Number task, L = Letter task, S=Shape task, C=Character task) appeared four times in pseudorandomized order. Task-pair repetitions and switches occurred equally often. For each task-pair transition, the four potential transition sequences in two consecutive chunks (RR, RS, SS, SR; R = Repetition chunk, S=Switch chunk) occurred equally often. Task pairs were not allowed to repeat more than three times in a row. The structure of individual tasks in the practice and chunks in the test phase was the same as in Experiment 1. For mean RT (in ms) and error rates (in %) as dependent variables, we used a 2 (Task-Pair Transition: task-pair repetition, task-pair switch) x 2 (Previous Transition: repetition chunk, switch chunk) x 2 (Current Transition: repetition chunk, switch chunk) repeated measures design.

4.2. Results

4.2.1. Data preprocessing

The first chunk of each block was excluded from all analyses (3.13% of all chunks). For the RT analyses, we additionally excluded chunks with errors in the current (9.96%) or previous chunk (8.18%), and chunks with RTs in the first or the second task faster than 150 ms or slower than 3000 ms in the current (1.37%) or previous chunk (1.09%). One participant had to be excluded prior to the final analyses due to an extreme mean RT (2187 ms), and another participant due to an extreme error rate (39.06%) more than 3 interquartile ranges above the third quartile.

4.2.2. RT

The 2 (Task-Pair Transition) x 2 (Previous Transition) x 2 (Current Transition) repeated-measures ANOVA of the RT showed significant main effects of Task-Pair Transition, $F(1, 49) = 5.59$, $p = .022$, $\eta_p^2 = 0.10$, Previous Transition, $F(1, 49) = 4.98$, $p = .030$, $\eta_p^2 = 0.09$, and Current Transition, $F(1, 49) = 165.43$, $p < .001$, $\eta_p^2 = 0.77$. Responses were slower when the task pair switched between chunks ($M = 713$ ms, $SE = 15$) compared to task-pair repetitions ($M = 702$ ms, $SE = 14$), when the previous chunk involved a task switch ($M = 712$ ms, $SE = 15$) rather than a repetition ($M = 703$ ms, $SE = 14$), and especially when the task switched within the current chunk ($M = 776$ ms, $SE = 18$) compared to when the task repeated ($M = 639$ ms, $SE = 12$). Furthermore, there was a significant interaction between Previous Transition and Current Transition, $F(1, 49) = 14.95$, $p < .001$, $\eta_p^2 = 0.23$. Overall, the switch costs were lower after a switch chunk ($M = 116$ ms, $SE = 11$) than after a repetition chunk ($M = 157$ ms, $SE = 13$). No other interaction was significant (all Fs < 1.70, all ps $> .198$; see Fig. 10).

To gain a better understanding of the transfer of sequential switch readiness across task pairs, we conducted exploratory analyses investigating the interaction of Previous Transition and Current Transition for task-pair repetitions and task-pair switches, respectively. For task-pair repetitions, this interaction was significant, $F(1, 49) = 15.04$, $p < .001$, $\eta_p^2 = 0.24$, showing the same pattern as the main analysis with lower switch costs after a switch chunk ($M = 117$ ms, $SE = 13$) than after a repetition chunk ($M = 170$ ms, $SE = 16$). For task-pair switches, the interaction failed to reach significance, $F(1, 49) = 2.88$, $p = .096$, $\eta_p^2 = 0.056$. The descriptive pattern was the same as in the analysis of task-pair repetitions with lower switch costs after a switch chunk ($M = 116$ ms, $SE = 13$) than after a repetition chunk ($M = 144$ ms, $SE = 14$; see Fig. 10).

4.2.3. Error rate

The 2 (Task-Pair Transition) x 2 (Previous Transition) x 2 (Current Transition) repeated-measures ANOVA of the error rates revealed only a significant main effect of Current Transition, $F(1, 49) = 7.28$, $p = .010$, $\eta_p^2 = 0.13$. Participants made more errors on task switches ($M = 5.14\%$, $SE = 0.61$) than on repetitions ($M = 4.13\%$, $SE = 0.45$). No other main or interaction effect was significant (all Fs < 2.03, all ps $> .160$).

4.2.4. Exploratory chunk sequence analysis

For the exploratory chunk sequence analysis in Experiment 3, we only included task-pair repetitions because on task-pair switches the task always switched between chunks leaving no comparable AA-AX and

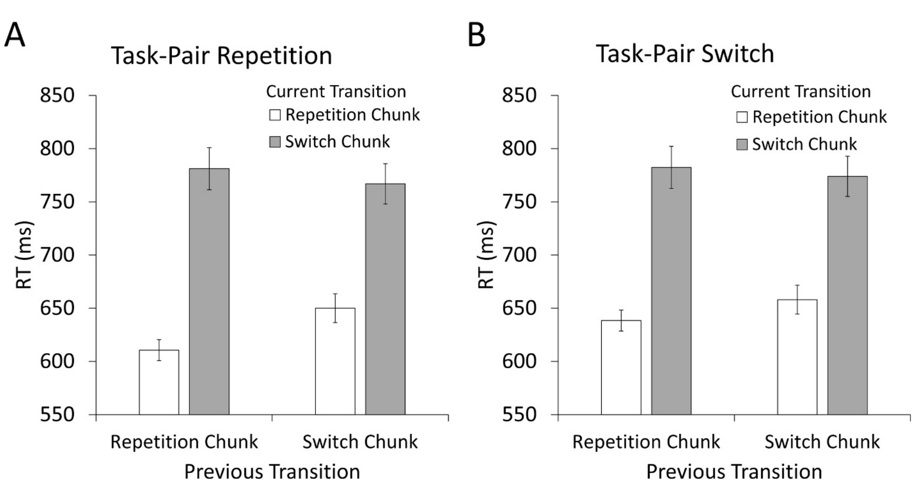

Fig. 10. RT (in ms) as a Function of Previous Transition (Repetition Chunk, Switch Chunk) and Current Transition (Repetition Chunk, Switch Chunk) for Task-Pair Repetitions (Panel A) and Task-Pair Switches (Panel B) in Experiment 3. *Note.* Error bars represent ± one standard error of the mean.

BA-AX sequences. The 4 (Chunk Sequence: AA-AX, BB-AX, BA-AX, AB-AX) x 2 (Current Transition: repetition chunk, switch chunk) repeated-measures ANOVA of the RT resulted in a significant main effect of Current Transition, $F(1, 49) = 132.49$, $p < .001$, $\eta_p^2 = 0.73$. The main effect of Chunk Sequence was not significant, $F(3, 147) = 1.72$, $p = .166$, $\eta_p^2 = 0.03$. There was a significant interaction of Chunk Sequence and Current Transition, $F(3, 147) = 7.97$, $p < .001$, $\eta_p^2 = 0.14$. Follow up analyses showed that the switch costs were highest in AA-AX and BB-BX and lowest for BA-AX and AB-AX. All pairwise comparisons were significant (all *ps* < .046) except for the difference between AA-AX and BB-AX ($p = .052$) and between BA-AX and AB-AX ($p = .362$; see Fig. 11). Again, this pattern is more in line with a switch-readiness account. A task-set activation account would have predicted the lowest switch costs in BB-AX. Again, the pattern of the BB-AX sequence was not driven by backward inhibition because the higher switch costs (compared to BA-AX and AB-AX) resulted from faster repetitions (all *ps* < .028).

4.3. Discussion

The results of Experiment 3 replicate the RT findings of Experiments 1 and 2. Participants showed reduced switch costs when the previous chunk involved a task switch. In the exploratory chunk sequence analysis, the pattern was again more in line with the switch-readiness than with the task-set activation account. The effect of sequential switch readiness on the switch costs was only significant when the task pair repeated. However, the descriptive pattern showed reduced switch costs after switch compared to repetition chunks, even when the task pair switched. Experiment 3 allows no clear conclusion as to whether switch readiness transfers between different pairs of tasks. To gain further insight, we conducted Experiment 4, this time focusing on the voluntary switch rate as the main dependent measure.

5. Experiment 4

Experiment 4 also focused on the transfer of sequential switch readiness between different task pairs. However, here we primarily aimed at modulations of the motivation to switch, the VSR. Therefore, the second task of every second chunk was now a free-choice task, and we again used the two different task pairs from Experiment 3.

5.1. Method

5.1.1. Participants

Experiment 4 was preregistered (https://aspredicted.org/mdhs-vrgt.pdf). A power analysis according to Langenberg et al. (2023), using the effect size of the RT interaction in Experiment 1 (partial eta squared = 0.18), with a power of 0.80, resulted in a required sample of at least 38 participants. We aimed for a minimum of 50 and collected 53

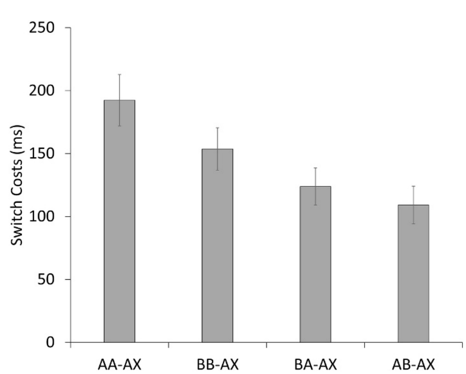

Fig. 11. Switch Costs (in ms) as a Function of Chunk Sequence (AA-AX, BB-AX, BA-AX, AB-AX) in Experiment 3. *Note.* Error bars represent ± one standard error of the mean.

participants. Eight participants had to be excluded (for exclusion criteria, see Data Preprocessing), resulting in a final sample of $N = 45$. The mean age of the final sample was 21.78 years ($SD = 2.72$), ranging from 18 to 28 years. Thirty-seven participants were female (7 male, 1 diverse) and 39 were right-handed (4 left-handed, 2 ambidextrous). All participants provided informed consent in accordance with the ethical standards of the national research committee and with the 1964 Helsinki Declaration and its later amendments. Psychology students received course credit for their participation.

5.1.2. Apparatus, procedure, and design

We used the same task pairs and stimuli as in Experiment 3. However, we applied the finger-to-task mapping of Experiment 2 with forced-choice tasks presented centrally and the stimuli in free-choice tasks *randomly* presented slightly above or below the center of the screen.

The procedure was similar to Experiment 3. After practicing each of the four tasks in separate blocks (16 tasks each), a free-choice practice (16 tasks) followed. Next, participants were familiarized with the trial structure of the test phase with two tasks per chunk and free choice in the second task of every second chunk. This practice entailed 8 chunks. The test phase consisted of four blocks with 64 chunks each. Each potential order of tasks and task pairs in two consecutive chunks (e.g., Letter-Number, Shape-Free Choice between Shape and Character) appeared equally often. The structure of individual tasks in the practice and chunks in the test phase was the same as in Experiment 1.

For the VSR (in %), we used a 2 (Task-Pair Transition: task-pair repetition, task-pair switch) x 2 (Previous Transition: repetition, switch) repeated measures design. For the mean RT (in ms) and error rate (in %) in forced-choice tasks, we used a 2 (Task-Pair Transition) x 2 (Previous Transition) x 2 (Current Transition: repetition, switch) repeated measures design. Note that the experiment was designed to maximize the number of design cells for the VSR analysis because the main dependent variable was the VSR. We still report the RT and error rate analyses. However, when analyzing RTs and error rates on forced-choice chunks (which always followed unpredictable free-choice chunks), the number of chunks per design cell can vary greatly, leading to less reliable data.

5.2. Results

5.2.1. Data preprocessing

We excluded the first chunk from all analyses (1.56% of all chunks). Additionally, for the RT and VSR analyses, we excluded chunks with errors in the current (22.09%) or previous chunk (11.58%), and chunks with RTs in the first or the second task faster than 150 ms or slower than 3000 ms in the current (2.23%) or previous chunk (1.84%). One participant had to be excluded prior to the final analyses due to an extreme mean RT (1920 ms), and seven participants due to an extreme error rate (ranging from 42.58% to 64.06%) more than 3 interquartile ranges above the third quartile.

5.2.2. VSR

The 2 (Task-Pair Transition) x 2 (Previous Transition) repeated-measures ANOVA of the VSR revealed significant main effects of Task-Pair Transition, $F(1, 44) = 12.71$, $p < .001$, $\eta_p^2 = 0.22$, and Previous Transition, $F(1, 44) = 23.45$, $p < .001$, $\eta_p^2 = 0.35$. Participants switched tasks more often when the task pair was repeated ($M = 29.96\%$, $SE = 1.66$) than when it was switched ($M = 26.42\%$, $SE = 1.76$), and after a switch chunk ($M = 30.92\%$, $SE = 1.80$) than after a repetition chunk ($M = 25.46\%$, $SE = 1.66$). The interaction between Task-Pair Transition and Previous Transition just failed to reach significance, $F(1, 44) = 3.98$, $p = .052$, $\eta_p^2 = 0.08$ (see Table 1 and Fig. 12).

To explore the transfer of sequential switch readiness across task pairs, we examined the effect of Previous Transition on the VSR separately for task-pair repetitions and task-pair switches. For task-pair

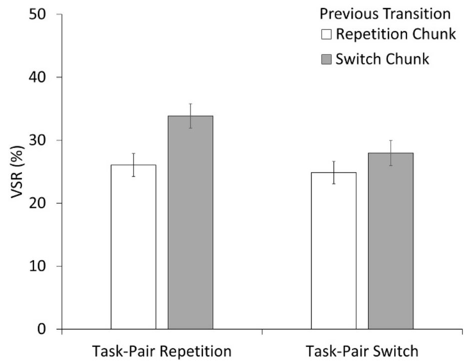

Fig. 12. VSR (in %) as a Function of Task-Pair Transition (Task-Pair Repetition, Task-Pair Switch) and Previous Transition (Repetition Chunk, Switch Chunk) in Experiment 4. *Note.* Error bars represent ± one standard error of the mean.

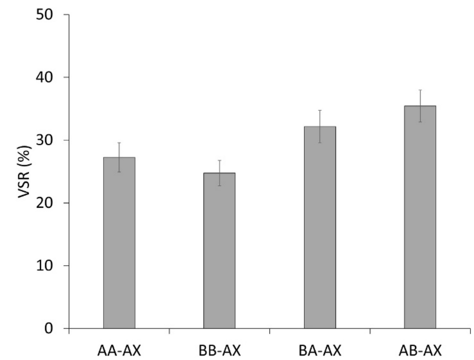

Fig. 13. VSR (in %) as a Function of Chunk Sequence (AA-AX, BB-AX, BA-AX, AB-AX) in Experiment 4. *Note.* Error bars represent ± one standard error of the mean.

repetitions, participants switched tasks significantly more often after a switch chunk than after a repetition chunk, $t(44) = 4.38$, $p < .001$, $d = 0.65$. For task-pair switches, participants also switched tasks significantly more often following a switch chunk than following a repetition chunk, $t(44) = 2.13$, $p = .039$, $d = 0.32$. Descriptively, the effect of Previous Transition was smaller for task-pair switches compared to task-pair repetitions (see Table 1 and Fig. 12).

5.2.3. RT

Due to missing design cells, two participants could not be included in the RT analysis. The 2 (Task-Pair Transition) x (Previous Transition) x 2 (Current Transition) repeated-measures ANOVA revealed significant main effects of Current Transition, $F(1, 42) = 92.68$, $p < .001$, $\eta_p^2 = 0.688$. Responses were slower when the task switched ($M = 874$ ms, $SE = 25$) compared to when the task repeated ($M = 720$ ms, $SE = 18$). No other main or interaction effect was significant (all $Fs < 1.32$, all $ps > .257$).

5.2.4. Error rate

Due to missing design cells, one participant could not be included in the error rate analysis. The 2 (Task-Pair Transition) x (Previous Transition) x 2 (Current Transition) repeated-measures ANOVA revealed significant main effects of Current Transition, $F(1, 43) = 5.07$, $p = .030$, $\eta_p^2 = 0.11$. Participants made more errors on task switches ($M = 8.94\%$, $SE = 1.14$) than on task repetitions ($M = 7.36\%$, $SE = 1.06$). No other main or interaction effect was significant (all $Fs < 3.99$, all $ps > .052$).

5.2.5. Exploratory chunk sequence analysis

For the chunk sequence analysis in Experiment 4, we also only included task-pair repetitions because on task-pair switches the task always switched between chunks leaving no comparable AA-AX and BA-AX sequences. The one-way repeated-measures ANOVA of the VSR resulted in a significant main effect of Chunk Sequence, $F(3,132) = 6.44$, $p < .001$, $\eta_p^2 = 0.13$. The highest VSR was evident for the AB-AX and BA-AX sequences, followed by AA-AX and BB-AX (see Fig. 13). All pairwise comparisons were significant (all $ps < .006$) except for the difference between AB-AX and BA-AX ($p = .286$), between AA-AX and BB-AX ($p = .299$), and between BA-AX and AA-AX ($p = .080$). This pattern is again more in line with a switch-readiness account because a task-set activation account would have predicted the highest VSR for BB-AX.

5.2.6. Duration of self-paced break in all experiments

In the following analyses, we explored the duration of the self-paced break between chunks.[6] After each chunk, participants had to press the spacebar to advance to the next chunk. This method was used to ensure that participants represented the tasks in chunks. Regarding the break, it would be interesting to investigate whether the Current Transition (repetition chunk, switch chunk) influenced the duration of the following self-paced break. One might, for example, expect shorter breaks after a switch chunk due to increased arousal. It is also plausible that participants take a longer break after experiencing an effortful switch chunk. Either way, differences in break duration may represent a confound for the present effects of the transition in the previous chunk. However, results of the break RT analyses showed no significant difference between the break duration after repetition and switch chunks in Experiments 1, 2, and 3 (see Table 2). Only in Experiment 4, the break duration was significantly longer after a switch chunk. Together, the four experiments showed no systematic pattern of break duration as a function of Current Transition. Therefore, the break duration cannot account for the present findings.

5.3. Discussion

The results of Experiment 4 showed that participants are more inclined to switch voluntarily following a switch chunk. The pattern of the chunk sequence analyses perfectly mirrored the predictions of the switch-readiness account. Critically, the effect was evident not only when the task pair repeated, replicating the VSR results of Experiments 1 and 2, but crucially also when the task pair switched. This finding suggests that, regarding the motivation to switch, sequential switch readiness can transfer from one task pair to a different task pair.

6. General discussion

The present study investigated whether switching tasks has an influence on switch readiness, in other words, whether people are better at switching and more inclined to switch after previously switching tasks. In four experiments, we found evidence supporting this idea. We presented two consecutive tasks per trial (chunk) with self-paced breaks between chunks to investigate the role of switching independent from

Table 2
Mean Duration of the Self-Paced Break Between Chunks as a Function of Current Transition (repetition chunk, switch chunk) and Respective t-Statistics per Experiment.

Experiment	Break Duration After Repetition Chunk	Break Duration After Switch Chunk	*t*-value	*df*	*p*-value	*d*
1	478 ms (24)	498 ms (32)	1.22	50	.229	0.17
2	510 ms (31)	487 ms (25)	1.33	52	.188	0.18
3	524 ms (109)	520 ms (102)	0.23	49	.819	0.03
4	447 ms (24)	522 ms (40)	3.20	44	.003	0.48

Note. SEs are presented in parentheses.

[6] We thank an anonymous reviewer for suggesting this analysis.

specific tasks (e.g., AB and BA were treated equally). Critically, participants switched tasks more often voluntarily and showed reduced switch costs when there was a task switch within the previous chunk. Notably, for VSRs, the effect even transferred to different task pairs (Experiment 4). The transfer on the level of switch costs failed to reach significance but showed the predicted descriptive pattern (Experiment 3). An additional explorative analysis per chunk sequence (AA-AX, BB-AX, BA-AX, AB-AX) provided evidence that the present results can be better explained by a switch-readiness account than by task-set activation (or backward inhibition) alone.

The present results uncovered a new property of cognitive control during task switching. The task transition in one chunk appears to influence processing of the following chunk. After a task switch, participants appear to be more flexible, in terms of reduced switch costs and increased VSR. Conversely, after a task repetition, participants appear to be more stable. There are two potential mechanisms by which this effect is produced. First, the present finding may represent passive inertia of the previously activated *control* set, similar to the lingering activation of *task* sets during task switching (Allport et al., 1994; Goschke, 2000). When a control set of switching is triggered through a task switch (or when a control set of repeating is triggered through a task repetition), the respective control set may persist and bias processing of the subsequent chunk. The fact that switch readiness seems to be independent of specific task activations and even transfers to new pairs of tasks suggests that the underlying mechanism is abstract in nature (for example, reduced between-task shielding after a switch chunk). Such a mechanism provides insights into task-general factors of cognitive flexibility and stability, as they are explored in dynamic systems models of task switching (cf. Musslick & Cohen, 2021). These models assume that task switching dynamics are determined by an energy landscape characterized by task attractors. The depth of these attractors acts as a task-general parameter which modulates cognitive flexibility. Our findings suggest that, unlike previously assumed (Musslick & Bizyaeva, 2024), adjustments in this attractor depth can happen on a smaller time scale and affect the entire task landscape (as evidenced by the transfer between task pairs). Alternatively, the present finding may represent a more active adaptation in response to the previous demand, similar to active task-set reconfiguration (De Jong, 2000; Rogers & Monsell, 1995). According to this reasoning, following a switch chunk, participants might actively prepare for a task switch after the first task of the then following chunk and likewise prepare for a task repetition following a repetition chunk. The present study is not suited to distinguish between these two possible mechanisms.

In a previous study by Brown et al. (2007), immediate task-set activation (Rogers & Monsell, 1995) and sequential switch readiness were perfectly confounded. Brown et al. investigated how the task transition in the previous trial influenced the switch costs in the current trial and found reduced switch costs following task switches. However, this effect can simply be explained by lingering effects of task-set activation. Repetitions after repetitions are faster due to the accumulated activation advantage of repeating the same task set multiple times. Faster switches after switches may simply reflect the advantage of switching back to the just-executed task set. To circumvent this issue, we used chunks of two tasks with self-paced breaks between chunks. The self-paced break reduces lingering effects of task-set activation between chunks. This was also confirmed by the exploratory comparison of the switch costs within and between chunks. The switch costs within chunks were larger than the switch costs between chunks (significant difference in all experiments except for Experiment 2; see Supplemental Material). Hence, the self-paced break successfully reduced the salience of the transition between chunks. Additionally, we varied the specific tasks within a chunk while keeping the transition constant (e.g., using BB instead of AA or using BA instead of AB). By using all potential task sequences equally often, the present study can distinguish between switch readiness and task-set activation. The results suggest that sequential switch readiness systematically modulates task switching. Additional analyses at the request of reviewers (see Supplemental Material) suggest that this effect was not the result of more careless responding following switch chunks or influenced by any systematic variations of the self-paced break duration as a function of the transition in the previous chunk.

The present results showed that sequential switch readiness during task switching even transferred to different task-set pairs. In Experiment 4, the VSR effect was still evident when the task pair switched, although somewhat reduced compared to task-pair repetitions. For the switch costs in Experiment 3, we observed the same descriptive pattern. This demonstrates that switch readiness exerts its influence on subsequent task processing, extending beyond specific task activation. This finding is particularly striking given the often-reported limitations of transfer during task switching. In fact, evidence for transfer effects of cognitive flexibility during task switching is sparse. For example, a context of frequent forced switching between tasks has been shown to increase flexibility in the form of reduced switch costs (Dreisbach & Haider, 2006; Monsell & Mizon, 2006; Schneider & Logan, 2006) and increased voluntary switching (Fröber et al., 2021; Fröber & Dreisbach, 2017) compared to a context of frequent task repetitions. However, this flexibility-enhancing effect appears to be limited to the frequency-inducing tasks and does not transfer to new tasks (Fröber et al., 2021; Siqi-Liu & Egner, 2020). That is, frequent switching between Task A and B did not increase the flexibility to switch between Task C and D. Thus, it is remarkable that the present sequential effect of switching generalized to different task pairs. The critical difference seems to be that, here, we looked into chunk-to-chunk adaptations, whereas the switch frequency effect described above is a list-wide effect. Moreover, we must acknowledge that the effect of control-set activation appeared to be reduced on task-pair switches compared to task-pair repetitions in Experiments 3 and 4. This suggests that specific task activation also contributes to the sequential effect.

The present findings align well with theoretical models of hierarchical control in multitasking contexts (Hirsch et al., 2025; Hirsch & Koch, 2024; Moss et al., 2023). The framework of hierarchical control conceptualizes task representations as multi-level control structures (Hirsch et al., 2025; Hirsch & Koch, 2024). According to this view, cognitive control operates across several hierarchical layers from concrete task-specific settings to more abstract representations. The current results suggest that switch readiness reflects such higher-level control adjustments. After a task switch, the activation of abstract switch readiness biases subsequent performance across different tasks consistent with the idea that higher-order representations can modulate lower-level task processing. Note, however, that beyond previous research on sequential adaptations in two-task chunks and sequence learning, the present results show that an abstract task structure transfers from one chunk to another without practice or foreknowledge and that not only performance but also task choice is affected.

Sequential adaptations can also be found in the field of conflict processing (Gratton et al., 1992; for reviews, see Braem et al., 2019; Duthoo et al., 2014; Egner, 2017). Typically, the congruency effect (difference between RT on incongruent and congruent trials) is reduced following incongruent trials. The potential mechanisms behind this so-called congruency sequence effect (CSE) are at the center of an ongoing theoretical debate. Firstly, the CSE may reflect bottom-up memory-driven effects. This account is based on the feature-integration theory (Hommel et al., 2004; Mayr et al., 2003; Schmidt, 2019) and states that complete repetitions or alternations of previous stimulus and response bindings facilitate responding. Secondly, the CSE may reflect control adjustments in response to conflict (Botvinick et al., 2001). Others try to combine both accounts by allowing event files to include more abstract control sets (Bugg & Crump, 2012; Egner, 2014, 2017). Applied to task switching, this would suggest that a task switch in one chunk creates a control set (like reduced between-task shielding) that is automatically retrieved in the next chunk, easing another task switch and hindering a task repetition. Note that effects of task activation might still contribute to switch costs, but in the paradigm used here, such effects should have cancelled each other out. In standard task-switching paradigms with one task per trial, effects of task-set activation and control-set activation may both contribute to sequential adjustments just like in conflict tasks (cf. Egner, 2023).

To conclude, the present results provide compelling evidence that task switching increases switch readiness independent from specific task activations. After a task switch within the previous chunk, participants showed reduced switch costs and an increased willingness to switch in the current chunk. Given that this effect appears to transfer even to a different task pair suggests that this sequentially induced switch readiness underlies an abstract mechanism (e.g., an unspecific decrease in task shielding). As such, the present findings highlight a novel property of sequential control during task switching.

CRediT authorship contribution statement

Jonathan Mendl: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Daniel Bratzke:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Gesine Dreisbach:** Writing – review & editing, Supervision, Resources, Conceptualization.

Declaration of competing interest

The authors declare that they have no competing financial or non-financial interests to disclose.

Data availability

The data is available via the following link: http://doi.org/10.5283/epub.78517.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2026.106458.

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