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Keep flexible – Keep switching! The influence of forced task switching on voluntary task switching

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ABSTRACT

Goal directed behavior depends on a dynamic balance between cognitive flexibility and stability. Identifying factors that modulate the balance between these control states is therefore of major interest for the understanding of human action control. In two experiments we used a hybrid paradigm combining forced- and free-choice task switching and measured spontaneous voluntary switch rate (VSR) as an indicator of cognitive flexibility. In Experiment 1 participants were free to choose a given task on 75%, 50%, or 25% of all trials. In the remaining forced-choice trials task repetitions and switches were roughly equally distributed. Results showed that VSR increases with increasing proportion of forced choices. To clarify whether the frequency of forced choices per se or the frequency of forced task switches in particular drives this effect we conducted Experiment 2. In a fully orthogonal between design participants were free to choose a given task on 75% or 25% of all trials with a predetermined switch rate in the remaining forced-choice trials of 75% or 25%, respectively. Results revealed an interaction of both manipulations: The highest VSR was found for the combination of 75% forced-choice trials with 75% forced switch rate, while VSR for 75% forced-choice trials with 25% forced switch rate was still higher than VSRs in both conditions with 25% forced-choice trials. This suggests that a context of frequent forced task switching changes global control parameters towards more flexible behavior.

1. Introduction

Cognitive control enables goal-oriented action, but it is challenged with two complementary adaptive functions (Dreisbach & Goschke, 2004; Goschke, 2003, 2013; Miller & Cohen, 2001): on the one hand, current goals have to be maintained and shielded against distraction, and, on the other hand, goals need to be updated and shifted, whenever a significant change in the environment occurs. Critically, both have benefits and costs: Flexibility enables adaptation to changing contexts but goes along with distractibility and – in the extreme – with dysfunctional pathological behavior. High stability supports goal maintenance and reduces distraction but might result in overly rigid and repetitive behavior. For a better understanding of human action control it is therefore mandatory to investigate how this flexibility-stability balance is controlled itself (see Hommel, 2015). Here we will show that a mere context of frequent forced task switches shifts the flexibility-stability balance towards higher flexibility.

The task switching paradigm can be seen as a prime example of the flexibility-stability dilemma (Grange & Houghton, 2014; Kiesel et al., 2010; Vandierendonck, Liefooghe, & Verbruggen, 2010). In this paradigm, participants have to switch between simple task rules. The typical finding is worse performance when the task rule switches as compared to task repetitions. Recent evidence suggests that task rules (as they are typically used in the task switching paradigm) help shielding against distraction (Dreisbach, 2012) but that this shielding is relaxed in the course of task switching (Dreisbach & Wenke, 2011; Reisenauer & Dreisbach, 2014). That is, task repetitions go along with a more stable and task switches with a more flexible control mode. From there, one might conclude that task switching itself shifts the balance towards more flexibility. Support for this claim comes from one study showing that switch costs were significantly lower and virtually absent within a block of frequent (i.e., 75%) task switches than in a block of frequent (i.e., 75%) task repetitions (Dreisbach & Haider, 2006). However, in that study, the results were mainly driven by RTs on task repetitions which were significantly slowed in blocks of frequent switches, calling the idea of increased flexibility under frequent task switches into question (see also Mayr, 2006; Mayr, Kuhns, & Rieter, 2013; Monsell & Mizon, 2006; Schneider, 2016; Schneider

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& Logan, 2006). Here, we will therefore use a more direct measure of cognitive flexibility, namely the voluntary switch rate (VSR) in a voluntary task switching paradigm (VTS; Arrington & Logan, 2004; for a recent review see Arrington, Reiman, & Weaver, 2014). More precisely, we used a hybrid paradigm, combining standard task switching (forced choices) with interspersed VTS trials (free choices). A recent study from our lab, using this paradigm with 80% forced choices and 20% free choices to study cognitive flexibility under changing reward prospects, had shown that participants deliberately switch more often when reward prospect increases than when reward prospect remains high (Fröber & Dreisbach, 2016). More precisely, in that study, participants received cues that either announced a high or a low reward before every trial. This made it possible to take the immediate reward history from one trial to the next into account (i.e., remain low, increase, remain high, decrease). In a series of five experiments, we could show that the voluntary switch rate was modulated by reward prospect: The lowest VSR was found in the remain high condition, highest VSR was found in the increase and decrease condition whereas an intermediate VSR showed in the remain low condition. Another interesting, and especially relevant observation for the present study was the overall rather high mean VSR although task switching in free-choice trials in that study was truly optional.[1] That is, unlike in typical VTS studies that use global instructions to prevent a strong repetition bias ("perform each task about equally often and in random order", first established by Arrington and Logan (2004)) participants in our previous study received no such instructions and were really free to choose whichever task they preferred. Usually, unrestricted VTS results in an increased repetition bias and, conversely, a rather small VSR (Arrington et al., 2014; Kessler et al., 2009; Liefooghe, Demanet, & Vandierendonck, 2010). So, the observation that participants deliberately switch more often in a context of frequent forced task switches might be taken as a further hint that switching itself increases flexibility. Here we will now directly investigate how the ratio of free to forced choice trials will alter the VSR. Specifically, we predict increasing VSR with increasing forced choices.

To this end, we used again a combination of free and forced choices with varying ratios of 25:75, 50:50, or 75:25 between subjects. Note that forced-choice trials contained approximately 50% task switches and task repetitions, each. This was done to prevent a selective training of task switching in a given group. That way, the expected increase of VSR with increasing forced choices could not be ascribed to selective training of task switches because – within a given group – task switches and task repetitions will receive the same amount of training. Moreover, in case that task switches would profit more from training than task repetitions, we will also analyze the first practice block. If practice has a selective effect on task switches, participants in the 75% forced-choice condition would show an increase in VSR from practice to the experimental block, whereas participants in the 25% forced-choice condition would not show such an increase.

2. Experiment 1

2.1. Method

2.1.1. Participants

Sample size was determined a priori for detection of a medium sized between-groups effect with a power level of 80% and a significance level of 5% using G*Power 3.1. 122 undergraduate students of Regensburg University were randomly assigned to one of three groups with either 75% (n = 42), 50% (n = 40), or 25% forced-choice trials (n = 40). 118 participants (*M*age = 22.78 years, *SD* = 4.37, 98 female) were included in the final data analysis (see Results for exclusion criteria). All participants signed informed consent and were debriefed after the session.

2.1.2. Apparatus and stimuli

Participants switched between a number and a letter task. Numbers (125, 132, 139, 146, 160, 167, 174, 181)[2] and letters (B, D, F, H, S, U, W, Y) were presented in black on a gray background above or below a fixation cross on a 19-in. TFT-monitor (1440 × 900 pixels) in 28-point Arial font. In forced-choice trials one stimulus appeared on screen, while in free-choice trials a number and a letter appeared simultaneously. The mapping of number or letter task to the upper or lower position was kept constant throughout the experiment, but was counterbalanced across subjects. Stimuli above fixation were always answered with the left hand ("Y" and "X" key on a QUERTZ-keyboard) and stimuli below fixation with the right hand ("N" and "M" key). Stimulus presentation and data recording was controlled with E-Prime 2.0.

2.1.3. Procedure

Each trial started with a fixation-display (500 ms), followed by the target-display until response. Participants categorized numbers as smaller or larger than 153, and letters as nearer to A or nearer to Z with a left or right button press, respectively. This spatial response mapping was kept constant across participants to avoid increased variance due to the spatial-numeric association of response codes (Dehaene, Bossini, & Giraux, 1993). The German words *Richtig!* ("correct!") or *Fehler*! ("error!") were presented as feedback (1500 ms). The trial ended with a fixation-cross with a variable intertrial interval between 150–250 ms after a correct response and 900–1200 ms after an error (see Fig. 1).

The experiment started with two single task blocks (16 trials each) and a short forced-choice only task switching practice block (16 trials). This was followed by one longer practice block (128 trials) and the experimental block (256 trials). In these two blocks the ratio of free- to forced-choice trials was set to 25:75, 50:50, or 75:25, respectively. Trials were presented in a pseudorandomized order excluding direct stimulus repetitions. Furthermore, no direct repetitions of rare trial conditions (free-choice trials in the 75% forced-choice condition, forced-choice trials in the 25% forced-choice condition) were allowed. The proportion of task repetitions and switches in forced-choice trials was roughly equally distributed. Critically, participants received unrestricted task instructions: Participants were informed that on free-choice trials, they were truly free which task they wanted to choose. Note that in typical VTS studies with 100% free choices, participants are told to try to select each task equally often and randomly in order to prevent a strong repetition bias (see Arrington & Logan, 2004; Kessler et al., 2009).

2.1.4. Design

A 3 (Forced-choice ratio: 75%, 50%, 25%) x 2 (Block: practice, experimental) mixed factors design was used. Forced-choice ratio was manipulated between, Block varied within participants. Spontaneous VSR in free-choice trials served as main dependent variable (see supplemental materials for reaction times (RTs) and error rates).

[1] Mean VSRs in the 20% unrestricted free-choice trials in Experiments 1 to 4 from Fröber and Dreisbach (2016) ranged from 33.6% to 39.8%, while mean VSRs in Experiments 1 and 2 (100% unrestricted free-choice trials) from Kessler, Shencar, and Meiran (2009) ranged from 4% to 13.2%.

[2] In Fröber and Dreisbach (2016) we used numbers from 1 to 9 without 5 for the number task. Participants rated this task as easier than the letter task, which is why we decided to use a more difficult number task here.