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Effects of absolute and relative practice on $n - 2$ repetition costs

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ABSTRACT

Recently, Grange and Juvina (2015) found decreasing $n - 2$ repetition costs with increasing practice. However, in their experiment, no differentiation between absolute and relative strength of the three tasks was possible because all tasks were practiced to the same degree. To further elucidate this issue, two experiments were designed in which for one of the three tasks, aspects of the task set changed during the course of the experiment (Exp. I: Stimulus–response mapping, Exp. II: Cue–task mapping). Replicating Grange and Juvina (2015), decreasing $n - 2$ repetition costs with increasing practice were observed, but the change of stimulus–response mappings in Exp. I did not affect $n - 2$ repetition costs. In Exp. II, $n - 2$ repetition costs were affected by the change of the cue–task-mapping, but no effect of absolute practice was visible. These results suggest that absolute practice influences $n - 2$ repetition costs as long as no change in relative strength is introduced on the level of mapping cues to tasks. If, however, relative task strength is varied, its impact overrides the influence of absolute practice. In addition, the data pattern points towards cue-related instead of response-related inhibitory processes causing $n - 2$ repetition costs.

1. Introduction

In everyday life, humans are confronted with the need to continuously adapt their behavior in accordance with changes in the environment. To investigate this flexible control of behavior experimentally, the task switching paradigm is a widely used tool: Participants have to switch between two or more simple classification tasks. As a result, reaction times (RT) and error rates (ER) are higher when the task switches compared to repetition trials, an effect termed switch cost or shift cost (see Kiesel et al., 2010; Vandierendonck, Liefooghe, & Verbruggen, 2010, for reviews). Two types of cognitive control processes are commonly assumed to be involved in task switching, namely the activation of the currently relevant task on the one hand and the inhibition of competing information on the other hand.

In task switching research, $n - 2$ repetition costs (also labeled backward inhibition effect, Mayr & Keele, 2000) are one of the most straightforward indications for an involvement of inhibitory processes. $N - 2$ repetition costs are indicated by the observation that, when switching among three tasks A, B, and C, reaction times (and sometimes also error rates) are higher for task sequences ABA compared to sequences of type CBA. That is, switching back to a recently abandoned task is accompanied by costs that are taken as evidence for the need to overcome inhibition attached to that task (cf. Koch, Gade, Schuch, & Philipp, 2010, for a review). However, although there are many studies showing the occurrence of $n - 2$ repetition costs in different experimental settings, many aspects of this effect still remain unclear.

Recently, Grange and Juvina (2015) showed that $n - 2$ repetition costs decline with increasing practice. This effect was explained by the automization of cue–task translation processes. Referring to Logan (1988), cue–task[1] translation processes are slow at the beginning of the experiment, because the cue indicating the identity of the upcoming task was formerly unrelated to the task (at least when using nontransparent cues). With increasing practice, cue–task associations accumulate in long term memory, causing a more automatic and, therefore, faster retrieval. On a complementary level, Grange and Juvina explained their results by a computational model of inhibition implemented in ACT-R (Grange, Juvina, and Houghton, 2013). For task performance, the successful retrieval of chunks of information from memory is needed, with the speed of retrieval being positively related to the activation level of the chunk. The extent of activation depends on the current context and on base-level learning, which represents the amount of practice with that chunk. Additionally, an inhibition parameter is implemented that is subtracted from base-level learning. As practice increases, base-level learning gets stronger until it outweighs inhibition, which then results in decreasing $n - 2$ repetition costs. To fully account for the data pattern, Grange and Juvina extended this model, including the assumption of increasing cue–task association strength and decreasing activation noise with practice.

However, based on the experimental design of Grange and Juvina (2015) it is not possible to distinguish whether practice in absolute terms or the relative strength of the tasks (i.e., the activation of one

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[1] Grange and Juvina (2015) use the term cue-target translation in this respect. However, for reasons of conceptual clarity, and to be consistent with the manipulation employed in Exp. II, the term cue–task translation will be used here.

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task in relation to the activation of the other tasks) governed the reduction in $n-2$ repetition costs with time, because all tasks were practiced to the same degree. That relative task strength can indeed have an influence on $n-2$ repetition costs was shown by Scheil and Kleinsorge (2014). In their study, preparation time was varied in a trialwise fashion to investigate the influence of preparation time of trials $n-2$, $n-1$, and n on $n-2$ repetition costs. $N-2$ repetition costs were highest when preparation time in both trial $n-2$ and $n-1$ was long. It was argued that a high amount of activation of the tasks to be inhibited (due to sufficient preparation in trial $n-2$) as well as a high amount of activation of the alternative task (due to sufficient preparation time in trial $n-1$) causes high $n-2$ repetition costs, because the necessity of inhibition as well as the possibility for it are high.

To further elucidate this issue, a task switching experiment with three tasks was designed in which one of the tasks was slightly changed after half of the blocks to decrease the relative strength of this particular task. Because the theoretical frameworks Grange and Juvina used to explain the practice effect on $n-2$ repetition costs involved cue-related processes as a main aspect, it seems straightforward to aim at cue-related task components to vary the relative task strength. However, cue-related processes as the locus of inhibition cannot be taken for granted as there are also findings suggesting different targets. For example, some authors argue that inhibitory processes causing $n-2$ repetition costs are response-related (e.g., Schuch & Koch, 2003). Furthermore, inhibition might be attached in a flexible way to the aspect of the task set causing greatest inter-trial conflict (Houghton, Pritchard, & Grange, 2009). Therefore, two experiments were conducted. In one experiment, one of the stimulus–response mappings was reversed whereas in the second, the cue of one task was changed. Consequently, the aims of the present study were twofold. First, a differentiation between effects of absolute practice and relative strength of the tasks on $n-2$ repetition costs was intended. Second, with varying different aspects of the tasks, response-related or cue-related, further insight into the target of inhibitory processes in task switching should be gained. If absolute practice guides the reduction of $n-2$ repetition costs, they should become smaller during the course of the experiment without being influenced by changing one of the tasks. If relative task strength induces the reduction, the change of one of the tasks should affect $n-2$ repetition costs. In this respect, an effect of the task change in the first experiment would point towards a response-related locus of inhibitory processes, whereas an effect in the second experiment would be indicative for cue-related processes being the target of inhibition. If changing one task influences $n-2$ repetition costs in both experiments, a flexible target, like the aspect causing greatest inter-trial conflict, would be a possible explanation.

2. Experiment I

2.1. Method

2.1.1. Participants

24 subjects (6 male) with normal or corrected-to-normal vision participated. Their mean age was 22.56 years (range: 18–30). Participants were assigned alternately to one of the three groups according the order of their appearance.

2.1.2. Stimuli, tasks, and apparatus

Stimuli consisted of two different shapes (x and +) presented in yellow or blue and with a size of either 3 cm × 3 cm or 6 cm × 6 cm. Task cues consisted of a dark gray diamond, square, or triangle surrounding the position of the imperative stimulus with a size of about 7 cm × 7 cm. Participants switched among three perceptual decision tasks in which they had to judge the stimuli regarding their size (big vs. small, indicated by the diamond), color (yellow or blue, indicated by the square), or their shape (x or +, indicated by the triangle). All tasks occurred with equal frequency. Stimuli were presented centrally on a light-gray background. Viewing distance was not controlled but approximated 60 cm. Initially, participants pressed the ‘y’-key of a German QWERTZ keyboard for small, blue, and x-shaped stimuli and the ‘-’-key for big, yellow, and +-shaped stimuli.

2.1.3. Design and procedure

After giving informed consent, participants were provided with on-screen instructions in which the tasks and the meaning of the task cues were explained. Instructions emphasized speed as well as accuracy. The experiment was run in a single session that took about 60 min. It consisted of 12 blocks of 120 trials each. Task repetitions were not allowed. After six blocks, participants were informed that for one task, the response mappings would be reversed, while for the other tasks, the mappings will remain the same. A different task was changed in each group.

Each trial began with the presentation of a fixation mark for 300 ms, followed by the task cue which was presented for 600 ms. After that, the cue disappeared and the imperative stimulus was presented for 2500 ms or until the participant's response. In case of an error, error feedback was presented for additional 1000 ms; in case of RTs slower than the RT deadline of 2500 ms, RT feedback was presented for additional 1000 ms.

2.2. Results

The first two blocks were considered as practice and excluded from analyses, as were the first three trials of each block. In addition, trials with RTs exceeding 2500 ms were omitted (1.1%), as were trial triplets involving an error in trial $n-1$ or $n-2$ (11.8%). From RT analyses, error trials were also excluded (5.0%). Mean RT and ER data were analyzed as a function of the within-participants factors Phase (first: blocks 3–6, second: blocks 7–9, third: blocks 10–12), Change (task with vs. without a change of the stimulus–response mapping), and Task Sequence (ABA vs. CBA).

For RT data, significant $n-2$ repetition costs of 31 ms occurred, $F(1, 23) = 17.88$, $p < .001$, $\eta_p^2 = .44$. Besides, there was a main effect of Phase, $F(2, 46) = 9.71$, $p < .001$, $\eta_p^2 = .30$. Mean RTs amounted to 824 ms in the first, 786 ms in the second, and 746 ms in the third phase, reflecting a general practice effect. Importantly, the interaction of both factors reached statistical significance, $F(2, 46) = 5.06$, $p < .05$, $\eta_p^2 = .18$. $N-2$ repetition costs significantly diminished over time, amounting to significant ($p < .001$, Bonferroni-corrected) 52 ms in the first, still

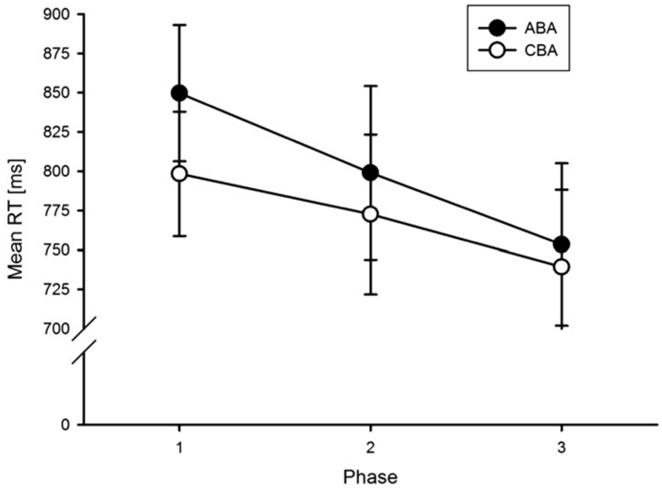

Fig. 1. Experiment I: Mean RT [ms] as a function of Phase and Task Sequence. Error bars represent SEM.