



Response-repetition effects in task switching—Dissociating effects of anatomical and spatial response discriminability[☆]

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ABSTRACT

In task switching, response repetitions typically lead to performance benefits for task repetitions but costs for task switches. We examined whether this cost–benefit pattern is affected by response discriminability (RD), varying (a) the anatomical response separation (within-hand vs. between-hand responses) and (b) the spatial separation (close vs. far response keys). We assumed that anatomical RD increases response competition generally, whereas spatial RD increases the salience of left–right coding and thus facilitates response selection. In two experiments, we found that spatial RD increased the response-repetition costs in task switches but similarly decreased the response-repetition benefit in task repetitions. The effect of spatial RD was response-specific but did not interact with task switching. This data pattern is consistent with a recent account that proposed that facilitated response selection increases response “self-inhibition” after response execution. In contrast, the influence of anatomical RD primarily consisted of an overall increase of reaction-time level in all conditions, whereas error rates decreased, suggesting a general shift in response criterion. Taken together, the data suggest that a self-inhibition mechanism on the level of motor response codes contributes to response-repetition effects in task switching, which is possibly independent of task-specific mechanisms of strengthening of associations.

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The cognitive mechanisms underlying flexible action control can be examined using the task-switching paradigm (see, e.g., Kiesel et al., 2010; Koch, Gade, Schuch, & Philipp, 2010; Monsell, 2003; Vandierendonck, Liefoghe, & Verbruggen, 2010, for reviews). A common version of this paradigm is the cuing paradigm, in which each task is indicated by an explicit cue prior to presentation of the target stimulus. In typical studies, bivalent stimuli (e.g., “7”) are mapped to the same set of response keys, so that, for example, the left key may indicate “larger than 5” (vs. smaller than 5) in the context of a magnitude task but “odd” (vs. even) in the context of a parity task (e.g., Koch, 2003). Accordingly, the responses are also bivalent; that is, they change their “meaning” as a function of the current task (Meiran, 2000; Schuch & Koch, 2003, 2004, 2010). Findings concerning response-repetition effects suggest a task-specific component of response coding in task switching. There typically are response-repetition benefits when the task also repeats but response-repetition costs when the task switches (e.g., Kleinsorge & Heuer, 1999; Rogers & Monsell, 1995). This interaction of response repetition

and task switching represents a highly robust empirical finding (see Kiesel et al., 2010, for a review).

To account for this cost–benefit pattern of response repetition in task switching, it has been suggested that task performance strengthens task-specific associations between responses and stimulus categories, which persist to produce positive priming in task repetitions but negative priming in task switches (Meiran, 2000; Schuch & Koch, 2004). However, according to a more recent account proposed by Hübner and colleagues, response-repetition effects in task switching are mainly due to motor response inhibition (Druey & Hübner, 2008; Hübner & Druey, 2006; Steinhauser, Hübner, & Druey, 2009). Specifically, these authors assume that in task switching the response code referring to the just executed response is inhibited to prevent accidental re-execution of the same response in the subsequent trial. In task switches, this kind of “self-inhibition” of response codes could explain the typically observed response-repetition costs. To explain the response-repetition benefit in task repetitions, the authors assume that the negative after-effect of response-specific self-inhibition is outweighed by the benefit of repeating the stimulus category (or even the stimulus itself), which should produce a strong positive priming effect.

Note that the task-specific “associative strengthening” account refers to the association between categories and responses, whereas the response-specific “self-inhibition” account refers to independent priming mechanisms on the level of the category code and the response

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code that jointly produce the characteristic cost–benefit pattern of response repetition in task switching. The present study aimed to further examine the mechanisms underlying response-repetition effects in task switching by exploring the influence of response discriminability (RD).

RD has been examined for example by Kornblum (1965), who manipulated anatomical RD by having subjects respond either with index and middle finger of one hand (within-hand separation of responses; low RD) or with the index fingers of both hands (between-hand separation; high RD). Reaction times (RTs) were longer (by about 25 ms) with within-hand separation compared to between-hand separation of responses. Moreover, Shulman and McConkie (1973) additionally manipulated stimulus–response (S–R) compatibility, which is a classic variable assumed to influence response selection (e.g., Proctor & Vu, 2006; Sanders, 1998), in different groups of subjects. They observed that the influence of anatomical RD was almost perfectly additive with the influence of S–R compatibility, suggesting that these two variables do not influence the same processing stage (e.g., Sternberg, 1969). To account for the effect of anatomical RD, Kornblum (1965) assumed that within-hand responses are characterized by a stronger degree of motoric co-activation of response codes (“response competition”, see also Reeve & Proctor, 1988), influencing “the relationship between motor codes” (Shulman & McConkie, 1973, p. 378). However, the existing evidence is based on single-task studies, and these studies did not examine whether anatomical RD interacts with response repetition. Because the data of Shulman and McConkie (1973) suggest that anatomical RD is not a variable that affects response selection, it can be assumed that high anatomical RD would lead to generally improved performance also in task switching, but it is yet to be explored whether it would specifically modulate the cost-benefit pattern of response repetition, which is often taken as another classic variable affecting the response-selection stage (Sanders, 1998).

Note, though, that anatomical RD arguably affects the ease in selecting the specific finger with which to respond (see Proctor & Vu, 2006), whereas response-repetition effects in task switching may be due to a more “cognitive” level of response coding. To test this idea, in the present study we also introduced a second, more cognitive manipulation of “response salience” that should also affect RD. To this end, we varied the spatial separation of the response (i.e., spatial RD) by comparing performance in the standard “close between-hand” condition with that in a between-hand condition in which the response keys were far apart.

Vu and Proctor (2002) found effects of “right-left prevalence” on spatial coding in the context of spatial response-selection tasks (Rubichi, Vu, Nicoletti, & Proctor, 2006, for review). These prevalence effects were more pronounced with high spatial RD, leading Vu and Proctor to conclude that high spatial RD increases the salience of response coding on the horizontal dimension. Based on this finding, we assumed that spatial RD facilitates response selection.

In the context of task switching, Druey and Hübner (2008) observed that a manipulation that facilitates response selection increases the response-repetition costs. Specifically, they found that the response-repetition costs were higher when the stimulus on the previous trial was “congruent” (i.e., called for the same response in both tasks) than when it was incongruent. According to Druey and Hübner (2008), this effect suggests that with facilitated response selection, the risk of erroneous response re-execution is increased, which is adaptively counteracted by “self-inhibition” of responses. Based on this suggestion, we assumed that high spatial RD, which should facilitate response selection, should also lead to increased response inhibition, so that we expected to find larger response-repetition costs in task switches and, conversely, a similarly reduced response-repetition benefit in task repetitions relative to a condition with low spatial RD.

In summary, the present study aimed to examine the influence of anatomical and spatial RD on response-repetition effects to investigate

whether these two types of RD would produce dissociable effects in task switching. Previous studies on RD did not compare effects of anatomical and spatial RD; moreover, previous studies did not investigate the effects of RD in task switching. In Experiment 1, we tested the influence of the two kinds of RD (anatomical and spatial) in task switching. In Experiment 2, we examined whether the observed effects of RD are specific to task switching or whether they also occur under single-task conditions.

1. Experiment 1

1.1. Method

1.1.1. Participants

Twenty-four participants (19 female, mean age = 23.3 years, and range 20–27 years) took part and received partial course credit or 5 Euro.

1.1.2. Stimuli and tasks

Stimuli were the digits 1–9, excluding 5. Their height was approximately 1.0 cm. Viewing distance was approximately 50 cm. Stimulus presentation and response registration were synchronized with the vertical refresh rate of the screen. Stimuli were centrally presented inside a square or diamond frame measuring 3.5×3.5 cm on a computer screen (15 in.). The shape of the frame served as the task cue. The tasks were to decide whether the digit was odd or even, or whether it was smaller or greater than 5. Stimulus order was random with the constraints that immediate repetition was not allowed, and repetition of the stimulus that occurred with the last episode of the same task was not allowed.

Responses were made on a German computer keyboard (QWERTZ). In the within-hand RD condition, the adjacent *h* and *j* keys had to be pressed with the index and middle finger of the dominant hand. In the close between-hand condition, the same *h* and *j* keys had to be pressed with the index fingers of both hands. In the far between-hand condition, the *a* and *#* keys (separated by 10 keys and 21 cm from center to center) had to be pressed with the index fingers of both hands (on a German keyboard, the *a* and *#* keys are equidistant from the *h* and *j* keys, respectively). The *h* and *j* keys were marked with green stickers, and the *a* and *#* keys with red stickers.

1.1.3. Procedure

Participants were informed that stimuli would be individually presented and that responses should be fast but accurate. They were then given a diagram of the S–R mappings for each task, placed below the screen. The S–R mappings were counterbalanced across participants. An error message appeared for 500 ms on the bottom part of the screen if they pressed the wrong key.

In each RD condition, the cue–stimulus interval was 200 ms, and the cue and digit stimulus remained on the screen until a response key was pressed. The response–cue interval was 1400 ms. Each block consisted of 120 trials, preceded by eight practice trials. The same RD condition was always used in two subsequent blocks, and the six possible different orders of the three RD conditions were fully counterbalanced across subjects. The experiment took about 40 min.

1.1.4. Design

The independent within-subjects variables were RD (within-hand, close between-hands, and far between-hands), task transition (switch vs. repeat), and response transition (switch vs. repeat). The influence of RD was examined in two non-orthogonal contrasts. Anatomical RD was examined by contrasting within-hand vs. close between-hand conditions, whereas spatial RD was examined by contrasting close between-hand vs. far between-hand conditions. The dependent variables were RT and error rate. Significance was tested at $\alpha = 0.05$.

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