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Response-repetition costs in choice-RT tasks: Biased expectancies or response inhibition?

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ABSTRACT

Repetition effects are often viewed as informative regarding the cognitive mechanisms of action control. One particular finding, namely costs for repeating the same response in subsequent trials, especially challenges theorizing. Costs for response repetitions have recently been reported in task-switch studies on task-switch trials (whereas benefits usually arise in task-repetition trials), but also in some choice-RT task studies. In three experiments, two of the most successful accounts for the response-repetition costs in choice-RT task studies and task switching were tested: an expectancy-based explanation, and an inhibition-based account. Using a choice-RT task introduced by Smith (1968) and manipulating the response–stimulus interval (RSI) and the categorizability of the stimuli, some specific predictions of the two accounts were tested. The results clearly revealed that expectancy-based explanations fail to account for the observed patterns of effects, whereas they are well in line with the predictions from the inhibition-based account. Finally, the results are further discussed with respect to alternative accounts from the field of task switching.

1. Introduction

Beginning with the now classic series of experiments by Bertelson (1963, 1965), sequential effects have been viewed as informative regarding the cognitive analysis of choice-RT task performance. Whereas most of the studies so far deal with concurrent stimulus + response repetition effects, already Bertelson (1965) broadened the focus by applying the so-called Information Reduction Procedure (IRP), in which several stimuli are mapped to one response and, consequently, allow the observation of pure response-repetition effects. Recently, response-repetition effects also received considerable attention in the context of task-switch studies, where it was found that repeating the same response results in benefits when at the same time the task repeats, and in costs when at the same time the task switches (e.g., Rogers & Monsell, 1995; see Altmann, 2011, for an overview).

In the following I will first review previous evidence regarding the effects of (pure) response repetitions in choice-RT tasks and task switching. After this short introduction, the two accounts that most successfully explained the respective results from the two fields will shortly be depicted: An expectancy-based account from the field of choice-RT tasks and an inhibition-based account from task switching. Finally, the rationale for the current study will be outlined.

1.1. Response repetition effects in choice-RT tasks

In the context of the choice-RT task studies, the effects of pure response repetitions (i.e. of response repetitions not occurring concurrently with a repetition of the relevant target stimulus) have been addressed in several studies. The results revealed a rather inconsistent picture: Whereas in most studies pure response repetitions produced considerable benefits (e.g., Bertelson, 1965; Eichelman, 1970; Notebaert & Soetens, 2003; Smith, Chase, & Smith, 1973), costs have been observed in other studies (e.g., Marczinski, Milliken, & Nelson, 2003; Mondor, Hurlburt, & Thorne, 2003; Smith, 1968). One main reason for the diverging results is categorizability of the stimuli (cf., Campbell & Proctor, 1993; Pashler & Baylis, 1991; Rabbitt, 1968): If the stimuli mapped to one response can be classified according to a common (stimulus) category (e.g. "letters" vs. "digits"), presenting two different stimuli of the same category in succession involves a repetition of the response, and this repetition results in net benefits relative to a response switch. If, however, the stimuli mapped to one response are members of different categories (e.g. a letter and a digit are assigned to each response, respectively), then presenting two different stimuli affording the same response in succession produces costs relative to a response switch. Moreover, in line with recent research in task

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switching (Grzyb & Hübner, 2012a; Hübner & Druey, 2006), it seems that if the non-categorizable stimuli are multidimensional, i.e. require the binding of features to determine the response, the costs are considerably increased relative to unidimensional (or univalent) stimuli.

Another aspect besides categorizability that affects the repetition effects in choice-RT task studies concerns the response–stimulus interval (RSI). In several studies it has been shown that concurrent stimulus + response repetitions can also result in costs if this interval is only long enough (e.g., Soetens, 1998; Vervaeck & Boer, 1980). For the simple spatial tasks with a high stimulus–response (SR) overlap that were most often used in the past, RSIs of 500 ms and longer proved to be sufficient to reverse the effect (e.g. Kirby, 1976; Notebaert & Soetens, 2003; Soetens, 1998). However, with more abstract stimuli as, for instance, letters, digits and symbols, even intervals of 1 s have not been sufficient to produce such a reversal (e.g. Campbell & Proctor, 1993; Pashler & Baylis, 1991).

1.2. Response repetition effects in task switching

As mentioned, response repetitions produce opposite effects in task-repetition and in task-switch trials: Whereas benefits usually arise in task-repetition trials, costs are frequently observed in task-switch trials (see Altmann, 2011, for an overview). This basic pattern proved robust against several variations as, for instance, repeating the physical response vs. repeating a common response feature (e.g., Hübner & Druey, 2008; Schuch & Koch, 2004), or actual response execution vs. only partial response preparation (Hübner & Druey, 2006; Schuch & Koch, 2010). At the same time, several factors have been shown to modulate the response-repetition effects in the two types of trials in mixed-task blocks. After congruent trials (i.e., trials in which the stimulus afforded the same response according to both tasks), for instance, the response-repetition costs in task-switch trials are usually increased and the benefits in task-repetition trials decreased when compared to after incongruent trials (e.g., Altmann, 2011; Druey & Hübner, 2008; Grzyb & Hübner, 2012b). A comparable parallel shift in the repetition effects of task-repetition and task-switch trials has recently been observed when comparing the effects on trials with high vs. low spatial response discriminability (Koch, Schuch, Vu, & Proctor, 2011). Depending on the actual conditions, the effects might even result in a reversal of the response-repetition benefits into costs in task-repetition trials (Cooper & Mari-Beffa, 2008; Druey & Hübner, 2008; Marí-Beffa, Cooper, & Houghton, 2012; Steinhauser & Hübner, 2006), which is especially challenging regarding the theoretical explanation of the fundamental pattern of response-repetition effects in task switching.

One aspect that was evaluated in only a few studies but is of relevance for the present study concerns the effect of the RSI on the respective response-repetition effects in task-repetition and task-switch trials (e.g., Kleinsorge, 1999; Rogers & Monsell, 1995). Across these studies, a clear tendency can be seen towards a reduction of the response-repetition benefits with increasing RSI in task-repetition trials. Regarding the response-repetition costs in task-switch trials a similar attenuation is looming, but the effect is distinctly less pronounced than the attenuation of the benefits in the task-repetition trials.

1.3. Theoretical accounts for response-repetition effects

In the context of the *choice-RT studies*, several explanations have been put forward to account for the different patterns of repetition effects. The most popular framework has already been suggested by Kirby (1976) and has since received considerable attention and support from several studies. According to this account, repetition effects reflect the interplay of two general mechanisms: *automatic facilitation* and *subjective expectancy* (cf. Jentzsch & Sommer, 2002a; Notebaert & Soetens, 2003; Soetens, 1998; Soetens, Boer, & Hueting, 1985; Sommer, Leuthold, & Soetens, 1999; Vervaeck & Boer, 1980).

One critical assumption within this theoretical framework relates to the role of time and can nicely be illustrated by how the RSI-effects are explained: Whereas the benefits with short RSIs are a consequence of "automatic facilitation", the costs with long RSIs are a consequence of subjective expectancies (e.g. Kirby, 1976; Soetens et al., 1985). Following the reasoning of Wagenaar (1972) the assumption is that, with sufficient time, participants tend to expect more alternations than repetitions. As a consequence, if actually a repetition follows, this is against the expectation, thus producing performance costs. However, such expectancies need some time before they can affect performance, and this time may vary between different tasks of different complexity (cf. Soetens, 1998). With the most simple tasks that have been used so far, namely tasks with a high degree of spatial SR-overlap, the minimum time necessary to build up and implement such expectations was supposed to be around 500 ms (Vervaeck & Boer, 1980).

More recent evidence based on event-related brain potentials (ERPs) suggests that expectancies might already be present earlier, as indicated by different amplitudes of the P300 for expected and unexpected events (Sommer, Leuthold, & Matt, 1998). However, despite this evidence for early expectancy effects in event-related potentials, behavioral effects of these expectancies have not been observed with RSIs of less than 500 ms (e.g., Sommer et al., 1999). Jentzsch and Sommer (2002b) therefore concluded that two different and independent variants of expectancy might co-exist: A passive, automatic variant which results in automatic facilitation, and an active, conscious variant requiring attention, which is related to concrete preparation. Under the assumption that the latter variant is biased towards overestimating switches relative to repetitions in random sequences of events, this explains why costs for repeated events (i.e. stimuli and/or responses) are observed relative to switched events if only sufficient time is provided for these expectancies to affect behavior.

In the context of *task switching*, several explanations have been put forward to account for the opposite response-repetition effects in task-repetition and task-switch trials. In the following, I will focus on the inhibition-based accounts which have been shown to cover a wide range of findings, including also those challenging the other accounts. The priming and inhibition account of Hübner and Druey (2006), which recently has also been implemented in a connectionist model (Oberauer, Souza, Druey, & Gade, 2013), is based on the assumption that responses are generally inhibited after they had been selected or executed (cf. Cooper & Mari-Beffa, 2008; Marí-Beffa et al., 2012; Smith, 1968, for similar accounts). Because such an inhibition should result in costs for response repetitions irrespective of the actual task sequence, a second mechanism has been assumed which counteracts the negative effects of response inhibition and therefore explains the response-repetition benefits in task-repetition trials: Only in task-repetition trials response repetitions go along with a repetition of the relevant stimulus category (e.g. "odd" if the task is to classify digits according to parity). If this category remains active even after responding, this residual activation might (over-) compensate the effects of response inhibition in task-repetition trials, thus resulting in overall repetition benefits in these trials. Evidence for such categorical priming has been revealed in two recent studies (Druey, in press; Oberauer et al., 2013).

The assumption of response inhibition in this account pertains to several models in which response self-inhibition has been suggested as a mechanism to prevent accidental response re-execution (i.e. perseveration) (e.g., Arbuthnott, 1996; Baddeley, Emslie, Kolodny, & Duncan, 1998; Houghton & Tipper, 1994; Juvina & Taatgen, 2009; Lewandowsky, 1999; Li, Lindenberger, Rünger, & Frensch, 2000; MacKay, 1987). Steinhauser, Hübner, and Druey (2009) also provided evidence for such an inhibition mechanism in their task-switch study using the lateralized readiness potential (LRP) as an indicator of response preparedness. In the LRP data, a bias in favor of switching the response was observed in task-switch *and* in task-repetition trials: