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Research report

Electrophysiological correlates of residual switch costs

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ARTICLE INFO

Article history:

Received 25 June 2008
 Reviewed 1 October 2008
 Revised 3 March 2009
 Accepted 28 July 2009
 Action editor Ray Johnson
 Published online 5 August 2009

Keywords:

Task switching
 Residual switch costs
 No-go
 ERP
 Response selection
 N2
 Conflict
 Interference
 Congruency

ABSTRACT

Switching among cognitive tasks results in switch costs which are only partly reduced even after sufficient task preparation. These residual switch costs are frequently explained in terms of interference of simultaneously active task representations that delays selection of a correct response. Recent studies showed that the benefit of a task- and response-set repetition can also explain residual costs. We aimed to extend the findings by clarifying the mechanisms underlying task- and response-mode repetition benefit as well as costs arising by switch of one or both dimensions. To this end we used a combination of task-switching and go/no-go paradigm during an electrophysiological recording. Particularly, we focused on the frontocentral N2, which has been usually related to conflict, but also to response selection. The behavioral results replicate previous findings of lack of residual switch costs due to slower responses in task repetitions (TRs) following no-go relative to go trials. This indicates elimination of TR benefit when in a previous trial no response was selected and prepared. In other words, task sets clearly benefits from repetition of response mode whereas interference seems to occur whenever the task-set, the response mode or both were switched. Trial incongruity increased reaction times. The event-related potentials (ERPs) revealed a frontocentral N2 in all conditions which followed the same pattern as the reaction times (RTs), showing smaller amplitude and peaking earlier when both the task and response mode were repeated relative to the three switching conditions. Similar to the behavioral data, the N2 increased as a function of incongruity. Finally, both the N2 amplitude and latency correspond closely to the residual switch costs. This finding suggests that task-set or response mode switching intensify and delay response selection, relative to the repetition of both dimensions.

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1. Introduction

In everyday life, people are confronted with number of changing cognitive tasks, which have to be managed in a close temporal succession. The ability to switch among different tasks necessitates balance between activation of the relevant and deactivation of the irrelevant task and has been assumed

to be a crucial executive function in humans (e.g., Goschke, 2002).

A common observation is the slowing of a response to the task that has to be switched relative to the repetition of the same task, which has been termed switch costs. It was proposed that switch costs reflect a time consuming process of re-adjustment of internal task representations (Rogers

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doi:10.1016/j.cortex.2009.07.014

and Monsell, 1995). A core finding was that switch costs are significantly reduced when people have the opportunity to prepare for a task switch (TS) in advance. However, the switch costs are often not eliminated by advance preparation. The remaining portion of reaction time costs has been denoted residual switch costs (Allport, et al., 1994; De Jong, 2000; Meiran, 1996, 2000; Rogers and Monsell, 1995). Residual switch costs were systematically analyzed by Rogers and Monsell (1995). They varied the response-to-stimulus interval (RSI) between blocks of predictable sequence of tasks and observed reduction of switch costs when the interval increased from 150 to 600 msec. A further increase did not diminish the costs. The authors explained the residual costs in terms of intrinsic limitations to complete the switch process during preparation.

Allport et al. (1994) originally attributed the residual switch costs to “task-set inertia” that means persisting activation of competing task-set from the previous trial that decays only slowly over time. They argued that during switching between tasks that require the same stimulus-set, the stimulus-response mapping of the recently executed but no-longer relevant task persists until the next trial. When a TS is required, the negative transfer of this no-longer relevant mapping interferes with the currently relevant one. Due to this proactive interference, some additional time is needed to select the adequate response and this is reflected in the residual switch cost (Allport and Wylie, 2000).

Mayr and Keele (2000) hypothesized that proactive interference consists of persisting inhibition of task sets: inhibition from a task-set that was abandoned in a previous trial hampers the reactivation of the same task, when it is relevant later. The authors used three tasks A, B, and C and compared switch costs in the last trial of ABA with CBA – sequences. They found larger switch costs in the ABA ($n - 2$ task repetition costs) relative to CBA – sequence. This finding, termed ‘backward inhibition’ implies that the more recently a task has been switched away from, the harder it is to switch back to. The authors suggested that residual switch costs may be also a consequence of persisting inhibition of task sets.

Schuch and Koch (2003) investigated the functional mechanism underlying backward inhibition and its contribution to the residual switch costs. In particular they tested the hypothesis that backward inhibition occurred as a function of response selection and not task preparation. This prediction was supported using a combination of task-switching and go/no-go paradigm. The participants were asked to switch among two tasks presented in a random sequence and to withhold their response in 25% of trials. Indeed, after no-go trials no backward inhibition and no switch costs have been observed. Schuch and Koch (2003) interpreted the residual switch costs as a consequence of persisting inhibition of currently irrelevant task-set arising during response selection. Moreover, the authors show that response preparation (i.e., selection) but not response execution is the crucial process for backward inhibition and switch costs to occur (but see Philipp et al., 2007 for findings regarding contribution of response execution to switch costs).

However, the elimination of residual switch costs after no-go trials yielded in Schuch and Koch’s study was not due to a decrease of RTs in switch trials but to increase of RTs in TR trials. This observation was tentatively interpreted in terms of (negative) priming of a no-go decision from trial $n - 1$ to n . In a further study Koch, Gade and Philipp (2004) investigated inhibitory processes during switching among response modes and found substantial costs for switch among simple (unconditional double-press) versus choice responses. Although this study did not explicitly investigate the no-go – go transition effects across trials, the general increase of reaction times (RTs) after a no-go trial may be due to the same mechanism, namely interference between two response modes.

In a later study Koch and Philipp (2005) investigated the response-selection account of residual switch costs in more detail and found that the increase of task repeat RT after no-go trials is due to lack of a TR benefit. This benefit only occurs when in a previous trial a particular response has been selected. In other words, response selection in $n - 1$ leads to an activation bias favoring TR in the following trial. This result emphasized the role of persisting activation of task-set after a response has been selected but at the same time it did not diminish the role of the inhibition of irrelevant task. In sum, Schuch and Koch (2003) and Koch and Philipp (2005) concluded that the absolute activation level of task-set (defined as a category–response – C–R association; e.g., digits smaller than 5 – left key) may explain slowing in switching trials: the closer the activation level is to the activation threshold, the faster the selection of a response. This activation level is decreased by persisting inhibition from previously abandoned or elevated by previously selected task, suggesting that the timing to activate a correct response in the current trial is determined by the persisting activation level of C–R associations.

The effect of switching between task sets can be additionally modulated by the overlapping stimulus-response assignments (Meiran, 1996; Rogers and Monsell, 1995). This so called congruency effect occurred when the stimuli are assigned to different responses than the same one. For example if the digits are mapped according to the task rules: smaller than 5 or even – left key and larger than 5 and odd – right key, the digits 2, 4, 7, 9 are mapped onto the same keys in both tasks (2 and 4 to the left and 7 and 9 to the right key). In contrast the remaining digits are mapped onto opposite responses (e.g., the digit 1 requires the left button press in the smaller/larger than 5 – task and the right button press in the odd/even task). These so called incongruent trials presumably reflect additional activation of the concurrent task resulting in performance decrements relative to trials that called for the same response (Allport and Wylie, 2000). Kiesel et al. (2007) supported this hypothesis showing that the congruency effect is a consequence of activation of concurrent stimulus-response associations.

According to previous findings of Koch and coworkers (e.g., Koch and Philipp, 2005) that showed that residual switch costs arise as a function of response related processes and are largely independent from task preparation, we focused mainly on mechanisms during implementation of a switching task that is on processes that occurred after presentation of a target. In particular, the aim of the present study was to test the response-selection account of residual switch costs during

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