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Research Report

Diversity of the P3 in the task-switching paradigm

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ABSTRACT

Electrophysiological studies investigating task switching usually reveal results of the parietal P3. In this study we investigated the frontal and parietal P3 after cues, targets and responses in a combined go/no-go task switch paradigm. We confirm behavioral findings showing reduction of switch costs after no-go trials. This was accompanied by a number of P3 findings: first, the cue-locked parietal P3 was increased after a switch relative to a repetition, regardless whether a go or no-go was previously required but the frontal counterpart was less positive after inhibited responses. Secondly, in the target-locked ERPs task-set switching decreased the P3 at parietal sites, while persisting inhibition from no-go in n-1 was associated with an attenuation of the frontal P3 relative to go in n-1. No impact of task set on the frontal P3 and response mode in n-1 on the parietal P3 was found, suggesting functional dissociation between task set switch and response mode in n-1. Thirdly, exactly the same pattern was observed in the response locked frontal and parietal P3. Fourthly, the task switch related parietal P3 attenuation after targets was also observed in current no-go trials, indicating task and response selection without response execution. No task switch effect on the frontal "no-go P3" was found. In sum, these results suggest that the cue-locked long-lasting P3 reflects task-set updating, whereas the post-target frontal P3 is associated with persisting response inhibition and parietal P3 is related to an after-effect of task-set activation in terms of response selection as it appears both in the target- as well as response-locked ERPs. Furthermore, the post-target parietal P3 effects are most likely due to N2 effects as a more pronounced N2 in switch trials the smaller the P3. A fronto-parietal network for an adaptive control of response requirements and task sets is proposed.

1. Introduction

The task switching paradigm is a very useful tool for investigating a number of cognitive control processes in humans (Monsell, 2003). It has been used to examine the ability to alternate between two or more tasks, to prepare for a forthcoming task and to maintain a number of tasks in working memory. In recent times behavioral studies were increasingly complemented by electrophysiological recordings which allow systematic analyzing neural correlates underlying these cognitive mechanisms with a high time resolution (see Karayanidis et al., 2010 for overview).

In the task switching paradigm participants are asked to classify the same stimuli according to different rules on a trial by trial basis. The crucial outcome are the so-called switch costs reflecting longer reaction times and higher error rates in

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switch relative to repetition trials (Allport et al., 1994; Rogers and Monsell, 1995). In a cueing paradigm (Meiran, 1996) the relevant task is conveyed by an explicit cue stimulus, that is presented prior to target onset to allow sufficient task preparation. Although the task can be fully prepared in advance, significant residual switch costs are usually observed (Allport et al., 1994; De Jong, 2000; Rogers and Monsell, 1995), which were originally attributed to "task-set inertia", that is persisting activation of a competing task set from the previous trial. In the current trial some additional time is needed to resolve the interference and select the response (Allport et al., 1994; see Kiesel et al. 2010 for overview).

1.1. *The role of response related mechanisms in task switching*

Mayr and Keele (2000) showed that this interference involves an inhibitory component which persists from a previously inhibited task. Schuch and Koch (2003) investigated the inhibitory process using occasional no-go trials and observed no residual switch costs after no-go trials, suggesting that competition during response selection and/or activation triggers switch costs (see Koch et al. 2010 for overview). In our recent report (Gajewski et al., 2010a) we investigated the impact of response inhibition on residual switch costs using the same paradigm. We focused on the frontocentral negative ERP-component the N2 and found a relationship between the amplitude and latency of the N2 on the one hand and residual costs on the other. We concluded that proactive task set interference has to be resolved during response selection, leading to an enhanced and delayed N2 and consequently enhanced residual switch costs. Interestingly, two earlier studies conducted by Hsieh and Yu (2003) and Hsieh and Liu (2005) investigated stimulus-locked LRPs (S-LRP) that have been also related to central response-selection processes before the motor response. Both reports showed delayed S-LRP and RTs for task switch relative to task repetition. This pattern was interpreted in terms of a carry-over effect existing at the response selection stage which accords with our proposal.

Two recent ERP studies investigated inhibitory processes in the task switching go no-go paradigm and focused mainly on the P3 like positive waves. Astle et al. (2006) addressed the question whether response execution in the previous trial (go vs. no-go) differently influences task preparation. They replicated the behavioral findings obtained previously and observed an increase of the parietal P3 (termed late parietal positivity; LPP) during task preparation in switch relative to non-switch trials regardless of whether the previous trial was a go or no-go, and a late frontal negativity (LFN) on go following go trials only. The authors proposed that the inhibition from the previous trial was overcome already during preparation for the following task as reflected in the LFN. The second ERP study conducted by Jamadar and coworkers (2010) used basically the same paradigm and replicated the behavioral results. Additionally, the authors analyzed cue-locked, target-locked and response-locked ERPs. In the cue-locked data again a larger LPP was found for switch than non-switch trials and no impact of go vs. no-go in n-1 was found, corroborating the finding yielded by Astle et al. (2006). Thus, the authors proposed that no-go in n-1 cannot contribute to the sequence effects as the inhibition in n-1 should affect the task activation already in the preparation interval. Finally, in contrast to previous findings (e.g. Karayanidis et al., 2003, Nicholson et al., 2005) only a marginal switch effect on the LPP was found in the target-locked data which was also not modulated by go or no-go in n-1. However, the crucial difference between the study provided by Astle et al. (2006) or Jamadar et al. (2010) on the one hand and Schuch and Koch (2003) or Gajewski et al. (2010a) on the other hand was the usage of different no-go stimuli. Whereas the former used unspecific no-go stimuli which did not indicate a response, the latter used no-go signals which were accompanied by specific target stimuli (digit) that enabled response selection.[1] Thus, differences in the response selection process in a previous no-go trial may be crucial for the divergent explanation of residual switch costs provided by Schuch and Koch (2003) or Koch and Philipp (2005) and Astle et al. (2006) or Jamadar et al. (2010).

A systematic analysis of the well established late positive ERPs (P3 family) as a function of previous or current informative no-go trial should help to disentangle task and response selection processes from response inhibition that may shed light on the still unresolved relative contribution of these functions to task switching.

Therefore, in the present study, we reanalyzed the data presented in Gajewski et al. (2010a) and focused on the impact of response selection and/or execution on the late positive ERPs during task preparation, implementation and execution. In order to do this, we analyzed frontal and centro-parietal positivity, the P3 (see Footnote 1 in Jamadar et al., 2010 regarding different labels) in task-set switch and repetition trials as a function of response mode (go vs. no-go) in n-1 in cue-, target- and response-locked ERPs in trial n.

1.2. *The role of P3 in task preparation, implementation and execution*

1.2.1. *Cue-locked P3*

As outlined above, in the cue-locked ERPs previous research consistently found a prominent parietal positivity (LPP or P3) which was more pronounced for task-switching than task-repetition trials (Barceló et al., 2000, 2002; Jost et al. 2008; Karayanidis et al., 2003, 2010; Kieffaber and Hetrick, 2005; Lorist et al., 2000; Nicholson et al., 2005, 2006; Rushworth et al., 2002). This cue-locked positivity consists of a number of overlapping potentials reflecting reconfiguration of stimulus sets, response sets and the mapping between them (see Karayanidis et al., 2010 for an overview), which was also interpreted in terms of task-set updating in working memory (e.g. Barceló et al., 2000, 2002) whenever a model of the environment requires revision (Donchin and Coles, 1988).

1.2.2. *Target-locked P3*

In contrast, the late parietal positivity in target-locked ERPs was found to be consistently smaller in switch than in non-switch trials (e.g. Barceló et al., 2000, 2002; Gajewski et al., 2010b; Hsieh

[1] We wish to thank an anonymous reviewer for stressing this point.