



Task-switching preparation across semantic and spatial domains: An event-related potential study



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ABSTRACT

Previous event-related potential (ERP) studies have identified the specific electrophysiological markers of advance preparation in cued task-switching paradigms. However, it is not yet completely clear whether there is a single task-independent preparatory mechanism for task-switching or whether preparation for a switch can be selectively influenced by the domain of the task to be performed. To address this question, we employed a cued-task switching paradigm requiring participants to repeat or to switch between a semantic and a spatial task. The behavioural results showed a significant switch cost for both domains. The ERP findings, however, revealed that switch and repeat trials for semantic and spatial domains differed in the amplitude modulation of an early P2 and a sustained negativity both expressed over fronto-central scalp regions. Further differences between the two domains also emerged over posterior-parietal electrodes. This pattern of data thus shows that advance preparation in task-switching can be selectively modulated by the domain of the task to be performed.

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1. Introduction

A hallmark of cognitive control is the ability to flexibly switch between tasks. One of the most used tools to investigate such ability is the task-switching paradigm in which participants have to repeat the same task or to switch between different ones. The general finding for task-switching paradigms is that response time (RT) gets longer and accuracy decreases for switch trials as compared to repeat trials, a phenomenon known as the “switch cost” (see [Kiesel et al., 2010](#); [Monsell, 2003](#); for reviews). The switch cost is reduced but not completely eliminated even by providing participants in advance with an explicit cue that instructs them to change task (i.e. the cued task-switching paradigm; [Meiran, 1996](#)). The observation that a residual switch cost still emerges with preparation intervals longer than 1 s ([Rogers & Monsell, 1995](#)) suggests that advance preparation cannot fully compensate for the behavioural

cost of alternating between different tasks (see [Jamadar, Hughes, Fulham, Michie, & Karayanidi, 2010](#)).

Some theories explain the switch cost during the cued task-switching paradigm by assuming that an active task-set reconfiguration process would be implemented for switch trials as compared to repeat trials in order to prioritize the new task-set against the previous one (e.g. [Rogers & Monsell, 1995](#)). Such a reconfiguration process is supposed to be time-consuming and highly dependent on executive control. Support for this claim comes from the finding of a reduction of the switch cost when the cue–target interval is increased and more time can thus be devoted to advance preparation.

Alternatively, other researchers attribute the switch cost to priming or other memory interference processes from the previous task-set that would not necessarily entail executive control (e.g. [Allport, Styles, & Hsieh, 1994](#); [Wylie & Allport, 2000](#)). This idea is strengthened by the observation that the switch cost is reduced with longer inter-trial intervals, which has been taken as evidence that allowing ample time before the subsequent trial is presented favours the spontaneous decay of the previous task-set interference. More recently, however, it is accepted that both reconfiguration and interference processes would contribute to the switch cost (e.g. [Vandierendonck, Liefooghe, & Verbruggen, 2010](#)).

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A number of studies using event-related potentials (ERPs) support the role of an active task-set reconfiguration process taking place during the cue–target interval. The excellent high temporal resolution of ERPs indeed allows researchers to track the time course of switch and repeat trials that follow the presentation of the cue and to compare the neural activity associated with each task condition. In such a way, it is possible to determine whether, and to what extent, switch and repeat trials can be differentiated during the preparation interval that precedes task performance.

Two main ERP components have been often associated with task-switching effects during the preparation interval: a sustained posterior positivity, sometimes termed “differential switch positivity” or simply “switch positivity” (e.g. Jamadar, Hughes et al., 2010; Karayanidis, Provost, Brown, Paton, & Heathcote, 2011), emerging around 300–400 ms after cue onset, and a concurrent or later sustained frontal negativity (e.g. Astle, Jackson, & Swainson, 2008; Lavric, Mizon, & Monsell, 2008). Both brain potentials are typically larger for switch as compared to repeat trials (see De Baene & Brass, 2014; Karayanidis et al., 2010; for reviews), although some studies also reported an enhanced frontal negativity for repeat trials before target onset (e.g. Nicholson, Karayanidis, Poboka, Heathcote, & Michie, 2005).

The switch positivity has been replicated across different studies and task manipulations (e.g. Kieffaber & Hetrick, 2005; Kopp, Lange, Howe, & Wessel, 2014; Li, Wang, Zhao, & Fogelson, 2012; Miniussi, Marzi, & Nobre, 2005; Nicholson et al., 2005; Rushworth, Passingham, & Nobre, 2002). A general consensus exists on the fact that this positivity would reflect anticipatory task-set reconfiguration processes that would be especially related to switch trials. In support of this interpretation, Karayanidis et al. (2011) (see also Lavric et al., 2008) found faster switch responses to be associated with larger amplitude of the switch positivity as compared to slower switch responses, suggesting that such a slow positivity is linked to “a switch-specific reconfiguration process” (p. 567).

Unlike the switch positivity, the functional meaning of the frontal negativity appears more controversial, perhaps due to the fact that this brain potential has been reported in fewer studies as compared to the switch positivity. Furthermore, most of the studies observing the frontal negativity have used a common average reference, which led to the suggestion that the frontal negativity and the switch positivity could represent the negative and the positive components of a dipolar distribution, respectively (see De Baene & Brass, 2014; Jamadar, Hughes et al., 2010; Karayanidis et al., 2010; Lavric et al., 2008).

However, contrary to this claim, Astle et al. (2008) found that the two brain potentials, which were measured in the same time interval, could be dissociated in task-switching paradigms that manipulated advance preparation of different response-sets. That is, whereas the switch positivity was present for both overt and covert (i.e. mental counting) responses, the frontal negativity was observed only when the task required an overt response. Moreover, in a study using a go/no-go version of the task-switching paradigm (Astle, Jackson, & Swainson, 2006), it was found that only the switch positivity was present following both go and no-go trials. By contrast, there was no difference in the frontal negativity between switch and repeat trials after a no-go trial, which suggested that this potential was sensitive to the fact that the response-set had been inhibited in the previous trial and this effect carried over to the current trial. Taking the above studies into account, a plausible explanation for the frontal negativity would be, thus, related to advance preparation of overt response-set processes (see Karayanidis et al., 2010).

In addition to these sustained positive- and negative-going potentials, another reliable ERP signature often reported in the task-switching literature is an early cue-locked fronto-central positivity (P2), emerging approximately at 200 ms after cue onset,

which is usually larger following a switch cue relative to a repeat cue (e.g. Finke, Escera, & Barceló, 2012; Periañez & Barceló, 2009; West, Langley, & Bailey, 2011). The enhanced P2 amplitude for switch trials has been generally attributed to the functioning of an early task-set updating process that would rapidly “detect” a relevant change in the task to be performed (see also De Baene & Brass, 2014).

To sum up, from this brief review of the main electrophysiological correlates of advance preparation in cued task-switching paradigms, it seems clear that preparing for a switch as compared to preparing for a repeat trial can differentially modulate some specific brain potentials developing during the cue–target interval. Most of the previous task-switching studies have focused on investigating which cognitive factors may influence the ERP markers of advance preparation.

Amongst others, it has been shown that the electrophysiological correlates of task-switching preparation are sensitive to: (1) the amount of information conveyed by the cue (e.g. Karayanidis et al., 2009; Nicholson, Karayanidis, Davies, & Michie, 2006), (2) the duration of cue–target and inter-trial intervals (e.g. Li et al., 2012; Nicholson et al., 2005), (3) the specific requirements (go vs. no/go) for response selection (e.g. Astle et al., 2006; Gajewski & Falkenstein, 2011; Jamadar, Michie, & Karayanidis, 2010) and (4) the participants' performance (fast vs. slow switch responses) in switching between tasks (e.g. Karayanidis et al., 2011; Lavric et al., 2008).

Much less is known about the role played by the domain of the tasks that are manipulated in cued task-switching paradigms. In other words, it is still unclear whether preparation for a task-switching is accomplished by a single, task-independent, central mechanism or whether it relies on different mechanisms according to the specific domain of the task to perform. Such a gap is mainly due to the fact that previous ERP studies have usually focused on the contrast between switch vs. repeat trials pooling over the tasks among which participants had to switch. This choice has been often motivated by the finding of a null behavioural interaction between the requirements to switch/repeat task and the specific task rules to be implemented, such that the ERP data have been averaged across the different tasks in order to increase the signal-to-noise ratio of switch and repeat trials (e.g. Goffaux, Phillips, Sinai, & Pushkar, 2006; Karayanidis et al., 2009; Nicholson et al., 2006). As a consequence, it is not completely clear to date whether task-switching preparation is domain-independent or rather it is influenced by the domain of the task to be performed (see also Ravizza & Carter, 2008).

Among the few researchers who have investigated task-switching across different tasks, Hsieh and Wu (2011) (see also Hsieh, Wu, & Lin, 2014) compared the electrophysiological correlates of advance preparation in task-switching between stimulus–dimensions vs. response–mappings. The authors reported both common and distinct modulations of cue-locked ERPs associated with the two task-switching types, which suggests the presence of both shared and unique mechanisms underlying preparation to shift across different tasks.

An issue which is still poorly explored, however, is the comparison of task-switching between tasks that are typically processed in distinct brain regions, like for instance semantic and spatial tasks, which are known to be mainly processed on the left and right hemisphere, respectively (e.g. Corbetta & Shulman, 2011; Fairhall & Caramazza, 2013; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997). In the present study, we asked whether there might be different preparatory mechanisms when shifting, on a trial-by-trial basis, between tasks that require participants to make a spatial decision vs. tasks requiring a semantic decision. To our knowledge, only a previous study by Miniussi et al. (2005) tackled a similar research question using a cued task-switching paradigm.

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