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A diffusion model analysis of developmental changes in children's task switching



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ABSTRACT

This study aimed to investigate the underlying processes of the development of cognitive flexibility between childhood and young adulthood. We performed a diffusion model analysis on the reaction time and accuracy data from four age groups (7-, 11-, 15-, and 21-year-olds), who performed a task-switching task. We decomposed the data into processes related to the reconfiguration of the cognitive system to a new goal (i.e., task-set reconfiguration) and processes related to the interference of the previous task (i.e., task-set inertia). The developmental patterns of both processes indicated a relatively early maturing mechanism, associated with task-set inertia, and a later maturing mechanism, relating to task-set reconfiguration. This pattern of results was interpreted in terms of the development of the neural mechanisms involved in task switching, that is, the (pre-)supplementary motor area and the ventrolateral prefrontal cortex.

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Introduction

Cognitive flexibility refers to the ability to flexibly adjust behavior to the changing demands of the environment and is a key component of human behavior (e.g., Miller & Cohen, 2001; Monsell, 2003).

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Cognitive flexibility can be examined using experimental tasks that require flexible switching between task demands. A particularly useful task is the task-switching paradigm (for a review of adult literature on task switching, see [Monsell, 2003](#); see also [Kiesel et al., 2010](#); [Vandierendonck, Liefvooghe, & Verbruggen, 2010](#)). The task-switching paradigm requires the participant to make a choice between two response alternatives such as deciding between the shape (e.g., circle, triangle) and color (e.g., yellow, blue) of a stimulus. The shape and color tasks are presented in mixed blocks, allowing the comparison of performance on task repetitions and task alternations. In adults, longer response latencies and increased error rates are typically observed on trials that require a task switch (e.g., a shape–color sequence of trials) compared with repeating trials (e.g., a shape–shape sequence of trials). The difference in performance between task-switch trials and task-repeat trials is referred to as switch costs ([Monsell, 2003](#)).

Two major theories have been invoked for the explanation of switch costs. One account suggests that switch costs can be attributed to the reconfiguration of the task set ([De Jong, 2000](#); [Meiran, 1996](#); [Rogers & Monsell, 1995](#)). More specifically, it is assumed that once a task set is implemented, it stays active until it has been replaced by another task set. Consequently, it has been argued that task-switching costs arise from an executive or control process that reconfigures the cognitive system such that the relevant task set is active for execution (e.g., [Rogers & Monsell, 1995](#)). The other account asserts that, once implemented, a task set persists and interferes with new task-set configurations. This residual activation of a task set from the recent performance of a task, dubbed “task-set inertia,” may interfere with the performance of the new task. This account assumes that switch costs reflect interference from the previous task at the level of stimulus–response associations, stimulus–stimulus associations, or response–response associations (e.g., [Allport, Styles, & Hsieh, 1994](#); [Wylie & Allport, 2000](#)).

One line of evidence for an executive control process account comes from studies showing that at least part of the task-switching costs, “residual switch costs”, persist even when participants have ample time between trials to prepare for the upcoming task. It is hypothesized that residual switch costs reflect the time taken by executive control processes, which must await stimulus presentation and, therefore, are insensitive to the preparation interval (e.g., [Monsell, Yeung, & Azuma, 2000](#)). In contrast, the “task carryover” account is supported by findings showing that switching from a difficult task to an easy task takes longer to complete than vice versa. This observation is consistent with the notion that the time needed for a task switch is determined primarily by the nature of the previous task. Thus, it is argued that greater inhibition is required to the easy task set when performing the difficult one, and this inhibition carries over to the next trial requiring the performance of the easy task. Overcoming this inhibition prolongs the selection of the appropriate response (e.g., [Allport et al., 1994](#)). An alternative explanation of the “task carryover effect” concerns the effect of inhibitory control when switching between tasks (for a review, see [Koch, Gade, Schuch, & Philipp, 2010](#)). This account assumes the involvement of an inhibitory mechanism that reduces the activation of the current task in order to switch to a different task. Evidence for the effect of inhibition during task switching was obtained in negative priming studies (e.g., [Koch et al., 2010](#)) and in $n - 2$ repetition costs (e.g., [Mayr & Keele, 2000](#)).

Initially, task-switching costs have been explained in terms of single factor models, emphasizing either task-set inertia or task carryover effects. More recently, most authors seem to entertain accounts of task-switching costs based on a plurality of causes (cf. [Monsell, 2003, p. 137](#)). Thus, [Ruthruff, Remington, and Johnston \(2001\)](#) proposed that both top-down and bottom-up processes might be active during a task switch; the former are required for programming mental operations involved in the upcoming task, whereas the latter are required for the actual execution of these operations. Similarly, [Mayr and Kliegl \(2003\)](#) suggested the existence of two processing stages during a task switch; the first processing stage is associated with the retrieval of task rules from long-term memory, and the second relates to the automatic application of rules to the stimulus at hand.

The notion of multiple mechanisms involved in task switching has stimulated research aimed at identifying the mechanisms active in a particular paradigm as well as their temporal dynamics during the task switch (for a review, see [Vandierendonck et al., 2010](#)). Recently, [Schmitz and Voss \(2012\)](#) applied diffusion modeling for isolating mechanisms involved in different task-switching paradigms. Diffusion modeling ([Ratcliff, 1978](#)) takes into account both latency and accuracy of reaction time (RT) data and allows for decomposing the effects on both in meaningful underlying constructs. The

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