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Task switching and shifting between stopping and going: Developmental change in between-trial control adjustments

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ABSTRACT

This study set out to investigate developmental differences in the ability to switch between choice tasks and to shift between Go/NoGo and choice tasks. Three age groups (7-year-olds, 11-year-olds, and young adults) were asked to consider the shape or color of a bivalued target stimulus. The participants performed a switch task in which a cue signaled the task to be performed (i.e., respond to shape vs. respond to color) and a shift task in which a cue instructed them to make a choice reaction to the shape of the stimulus or to respond (Go) versus inhibit (NoGo) to the color of the stimulus. The ability to switch was examined by considering choice–choice switches versus choice–choice repeats. The ability to shift was examined by considering NoGo-to-choice shifts versus choice–choice repeats and NoGo-to-Go shifts versus Go–Go repeats. The results showed that responding on Go trials was delayed following response inhibition on a NoGo trial. This delay did not discriminate between age groups. Responding on choice trials was considerably slowed when following response inhibition on NoGo trials. This slowing decreased with advancing age. Finally, responses on switch trials were slower compared with repeat trials, and this slowing was disproportionately large in young children compared with the other two age groups. This pattern of findings was interpreted in terms of a generic mechanism involving between-trial control adjustments in the setting of response thresholds that are likely to be mediated by a complex neural network implicating the dorsolateral prefrontal cortex and the presupplementary motor cortex.

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Introduction

The ability to perform goal-directed, flexible behavior displays a clear developmental trend. In children, this ability improves gradually (although adolescents may still display behavior that is both impulsive and shortsighted; for reviews, see Diamond, 2002; Welsh, 2002). In terms of experimental task performance, the behavior of young children is often stimulus-bound and impulsive (cf. Zelazo, Craik, & Booth, 2004). On cognitive flexibility tasks (i.e., tasks that require flexible switching between task demands), children display strongly perseverative behavior; that is, they persevere in a given mental set or activity and cannot shift easily from one set or activity to another (Cuneo & Welsh, 1992). Adults generally perform adequately on cognitive flexibility tasks and have little trouble in inhibiting responses that a change in task demand has rendered inappropriate (e.g., Monsell, 2003). These findings are usually interpreted in terms of developmental improvement in executive function, which in turn is associated with the maturation of the prefrontal cortex (e.g., Blakemore & Choudhury, 2006; Chugani, Phelps, & Mazziotta, 1987; Giedd et al., 1999; Gogtay et al., 2004; Huttenlocher, 1979; Pfefferbaum et al., 1994; Sowell et al., 2004; Yakovlev & Lecours, 1967; for reviews, see Amso & Casey, 2006; Casey, Tottenham, Liston, & Durston, 2005).

Traditionally, cognitive flexibility has been assessed using neuropsychological tasks that are complex in the sense that they involve a variety of processes (e.g., problem solving, performance monitoring) in addition to cognitive flexibility itself. The role of various processes in complex tasks (e.g., Wisconsin Card Sorting Task) can render task performance difficult to interpret (Grant & Berg, 1948; Heaton, Chelune, Talley, Kay, & Curtis, 1993). The task switching paradigm was introduced to avoid the interpretational difficulties associated with complexity. This paradigm is a tool for assessing the component processes that underlie cognitive flexibility in the absence of problem solving (cf. Cepeda, Kramer, & Gonzalez de Sather, 2001). The task switching paradigm requires an individual to switch between two simple choice tasks such as deciding the color (e.g., red, blue) or the shape (e.g., circle, triangle) of a stimulus. The two tasks are presented in mixed blocks, allowing the comparison of performance on task repetitions and task alternations. Typically, responses are slower and less accurate on alternation trials than on repetition trials (e.g., Allport, Styles, & Hsieh, 1994; Meiran, 1996; Monsell, 2003). The differences in performance on task alternation and repetition trials are coined "switch costs." These costs are attributed alternatively to the reconfiguration of task sets on alternation trials (De Jong, 2000; Meiran, 1996; Rogers & Monsell, 1995), to the passive decay of the previous task set from working memory (Meiran, Chorev, & Sapir, 2000; Spector & Biederman, 1976), or to proactive interference (Allport et al., 1994; Wylie & Allport, 2000).

Studies of the development of the ability to switch flexibly between tasks during childhood and adolescence have revealed a decrease of task switch costs as children grow older (e.g., Cepeda et al., 2001; Chevalier & Blaye, 2009; Cragg & Nation, 2009; Crone, Bunge, van der Molen, & Ridderinkhof, 2006a; Davidson, Amso, Anderson, & Diamond, 2006; Deak, Ray, & Pick, 2004; Ellefson, Shapiro, & Chater, 2006; Gupta, Kar, & Srinivasan, 2009; Reimers & Maylor, 2005; but see Kray, Eber, & Lindenberger, 2004, for disparate results). This decrease is attributed to the improvement of cognitive flexibility, which in turn is attributed to development of its underlying neural substrate in the prefrontal cortex (e.g., Bunge & Wright, 2006; Diamond, 2002; Huizinga, Dolan, & van der Molen, 2006; Kharitonova, Chien, Colunga, & Munakata, 2009; Rougier, Noelle, Braver, Cohen, & O'Reilly, 2005; Zelazo, 2004).

The current study set out to assess developmental differences in the ability to switch tasks, but its primary focus was on a related issue—the ability to shift from stopping to going. In adults, responses are delayed and the task switch effect was reduced or even annihilated when the immediately preceding trial required response inhibition (e.g., Gade & Koch, 2005; Hoffmann, Kiesel, & Sebald, 2003; Jamadar, Michie, & Karayanidis, 2010; Kleinsorge & Gajewski, 2004; Rieger & Gauggel, 1999; Rieger, Gauggel, & Burmeister, 2003; Schuch & Koch, 2003; Verbruggen & Logan, 2008). This finding is consistent with the observation that responses are delayed when the previous trial elicited a conflict between competing responses such as in Eriksen Flanker tasks (e.g., Gratton, Coles, & Donchin, 1992), Simon tasks (e.g., Ridderinkhof, Span, & Van der Molen, 2002), and Stroop tasks (e.g., Swick & Jovanovic, 2002). The response slowing on the postconflict trial has generated various interpretations