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A meta-analysis of the Dimensional Change Card Sort: Implications for developmental theories and the measurement of executive function in children

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ABSTRACT

The Dimensional Change Card Sort (DCCS) is a widely used measure of executive function in children. In the standard version, children are shown cards depicting objects that vary on two dimensions (e.g., colored shapes such as red rabbits and blue boats), and are told to sort them first by one set of rules (e.g., shape) and then by another (e.g., color). Most 3-year-olds persist in sorting by the pre-switch rules, whereas 5-year-olds switch flexibly. We conducted a meta-analysis of standard and experimental versions of the task ($N = 69$ reports, 426 conditions) to examine the influence of diverse task variations on performance. Age, how the test stimuli were labeled for the child, emphasis on conflict in the verbal introduction of the post-switch rules, and the number of pre-switch trials each independently predicted switching on the standard DCCS, whereas pre-switch feedback, practice, and task modality did not. Increasing the relative salience of the post-switch dimension was associated with higher rates of switching, and, conversely, decreasing post-switch salience was associated with lower rates of switching, and under both kinds of manipulation performance continued to be associated with age. Spatially separating the dimensional values was associated with higher rates of switching, and it was confirmed that the degree of spatial separation matters, with children benefiting most when the dimensional values are fully spatially segregated.

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Switch rates tended to be higher in versions on which children were prompted to label the stimuli compared to when the experimenter provided labels, and lower when reversal instructions were used in conjunction with the standard task stimuli. Theoretical and practical implications for the study and measurement of executive function in early childhood are discussed.

Introduction

Being able to flexibly control our thoughts, actions, and emotions, especially in the face of conflicting habits and desires, is a key developmental achievement. Children are notorious for struggling with control, showing difficulty with simple tasks like sitting still and listening, raising their hand instead of blurting out thoughts, and flexibly switching from one activity to another. This skill, termed executive function (EF), develops markedly in the early childhood years (Carlson, 2005; Diamond, 2013; Zelazo et al., 2013), and can be described as the top-down, neurocognitive processes involved in goal-directed behavior, including inhibition of habitual or dominant responses, shifting between tasks or mental sets, and monitoring and updating information in working memory (Miyake & Friedman, 2012; Miyake et al., 2000). EF supports the development of a range of social and academic skills in childhood (e.g., theory of mind, math, and reasoning; Carlson & Moses, 2001; Hughes, 1998; Mazzocco & Kover, 2007; Richland & Burchinal, 2012) and also predicts numerous outcomes associated with success in adulthood (e.g., academic achievement, health, and wealth; Blair & Razza, 2007; Moffitt et al., 2011). Not surprisingly, deficits in EF can have wide-ranging negative consequences for adaptive functioning in children and adults (e.g., Bechara, Damasio, Damasio, & Anderson, 1994; Biederman et al., 2004; Pennington & Ozonoff, 1996). Given its central importance to healthy human functioning and development, gaining insight into the nature of EF and developing sensitive tools to measure it are key research goals.

One task that has been widely used in research on the development of EF in early childhood is the Dimensional Change Card Sort (DCCS) task (Frye, Zelazo, & Palfai, 1995; Zelazo, 2006; see Fig. 1). In the *standard* DCCS (see Zelazo, 2006 for a complete description of the most commonly used and recommended procedure), children are shown two target cards (e.g., a blue rabbit and a red boat) and then presented with a series of test cards (e.g., red rabbits and blue boats) that they are instructed to sort according to one of the dimensions (e.g., by color). On each trial, the experimenter repeats the relevant rules, labels the test card by the relevant dimension, and gives the card to the child to sort. After several trials (typically 5 or 6), children are instructed to sort by the other dimension (e.g., shape). Three-year-olds tend to perseverate and continue to sort the cards according to the initial sorting rules. By contrast, typically developing 5-year-olds tend to switch flexibly. This task is often described as a measure of cognitive flexibility or set-shifting, and, like most measures of set-shifting, performance on the DCCS likely involves several aspects of EF, including working memory to maintain the rules in mind, and inhibitory control to suppress attention to the previously relevant dimension.

Over the past two decades, the DCCS has been used in over 150 studies and has been modified in theoretically motivated ways to examine cognitive mechanisms that underlie switching and EF. Developmental theories of EF that address the DCCS have focused on reflection and rule complexity (Zelazo, Müller, Frye, & Marcovitch, 2003), attentional inertia and inhibition (Kirkham, Cruess, & Diamond, 2003), representational redescription (Kloo & Perner, 2005), and working memory (Morton & Munakata, 2002).

On the Cognitive Complexity and Control-Revised account (CCC-r; Zelazo et al., 2003), successful switching requires the formulation and use of a higher-order rule for switching between dimensions (e.g., *If it's the color game, then the red ones go here and the blue ones go there; but if it's the shape game, then the rabbits go here and the boats go there)*, which is achieved through developmental increases in reflection. Zelazo et al. (2003) examined performance on more than a dozen versions of the task to test theoretical predictions. For example, they tested the hypothesis derived from the CCC-r theory that a hierarchical rule is needed whenever rules are nested under different setting conditions (i.e.,