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Preschoolers can form abstract rule representations regardless of cognitive flexibility

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ABSTRACT

The abstractness of rule representations in the pre-switch phase of the Dimensional Change Card Sorting (DCCS) task was studied by letting 3- and 4-year-old children perform a standard DCCS task and a separate generalization task. In the generalization task, children were asked to generalize their sorting rules to novel stimuli in one of three conditions. In the *relevant change* condition, values of the relevant dimension changed; in the *irrelevant change* condition, values of the irrelevant dimension changed; and in the *total change* condition, values of both dimensions changed. All children showed high performance on the generalization task in the relevant change condition, implying an abstract rule representation at the level of dimensions ("same colors go together"). Performance in the relevant change condition was significantly better (and faster) than performance in the other two conditions. Children with high cognitive flexibility (switchers on the DCCS task) more often switched their attention to the irrelevant dimension in the generalization task only if values of the irrelevant dimension changed. Children with low cognitive flexibility (perseverators) were more often inconsistent in their sorting on the generalization task if values of both dimensions changed. The difference in performance on the DCCS task between switchers and perseverators seems to result from the processes that operate on the learned sorting rules and not from the abstractness of the rule representations children have.

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Introduction

Flexibility is an important ability in the current rapidly changing society. One should be able to change plans in response to relevant changes in the environment and, complementarily, to maintain activities when changes in the environment are irrelevant. Cognitive flexibility is improving substantially during the preschool years (Carlson, 2005), and the Dimensional Change Card Sorting (DCCS) task is a widely used paradigm to study this in preschoolers (Zelazo, 2006). In this task, children are required to sort two bivalent test cards according to shape or color on two stacks marked by target cards. Each test card matches one target card on color and the other target card on shape. After sorting a series of test cards according to one dimension (e.g., color), children are asked to sort the same test cards according to the other dimension (e.g., shape). Nearly all 3- and 4-year-olds sort correctly in the first phase of the task (the pre-switch phase) regardless of which dimension is presented first. Most 3-year-olds perseverate in the second phase of the task (the post-switch phase) by sorting test cards according to the initial dimension, whereas most 4- and 5-year-olds switch immediately to the new dimension when asked to do so (Kirkham, Cruess, & Diamond, 2003; Perner & Lang, 2002; Zelazo, Frye, & Rapus, 1996).

A number of theoretical frameworks have been proposed to explain perseverative behavior at the DCCS task. According to *attentional inertia* theory, perseverators may know the new rules they should be following but fail to suppress attention to the pre-switch relevant information (Kirkham et al., 2003). The *activation deficit* account assumes that perseverators fail to activate previously inhibited information (Chevalier & Blaye, 2008; Müller, Dick, Gela, Overton, & Zelazo, 2006). According to the *redescription* account, perseverators can conceptualize a stimulus in a single way (i.e., using the pre-switch rules) but fail to redescribe the stimulus in another way (i.e., according to the post-switch rules) (Perner & Lang, 2002). The *cognitive complexity and control* (CCC) theory assumes that perseverators cannot formulate and use a higher order rule for selecting which pair of rules (color rules or shape rules) must be used on a particular trial (Zelazo, Müller, Frye, & Marcovitch, 2003). Finally, the *competing memory systems* theory supposes that flexible behavior depends on the competition between active and latent memory traces. Perseveration occurs when an active memory trace of the current sorting rules is not strong enough to compete against a latent memory trace of the previously relevant sorting rules (Munakata, 1998).

The competing memory systems account hypothesizes that there is a fundamental difference in rule representations between switchers and perseverators (Cohen & Servan-Schreiber, 1992; Morton & Munakata, 2002). The active memory traces of switchers are thought to rely on later developing prefrontal cortical regions that represent the sorting rules in a more abstract form, whereas the latent memory traces of perseverators are thought to rely more on earlier developing posterior cortical regions that represent the sorting rules in a more stimulus-specific form (Patalano, Smith, Jonides, & Koeppe, 2001). Unlike the competing memory systems account, the first four theoretical frameworks assume that perseverators and switchers do not necessarily differ in how they represent the sorting rules. Instead, switchers and perseverators are supposed to differ in the processes that operate on the learned sorting rules (e.g., inhibition, reactivation, redescription, reflection).

Representations of sorting rules in the DCCS task

Knowledge about the level of abstraction of the representations of children's sorting rules is particularly relevant to further understanding of processing in the DCCS task. Hence, an important aim of the current study was to study the abstractness of the rule representations of children after the pre-switch phase of the DCCS task when they need to switch rules. The rule representations in the DCCS task could theoretically have three levels of abstraction. The least abstract level is a representation at the level of the specific stimuli. Sorting rules can then, for example, be formulated as "the red car goes with the red rabbit and the blue rabbit goes with the blue car." The second level is a representation at the level of the values of dimensions. Sorting rules can then, for example, be formulated as "red goes with red and blue goes with blue." Finally, the most abstract level is a representation at the