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Reflection training improves executive function in preschool-age children: Behavioral and neural effects

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ABSTRACT

To assess the role of reflection in executive function, preschool-age children who perseverated (failed) on a pre-training version of the Dimensional Change Card Sort (DCCS) were given training with a different version (different stimuli) in which they were provided with corrective feedback and taught to reflect on the conflicting rule representations involved in the task. In Exp. 1, reflection training was based closely on Kloo and Perner (2003). Exp. 2 used a shortened (15 min) version of the training protocol. In Exp. 3, this version of *reflection training* was compared to *corrective feedback* alone or *mere practice* with the task (without feedback). In all 3 experiments, children who received reflection training showed substantial improvements in performance on the pre-training version of the DCCS, whereas children in control conditions did not. In Exp. 3, these improvements were accompanied by a reduction from pre- to post-training in the amplitude of the N2 component of the ERP, an index of conflict detection. Results suggest not only that EF can be trained using a brief intervention targeting reflection, but also that training-related improvements in performance are associated with the down-regulation of ACC-mediated conflict detection. Implications for education are discussed.

Executive function (EF) refers to the top-down neurocognitive processes involved in flexible, goal-directed problem solving (Zelazo et al., 2008). There is currently considerable interest in the early development of EF, in part because EF measured in early childhood predicts important developmental outcomes, including math and reading skills in preschool and the early school grades (e.g., Blair and Razza, 2007), cognitive control (Go-Nogo performance) and SAT scores in adolescence (e.g., Eigsti et al., 2006), and socioeconomic status in adulthood (Moffitt et al., 2011). While this research suggests that individual differences in EF remain relatively stable from early childhood to adulthood, a growing number of studies have now shown that EF can be trained (see Diamond and Lee, 2011, for review). Much of this research has focused on the preschool years, a period of rapid development of EF that occurs just prior to a sharp increase in the demands placed on children's developing EF (i.e., as they transition to school).

Interventions shown to improve EF include specific preschool curricula (e.g., Diamond et al., 2007; Lillard and Else-Quest, 2006), certain extra-curricular activities (e.g., music, exercise, and martial arts), and laboratory-based efforts targeting specific EF skills (e.g., Dowsett and Livesey, 2000; Jolles et al., 2011; Karbach and Kray, 2009; Klingberg et al., 2005; Kloo and Perner, 2003; Rueda et al., 2005, 2012; Tamm et al., 2010; Thorell et al., 2009). While these studies clearly reveal the considerable plasticity of EF in early childhood, key questions remain concerning why EF interventions are effective: What are the active ingredients, and how do they act? The goal of the current study was to isolate the role of reflection, or the reflective reprocessing of information, in EF training in preschool age children.

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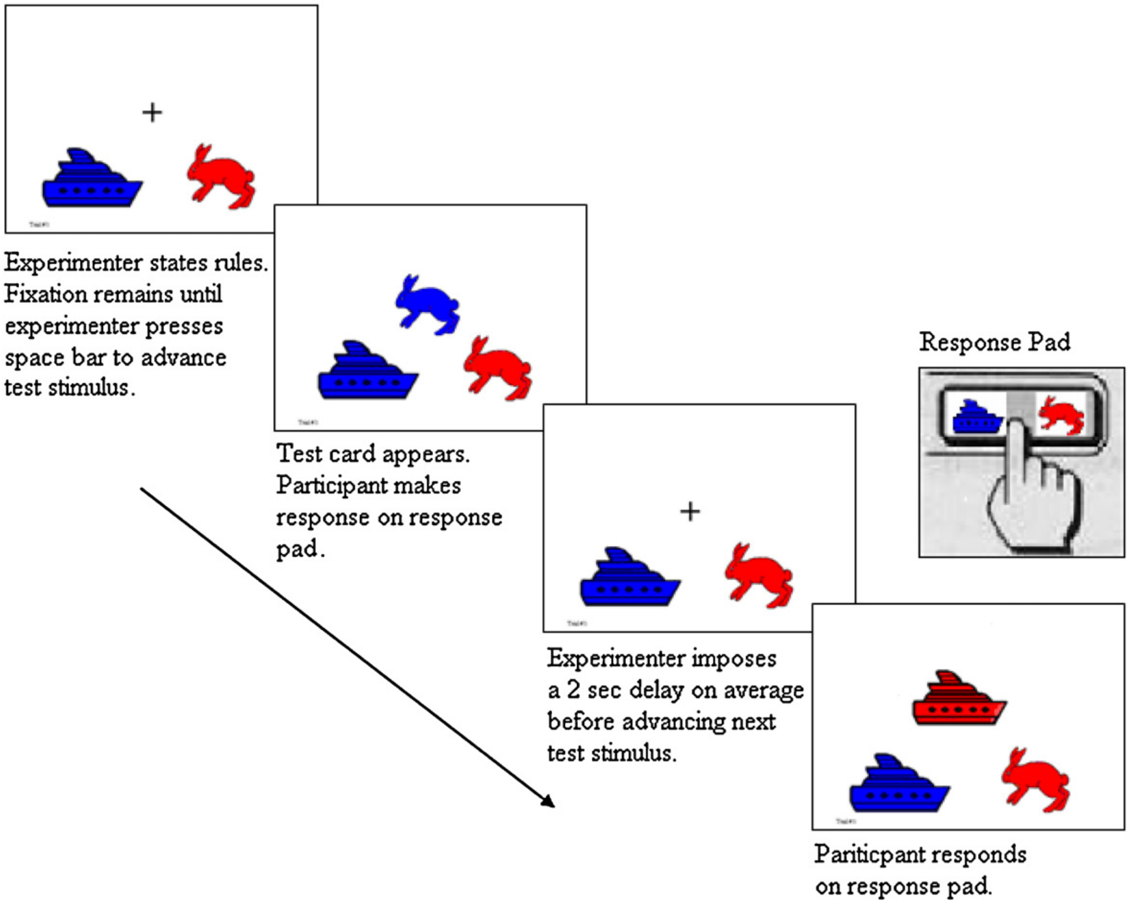

Fig. 1. Sequence of events for the computerized version of the pre- and post-training Dimensional Change Card Sort.

A well-studied developmental transition in EF occurs in children's performance on the Dimensional Change Card Sort (DCCS; Zelazo, 2006; see Fig. 1), in which children are required to sort bivalent test cards (e.g., red rabbits and blue boats) first according to one dimension (e.g., color) and then according to the other (e.g., shape). Most 3-year-olds perseverate on the post-switch phase of the DCCS, continuing to sort by the pre-switch dimension, whereas by 5 years of age, most children switch flexibly. Performance on more difficult versions of the task (e.g., speeded versions with more frequent, unpredictable switches between dimensions) continues to improve during adolescence, reaches a peak in young adulthood, and then declines in senescence (e.g., Diamond and Kirkham, 2005; Zelazo et al., in press).

Several different accounts have been offered of the developing cognitive processes that underlie age-related behavioral changes on this task (e.g., Bunge and Zelazo, 2006; Kirkham et al., 2003; Morton and Munakata, 2002; Zelazo et al., 2003). For example, Zelazo et al. (2003) have highlighted the importance of increases in the reflective reprocessing of information, allowing for the formulation, selection, and maintenance in working memory of higher-order rules. According to the Cognitive Complexity and Control theory-revised (CCC-r; Zelazo et al., 2003), children who perseverate on the DCCS have difficulty reflecting on their (conflicting) rule representations and formulating a hierarchical rule system that resolves the conflict inherent in the rules and the bivalent stimuli. The rapid development of self-reflection during the preschool years allows children to recognize that they know two different ways of approaching the task: "If I'm sorting by color, then the red rabbits go here; but if I'm sorting by shape, then they go there."

Other approaches emphasize different cognitive processes such as active (working) memory (Morton and Munakata, 2002), inhibition of attention (Kirkham et al., 2003), and redescription (the understanding that a stimulus can be redescribed from a different perspective; Kloo and Perner, 2003). Despite their differences, however, all of these accounts acknowledge that a key challenge for younger children is resolving, by one means or another, how to respond flexibly to the conflicting information in the task (i.e., the conflicting rules and/or the conflict inherent in the bivalent stimuli).

As an experimental test of their hypotheses, Kloo and Perner (2003, Exp. 2) trained children for approximately 30 min (2× 15 min training sessions over the course of several weeks) to reflect on their rule representations during