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Cognitive flexibility training in three-year-old children

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ABSTRACT

The Dimensional Change Card-Sorting task (DCCS) is frequently used to assess preschool-children's executive abilities. Children are asked to sort bidimensional cards (a blue boat) first according to one dimension (color) and then according to the other (shape). Redescription theory argues that 3-year-olds' failure in the DCCS is linked to their difficulties in flexibly describing an object on two perceptual dimensions successively when they are integrated within the same object. 103 3-year-old children were tested with the DCCS and 53 were placed in a redescription-training group with two versions of the DCCS. Two separated unidimensional objects on the same card were used for the spatially distinct DCCS. In the interlaced DCCS, color and shape could be separated or superimposed within a single object. Results showed an improvement in DCCS performance after training, particularly when using the interlaced DCCS, underlying the role of redescription in the development of cognitive flexibility.

1. Introduction

Cognitive flexibility is an executive function (EF) that clearly emerges during the preschool period. Cognitive flexibility is also referred to as "shifting or switching" abilities, allowing one to alternate between two or more representations, tasks, strategies or behaviors in an adaptive way (Chevalier, 2010; Jacques & Zelazo, 2005). Around 3–4 years old, children show a dramatic change in the EF domain, leading to an increase in their switching capacities. For preschool children, cognitive flexibility is typically evaluated with card sorting tasks such as the Dimensional Change Card Sort Test (DCCS; Frye, Zelazo, & Palfai, 1995; Zelazo, Müller, Frye, & Marcovitch, 2003). In this task, children have to sort bidimensional test cards (e.g. color and shape) into two boxes, one box for the first dimension and the other for the second dimension (Chevalier & Blaye, 2006). After sorting the test cards according to the first dimension ("pre-switch phase"; e.g. the color), the children are asked to sort the card according to the second dimension ("post-switch phase"; e.g. the shape; Zelazo, 2006). Before 4 years of age, the standard DCCS is characterized by consistent failure in the post-switch phase: younger children perseverate in sorting the cards according to the first criterion (e.g. color) despite explicit instructions for each trial by the experimenter (Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Jacques & Zelazo, 2005; Kirkham, Cruess, & Diamond, 2003). Children aged 4 years and older typically manage to switch to a new rule as they no longer give perseverative responses based on the previous criterion. In the current study, we aimed to understand whether the key transition occurring between 3 and 4 years old toward more flexible behavior is related to a conceptual change or to an improvement in executive function.

Several theoretical models have provided a conceptual background to explain the cognitive processes of flexibility in 3- to 5-year-

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old children (Zelazo et al., 2003). Most of them argue that the difficulties shown by 3-year-olds in performing the task can be explained by a conceptual deficit.

According to cognitive complexity and control theory (CCC theory, Zelazo, Frye, & Rapus, 1996), the DCCS is characterized by a big "if-if then" rule with two embedded "if" rules that allow children to sort the test cards correctly ("then") depending on the game (e.g. color or shape game; first "if" rule) and on the object depicted on the test card (e.g. blue boat or yellow rabbit, second "if" rule). Depending on the answers to these two embedded rules, children are then able to decide in which box the test card has to go. However, at 3, while children can understand these two pairs of rules, they cannot reason on these rules: They do not know when they have to switch between the rules. Three-year-old children may not have sufficient reflective skills to manipulate the rules and switch from one to the other (Zelazo, 2015). However, several studies have shown that the DCCS can be modified in such a way that it still needs the embedded rule structure to be performed, but results in a significant improvement of children's performance at 3 (reversal switch; use of target puppets, see Perner & Lang, 2002)

A revised version of CCC has therefore been proposed (CCC-r; Zelazo et al., 2003) in which the conflict between test and target cards is mandatory for the use of the embedded rules. However, it is still not clear why it is easier for the children when the dimensions are separated on the card. Kloo, Perner, Aichhorn, and Schmidhuber (2010) suggest that this simplification can be understood in two ways: either because the separation of the dimensions makes them more salient and thus improves the deep conceptual comprehension of the child (redescription theory; Kloo & Perner, 2003, 2005; Zelazo, 2015) or because it helps to reduce the executive conflict between the dimensions (attentional inertia; Diamond, Carlson, & Beck, 2005; Diamond & Kirkham, 2001).

The redescription theory developed by Kloo and Perner (2003, 2005) posits that the failure of 3-year-old children in the DCCS is due to their inability to understand that an object can be described in different ways. This ability only emerges between the age of 4 and 5. Some studies have shown that using redescription training with corrective feedback based on the DCCS task improved performance in the standard DCCS at age 3 but interestingly also improved performances in theory of mind (e.g.: False Beliefs tasks; Kloo & Perner, 2003). Thus, redescription training helped children to understand that an event or an object may have alternative representations or descriptions depending on the point of view or on the goal (Melot & Angeard, 2003; Slaughter & Gopnik, 1996).

Performing the DCCS requires describing the same bidimensional object in one way and then in another way (e.g., by shape and then by color). According to Kloo (2003), failure among 3-year-olds is due to the use of a general sorting rule (e.g.: children put together all the cards that depict the same object) for both the pre-switch and the post-switch phase. Because DCCS instructions do not explicitly explain the need to consider the cards differently between the two phases of the test, children continue to sort the cards according to the first dimension they used, in accordance with the general rule they have built (Kloo & Perner, 2005). This incapacity to understand that the bidimensional cards have to be *re*-described is the core of redescription theory (Kloo & Perner, 2003, 2005). If the need to redescribe the card according to the two dimensions is made more explicit, it should help children to grasp the presence of the two dimensions and then lead to better performances at age 3. To support this theory, the authors created a new version of the DCCS to emphasize the two perceptive dimensions by visually separating them on the card (Kloo, Perner, Aichhorn, & Schmidhuber, 2010). In this "spatially distinct" version of the DCCS, color and shape are depicted in two different objects and locations on the same card (e.g.: the outline of an apple [the shape] is located on the left side of the card and a red circle [the color] on the right side.) This spatially distinct version appears to be easier for 3- to 4-year-old children than the standard DCCS (Kloo & Perner, 2005). However, in this spatially distinct version, the concept of redescription (the need to consider *one* object in a different way to before) may not really be fully engaged (Kloo & Perner, 2005). In both the standard and the separated DCCS, the card has to be redescribed from the pre- to the post-switch phase. However, in the separated DCCS, the child has to switch between two unidimensional objects whereas the standard DCCS requires redescribing a single bidimensional object. Thus, in the separated version although children may understand the existence of the two dimensions because they are displayed as two different objects and locations on the card, they may not fully comprehend that a single object can be considered bidimensional. The same issue arose when authors tried to integrate the dimensions on the card by overlapping them (Overlapping DCCS; Kloo et al., 2010) or making them contiguous (Diamond et al., 2005). In their contiguous DCCS version, Diamond et al. (2005) depicted the black outline of an object on a colored background. Even if the background is not an object itself, it is still a distinct dimension that can be processed independently from the shape. Hence, the cards do not display bidimensional objects but two one-dimensional stimuli that do not require children to call on redescription to perform the task. This may explain why Diamond et al. (2005) found a better performance in their DCCS at age 3 than in the standard DCCS.

According to Kloo et al. (2010), the DCCS version of Diamond et al. (2005) just reduces the executive demand by making inhibition of the first perceptual dimension unnecessary. In contrast to redescription theory, the attentional inertia account developed by Diamond et al. (2001, 2005) argues that 3-year-olds' failure is not related to a conceptual deficit but to executive inefficiency. According to this theory, 3-year-olds' difficulty can be explained by their inability to disengage their attentional focus from the first perceptual dimension (*e.g.* the color) in order to concentrate on the second (*e.g.* the shape). Even if children are able to understand the coexistence of two dimensions and the need to describe the object according to these dimensions successively, their attention remains focused on the first perceptual dimension. The lack of inhibition and the inability to disengage from a mindset that is no longer relevant is claimed to explain their difficulties. Visually separating the dimensions on the card helps to reduce the inhibition cost and thus allows 3-year-olds to inhibit the first and now inadequate dimension in order to switch to the second (Diamond et al., 2005).

A new version of the DCCS therefore needs to be created to highlight redescription instead of reducing inhibition and executive demand as in the existing separated versions of the DCCS. Thus, the first goal of the present study was to verify the contribution of redescription to 3-year-olds' success in the DCCS. We gave children redescription training focusing on the conceptual understanding of the need to consider that the cards have two representations and describe them according to each dimension alternatively. We predicted that redescription training would improve performance in the standard DCCS. Children failing the standard DCCS were randomly assigned to one of two training groups: The neutral training group (*i.e.* that had no effect on the post-test

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