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Executive function and verbal self-regulation in childhood: Developmental linkages between partially internalized private speech and cognitive flexibility

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ABSTRACT

Recent studies have noted that executive function and the use of self-regulatory private speech are related in childhood, and proposed that the critical leap that occurs in the development of executive function between the ages of three and six years may be due to the onset of language-based self-regulatory functions at this age. This research explored the relationship between executive function and private speech in a cross-sectional study of 81 children between four and seven years of age. The children performed an executive function task, the Dimensional Change Card Sort (DCCS), and children's use of private speech was observed during a categorization task. The results indicated that, after controlling for children's age, gender, verbal abilities, and fluid reasoning, children's use of partially internalized private speech during the categorization task was significantly related to the number of phases successfully passed on the DCCS task, which required them to switch between card sorting rules. Children who used more partially internalized private speech were more likely to pass the most challenging phase of the DCCS task that assesses the ability to flexibly use different sorting rules according to a higher-order rule. We discuss the role of verbal mediation in the development of cognitive flexibility and its implications for the design of intervention programs for children who possess deficits of executive function.

1. Introduction

A significant number of recent studies have analyzed the development of executive function (EF) during childhood (Brocki & Bohlin, 2004; Carlson & Meltzoff, 2008; Davidson, Amso, Cruess, & Diamond, 2006; Henning, Spinath, & Aschersleben, 2011). EF is defined as the skill set that allows the child to plan, monitor, and evaluate his or her performance when solving a problem (Zelazo & Frye, 1997; Zelazo, Müller, Frye, & Marcovitch, 2003). EF is an integrated construct that consists of different subcomponents: response inhibition, working memory, and attentional set shifting (Miyake et al., 2000; Zelazo, Carter, Reznick, & Frye, 1997). Each of these EF components develops gradually from the earliest years of life; however, researchers have frequently observed a critical change in the development of EF between three and six years of age (Garon, Bryson, & Smith, 2008). Despite the consistency of the evidence regarding this qualitative change in the development of EF, there is not complete agreement on possible explanations about its nature and the mechanisms that support its occurrence. Our study's main objective was to investigate the characteristics of this critical leap in the development of EF in early childhood by examining the relationship between children's performance on an EF task and children's self-regulatory private speech observed in a categorization task.

The Dimensional Change Card Sort task (DCCS; Frye, Zelazo, & Palfai, 1995; Zelazo & Frye, 1997) is a simplified version of the Wisconsin Card Sort Task (WCST; Grant & Berg, 1948) that is similar in purpose and form. The DCCS is a very useful tool to evaluate the EF of children between the ages of three and six years (Carlson, 2005; Jacques, Zelazo, Kirkham, & Semcesen, 1999; Müller, Zelazo, & Imrisek, 2005). In the standard version of the DCCS task (Zelazo, 2006), children are first asked to order a series of bivalent cards according to a rule (e.g., color), the pre-shift phase. In the second phase of the task, post-shift, the sorting rule is changed (e.g., to shape). Finally, in the most advanced phase, border phase, the children are asked to use both rules at the same time depending on the presence of a third marker on the card (e.g., a black border). In the DCCS task, children's cognitive flexibility is increasingly challenged by switching from one rule to another; first, in the post-shift phase, children have to switch to the new sorting criterion and not persevere to ordering the bivalent test cards with the rule of

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the preceding phase, and second, in the border phase, children have to flexibly switch the set of rules using a higher-order rule (Kloo, Perner, Aichhorn, & Schmidhuber, 2010; Zelazo, 2006). In a study of children between 3- and 6-year-olds, Henning et al. (2011) observed that only approximately 50% of the children between 3- and 4-year-olds passed the second phase of the DCCS (post-shift), while the majority of the 5-year-olds (80%) and 6-year-olds (92%) passed the second phase. However, 90% of the 5-year-olds and 77% of the 6-year-olds failed the third phase of the DCCS test, which requires the use of several alternative rules.

Child difficulties in the performance of the DCCS task may be due to a lack of capacity for representational flexibility (Happaney & Zelazo, 2003; Jacques et al., 1999; Müller et al., 2005). Other researchers have justified these results in terms of difficulty encountered along some of the EF dimensions, such as a problem in response inhibition (Bialystok & Martin, 2004; Carlson & Meltzoff, 2008), difficulty in maintaining the goals of the task in the working memory (Morton & Munakata, 2002; Munakata, Morton, & Yerys, 2003), or an inability to redirect the attention to an important new dimension while the previous dimension is still present ('attentional inertia'; Diamond, Kirkham, & Amso, 2002; Kirkham, Cruess, & Diamond, 2003).

The critical leap that occurs in the development of EF between the ages of three and six years may be due to the onset of language-based self-regulatory functions at this age (Zelazo & Frye, 1997; Zelazo et al., 2003). These verbal self-regulatory functions emerge when children's language becomes a tool to guide goal-directed behaviors. The verbal mediation of behavior should provide children with greater cognitive flexibility (Jacques & Zelazo, 2005; Zelazo & Frye, 1997). Some studies have found a positive association between performance in the DCCS task and children's verbal skills, an outcome that partially supports the claims about the mediating role of language in the development of EF (Carlson & Beck, 2009; Fuhs & Day, 2011; Henning et al., 2011; Müller et al., 2005).

However, the empirical studies that were devoted to test the hypothesis about the critical role of verbal self-regulatory functions in the developmental leap in EF have not provided conclusive results. These studies have focused on the use of 'verbal labeling' as a resource to test the hypothesis of verbal self-regulation in the DCCS task by asking the children to label aloud the rule that they used to sort the cards on each item. Kirkham et al. (2003), in a sample of three-year-old children, compared children's performance on a standard version of the DCCS with that on a verbal labeling condition in which children were encouraged to label the test card's sorting dimension on the first pre- and post-switch trial. Kirkham et al. found that the performance in the post-switch phase improved when the children were trained to state the label aloud. However, Müller, Zelazo, Lurye, and Liebermann (2008) failed to replicate the labeling effect in three-year-old children performing the DCCS task. Müller et al. did not find an improvement in children's performance in Kirkham et al.'s verbal labeling condition (Experiment 2). In Müller et al.'s study (Experiment 1), the labeling effect was not observed when the child was prompted to label the relevant sorting dimension either on the first trial only or on every trial.

In addition, there is no theoretical agreement among the researchers regarding why verbal labeling could improve children's execution in the DCCS task. Kirkham and Diamond (2003) proposed that the verbal labeling reduces attentional inertia, while Munakata et al. (2003) suggested that verbal labeling extends the amount of time that the rule remains in working memory. Happaney and Zelazo (2003) proposed that verbal labeling facilitates the ability to reflect on the rule system. A contradictory interpretation of the results may have been observed because the verbal labeling procedure was not adequate to assess the effect of verbal mediation on DCCS task performance. As research from the dual-task paradigm has shown, forcing children to perform a verbal task (labeling) while simultaneously performing an EF task could cause the verbal task to interfere in the performance of the EF task due to an articulatory suppression effect (Emerson & Miyake, 2003; Lidstone, Meins, & Fernyhough, 2010). On the other hand, verbal labeling the rule allows researchers to observe whether the children know the rule. The children's knowledge of the rule does not necessarily indicate that they use it in their attempts to solve the EF task (Happaney & Zelazo, 2003). Taking into account these results, we suggest that another approach to measure the effect of verbal regulation on EF development would be to examine the spontaneous task-relevant self-regulating speech used by children while they perform EF tasks (Winsler, 2009).

Several researchers have suggested that the development of EF in children may be associated with a qualitative change in the self-regulatory function of language (Fernyhough & Fradley, 2005; Jacques & Zelazo, 2005; Müller et al., 2008; Wallace, Silvers, Martin, & Kenworthy, 2009; Zelazo & Frye, 1997). Following Vygotsky (1934/1987), the self-regulatory function of language emerges between the ages of three and five years as children begin to use private speech, which is a type of speech that is not addressed toward others. It has been widely observed that children's overt private speech increases from three to five years of age, then declines in frequency as it is transformed first in partially internalized private speech (whispers and muttering), and then into verbal thought, or inner speech (Berk, 1986; Winsler, 2009; Winsler, Diaz, & Montero, 1997; Winsler & Naglieri, 2003). There are, in the extant literature, numerous studies that support these developmental trajectories in children's use of self-talk and the assumption that children's private speech is positively correlated with concurrent or future task performance (Fernyhough & Fradley, 2005; Lidstone et al., 2010; Winsler, Diaz, Atencio, McCarthy, & Chabay, 2000; Winsler, Diaz, McCarthy, Atencio, & Chabay, 1999). According to Vygotsky, the internalization of speech represents how cognitive performance begins to be verbally mediated in childhood, allowing language to become a tool for planning, controlling, and evaluating actions (Al-Namlah, Fernyhough, & Meins, 2006; Al-Namlah, Meins, & Fernyhough, 2012). Thus, verbal mediation allows children to maintain more than one rule in mind, to inhibit prepotent responses, and to keep a goal in focus; skills that are directly linked to EF (Diamond et al., 2002; Fuhs & Day, 2011). It has been claimed that more highly internalized forms of speech indicates more advanced verbal mediation, and that the rate and internalization level of children's private speech in performing a task can be representative of children's verbal self-regulatory strategies across different tasks, contexts, and timepoints (Lidstone, Meins, & Fernyhough, 2011). Winsler, De Leon, Wallace, Carlton, and Willson-Quayle (2003) found evidence for children's private speech stability across different tasks and timepoints, and consistency with children's reported behavior at school and home – children whose private speech was more partially internalized had fewer externalizing behavior problems and better social skills.

It has been proposed that the development of EF in childhood could be connected to the self-regulatory function of private speech (Fernyhough & Fradley, 2005; Winsler, 2009). Some studies have shown that overt private speech was more frequently used among children who possessed an EF deficit, such as an autism spectrum disorder or ADHD (Winsler, Abar, Feder, Schunn, & Alarcón, 2007; Winsler, Manfra, & Diaz, 2007). Other studies have reported positive relationships between the use of partially covert private speech and performance on EF tasks. In recent works, the Tower of London task (TOL; Shallice, 1982) has been used to examine the private speech used by children performing this task. The TOL task requires (a) EF-type skills (such as planning and monitoring) to place pieces in accordance with a model target and (b) the inhibition of incorrect movements. Fernyhough and Fradley (2005) evaluated children