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Program of arithmetic improvement by means of cognitive enhancement: An intervention in children with special educational needs

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ABSTRACT

This study reports the cognitive and arithmetic improvement of a mathematical model based on the program PASS Remedial Program (PREP), which aims to improve specific cognitive processes underlying academic skills such as arithmetic. For this purpose, a group of 20 students from the last four grades of Primary Education was divided into two groups. One group ($n = 10$) received training in the program and the other served as control. Students were assessed at pre and post intervention in the PASS cognitive processes (planning, attention, simultaneous and successive processing), general level of intelligence, and arithmetic performance in calculus and solving problems. Performance of children from the experimental group was significantly higher than that of the control group in cognitive process and arithmetic. This joint enhancement of cognitive and arithmetic processes was a result of the operationalization of training that promotes the encoding task, attention and planning, and learning by induction, mediation and verbalization. The implications of this are discussed.

1. Introduction

The present study aims to improve the arithmetic abilities of the children who present educational support needs associated with low intelligence and children who have learning difficulties throughout their school years.

Current studies show that children's basic knowledge in kindergarten of counting, numbers, and elemental arithmetic are powerful predictors of mathematical achievement in subsequent schooling (Duncan et al., 2007). However, achievement of basic mathematical competence, in addition to domain specific skills, also requires general domain skills that affect learning (Geary, 2011; Mazzocco, Feigenson, & Halberda, 2011; Passolunghi & Lanfranchi, 2012).

Among the domain specific mathematical skills (Geary, 2011), the skill of numerical comparison, which addresses the magnitude of the number—its value—has been underscored. Knowledge of numbers requires verbal and symbolized learning of numbers, reading, the place value, numeric sequences, and arithmetic operations with one or more digits (Levine, Jordan, & Huttenlocher, 1992; Siegler & Booth, 2004). There is evidence of the relationship of the ability to understand and represent numerical magnitude with the development of mathematics (De Smedt et al., 2009; Geary, Bow-Thomas, & Yao, 1992).

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Failures in the basic skills of number comparison, counting, reading and writing numbers, and place position lead to difficulties in solving arithmetic operations (Geary, Hamson, & Hoard, 2000; Landerl, Bevan, & Butterworth, 2004).

Among the general domain skills related to learning and also to learning mathematics, the short-term memory, the working memory (Geary, 2011; Passolunghi & Lanfranchi, 2012), and planning (Best, Miller, & Naglieri, 2011; Das, Naglieri, & Kirby, 1994) have been particularly underscored. Deficits in the working memory components of the visual–spatial sketchpad (McLean & Hitch, 1999) and the phonological loop (Geary, 2011) lead to differential learning difficulties in various specific learning areas of mathematics and number representation, problem solving, and the numerical line that are attributed to the visual–spatial sketchpad, whereas other difficulties, such as counting to solve simple addition problems, are attributed to the phonological loop.

Students with poor performance in mathematics also perform poorly in executive control tasks and inhibition of irrelevant information (Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007; Murphy, Mazzocco, Hanich, & Early, 2007; Passolunghi & Siegel, 2004; St Clair-Thompson & Gathercole, 2006). Their central executive is particularly compromised (Bull, Johnston, & Roy, 1999; Geary et al., 2007; Swanson, 1993), with each one of its components (maintaining information in working memory, task switching, and inhibiting the retrieval of irrelevant information) affecting mathematical learning in a different way (Bull & Scerif, 2001; Murphy et al., 2007; Passolunghi, Cornoldi, & De Liberto, 1999; Passolunghi & Siegel, 2004).

Poor performance is also observed in mathematical tasks that require planning (Das et al., 1994). Planning is currently considered a general domain skill (Best et al., 2011) that influences mathematical performance at all schooling stages (Garofalo, 1986; Kroesbergen, Van Luit, Naglieri, Taddei, & Franchi, 2010; Naglieri & Das, 1987; Naglieri & Das, 1997b). Planning difficulties are revealed in mathematical disabilities (Naglieri & Gottling, 1995; Naglieri & Gottling, 1997; Naglieri & Johnson, 2000). Planning refers to the use of cognitive strategies to manage goal-oriented behaviors and to the development and implementation of an approach to tasks that are not carried out habitually (Das et al., 1994; Locascio, Mahone, Eason, & Cutting, 2010; Mahone et al., 2002). Planning processes are necessary for students' decision-making about problem solving, self-monitoring, retrieval and application of the mathematical facts, and assessment of their responses (Das et al., 1994). Planning has been operationalized in the D.N: CAS (Naglieri & Das, 1997a) by means of complex tasks whose resolution requires the elaboration of action steps before their execution, assessing these actions (updating the working memory), avoiding or eliminating non-target behavior (inhibition), and changing the course of action if necessary (Naglieri & Das, 2005).

Much of the research on intervention, improvement, and retrieval with poor arithmetic calculators has focused on the development of counting procedures or the retrieval of arithmetic facts due to broadly accepted viewpoint that both disabilities are an explanation and a source of poor mathematical performance (Fuchs et al., 2010).

Other explanations of mathematical learning difficulties have included the improvement of general domain skills such as cognitive control (Diamond, Barnett, Thomas, & Munro, 2007), working memory (Holmes, Gathercole, & Dunning, 2009; Klingberg et al., 2005) or the effects of executive functioning (Thorell, Lindqvist, Nutley, Bohlin, & Klingberg, 2009).

Research on intervention has also focused on the improvement of academic learning skills through training programs based on cognitive processes. These programs are designed to improve the cognitive development underlying domain specific learning in order to improve both the domain specific and cognitive processes by means of which students learn to interpret, recall, manipulate, and use information (Das, Parrila, & Papadopoulos, 2000).

The present study presents the results of a cognitive mathematical intervention program based on the *PASS Remedial Program PREP* model, for the improvement of mathematics and the underlying cognitive processes.

PREP or *PASS Remedial Program* (Das, 2000; Das, Carlson, Davidson, & Longe, 1997) is a model of academic and cognitive intervention that has been used in research of reading for more than three decades. The first studies (Brailsford, Snart, & Das, 1984; Crawford & Das, 1992; Kaufman & Kaufman, 1979; Krywaniuk & Das, 1976; Spencer, Snart, & Das, 1989) found that simultaneous processing is closely related to reading comprehension, and successive processing to decoding words. In a second analysis, using the *PASS Reading Enhancement Program* (Carlson & Das, 1997; Das, 1999, 2000; Das, Mishra, & Pool, 1995; Papadopoulos, Das, Parrila, & Kirby, 2003; Parrila, Das, Kendrick, Papadopoulos, & Kirby, 1999), improvement was also observed in word reading, reading comprehension, and cognitive processing strategies (Hayward, Das, & Janzen, 2007). Das et al. (1995) proved the higher efficacy of the complete reading PREP compared to the application of global PREP tasks only and to the PREP bridge tasks. Carlson and Das (1997) reported the efficacy of PREP in an experimental group of 4th grade students in Chapter 1 programs and in a control group in Word Attack and Word Identification. The results showed significant post-intervention improvement with PREP, as well as significant Group × Time interaction effects. Papadopoulos et al. (2003) also reported a long-term effect of the reading results of the PREP through a significant improvement in pseudo-word reading in comparison with a control group.

Subsequent replication studies have essentially reproduced the original results with children from 3rd, 4th, 5th, and 6th grade (Boden & Kirby, 1995); in 1st grade (Parrila et al., 1999) and 2nd grade (Ramos, Conde, Alfonso, & Deaño, 2014). Currently, studies with reading PREP successfully analyzed its efficacy to jointly improve reading difficulties and the underlying cognitive weakness, emphasizing its preventive value for reading difficulties (Papadopoulos, Charalambous, Kanari, & Loizou, 2004; Ramos et al., 2014).

The results of the above-mentioned PREP programs show that the most effective procedure to teach these cognitive skills includes teaching inference, internalization of principles, mediation, and verbalization designed to allow subjects to