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The role of the different components of attention on calculation skill

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ABSTRACT

Attention is a heterogeneous function that comprises different components. Many studies have investigated the role of attention on academic achievement. However, the influence of attention on calculation performances has not been clearly defined. This study aimed to investigate the contribution of the different components of attention on calculation skill during primary school.

Participants: 314 children who attended the first, third and fifth grades of two public primary schools in Italy participated in this study.

Measures: The study was conducted using two standardized instruments assessing calculation and attention skills.

Results: Results highlighted several interesting points concerning the relationships that occur among attention and calculation skills. Findings showed that attention plays a pivotal role in arithmetic performances. Different components of attention affected written calculation ability, numerical knowledge, calculation accuracy and calculation speed in children attending primary school. Statistical analyses for each scholastic grade showed that attention is of key importance in acquiring calculation skill.

1. Introduction

Attention is a heterogeneous function that underlies and energizes all cognitive activities, such as learning, memory, thinking and reasoning. It needs to function adequately for the correct development of complex cognitive abilities and regular scholastic progress (Noterdaeme, Amorosa, Mildenberger, Sitter, & Minow, 2001).

Attention comprises several components: “simple reaction time”, “simple immediate span of attention”, “selectivity”, “maintenance”, “divided attention”, and “attentive shifting”. “Simple reaction time” is the time needed to perceive the appearance of environmental stimuli. “Simple immediate span of attention” determines how much information can be grasped at once. It is not only a form of working memory but also an integral component of attentive functioning (Howieson & Lezak, 1994). “Selectivity” is the capacity to highlight a stimulus while suppressing awareness of competing distractions (Johnston & Dark, 1986; Russell, 1975). “Maintenance”, also defined as “sustained attention”, determines how much information can be grasped and maintained at the same time (Douglas, 1972; Howieson & Lezak, 1994). “Divided attention” is the capacity to respond to more than one task at a time or to multiple elements or operations within a task as in a complex mental task (Sohlberg & Mateer, 1989; Stuus et al., 1989). Finally, “attentive shifting”, consists of the capacity to shift focus and tasks (Johnston & Dark, 1986; Sack & Rice, 1974; Sohlberg & Mateer, 1989). Each of these aspects of attention is regulated by different neural structures that are activated during the operation of daily behavior (Desimone & Duncan, 1995; Mangun, 1995).

Attention increases with age; age-related changes in attention ameliorate a child response to environmental stimuli.

Many studies have examined the role of attention on academic achievement (Alexander, Entwisle, & Dauber, 1994; Raver, Smith-Donald, Hayes, & Jones, 2005). These studies suggested that the ability to control and sustain attention can predict achievement test scores during preschool and early elementary grades. Attention skills are associated with later academic achievement (Duncan et al., 2007; Howse, Lange, Farran, & Boyles, 2003; McClelland, Morrison, & Holmes, 2000; Yen, Konold, & McDermott, 2004). They influence scholastic performances both directly and indirectly. Attention influences, in fact, learning processes and children's engagement in scholastic activities (Ladd, Birch, & Buhs, 1999; Pianta & Stuhlman, 2004).

Several studies have analyzed the role of attention in the acquisition of basic scholastic skills, such as reading and writing (Kristjansson, 2007; La Berge, 1990; Muter, Hulmle, Snowling, & Stevenson, 2004; Vellutino, Fletcher, Snowling, & Scanlon, 2004) in children attending primary school. Only few studies analyzed the relationship between attention and mathematical performances. Furthermore, the majority of these studies have investigated specific math disabilities (Geary & Hoard, 2005; Rourke, 1993; Temple & Sherwood, 2002) or subcomponents of mathematical skills (Geary, 1993; Geary, Hoard, & Hamson, 1999; Jordan, Hanich, & Kaplan, 2003; Kulak, 1993). Geary et al. (1999) suggested that attention plays a pivotal role in math learning

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because it affects how children initiate and direct their processing of information in different tasks, how they comprehend those tasks, and how they retrieve representations of to-be-remembered information when doing tasks. However, the role of the different components of attention on math performances has not been clearly defined.

Deficits in attention have been associated to difficulties in the acquisition of scholastic skills, such as reading, writing, and arithmetic (Mayes & Calhoun, 2006). In this regard, learning disabilities often occur along with and/or are complicated by problems in attention (Johnson, Altmaier, & Richman, 1999; Commodari, 2012).

Students with attention deficit disorder, with or without hyperactivity (ADHD), generally have poor scholastic outcomes (e.g., Barkley, Fischer, Edelbrock, & Smallish, 1990; Fergusson, Lynskey, & Horwood, 1997) and often present learning disabilities (Mayes & Calhoun, 2006). With respect to math skill, research on ADHD showed that children with this pathology presented poorer performances in the calculation and mathematical problem solving, compared to their peers who presented a typical development (Gagne, 1983; Kercood, Zentall, & Lee, 2004; Stoffel, 2004; Zentall, Smith, Lee, & Wieczorek, 1994).

1.1. Arithmetic skill and its cognitive prerequisites

Math skill is the individual's ability to accurately predict, quantify, and verify relationships.

The use of numbers to describe or explain these relationships is an expected progression of the development of mathematics competence (Vanderheyden & Burns, 2009). Mathematical performance is made up of a number of components, such as basic knowledge of numbers, memory for arithmetical facts, understanding of mathematical concepts, and the ability to follow procedures (Dowker, 1998; Gersten, Jordan, & Flojo, 2005).

McCloskey, Caramazza, and Basili (1985) differentiated the ability to understand and produce numbers from the ability to calculate. According to their model the number-processing system involves distinct mechanisms for number comprehension and number production. Within the comprehension and production subsystems, the components for processing Arabic numbers are separated from the components for processing verbal numbers. The calculation system includes three major components, in addition to number-processing mechanisms: a cognitive mechanism for processing of operational symbols or words that identify the operation to be performed, retrieval of basic arithmetic facts, and execution of the calculation procedure. These components are diversely involved in mental and written calculations. Furthermore, any calculation task requires some sort of number-production and/or comprehension abilities. Hence, damage to a component of the number processing system should lead to deficits on calculation tasks requiring that component of processing.

On the basis of this model, Cornoldi and Lucangeli (2004) identified as the main components of calculation competence the following skills: numerical knowledge, calculation accuracy, and calculation speed. Numerical knowledge is the set of skills and knowledge that enables a child to understand numerical quantities and their transformations (Dehaene, Dupoux, & Mehler, 1990; Lucangeli, 1999). Calculation accuracy and speed determine a child's capacity to solve correctly and rapidly arithmetic calculations (Cornoldi & Lucangeli, 2004; Jordan & Montani, 1997). These abilities are involved in mental and written calculations. However, mental and written calculations require different, even if related, procedures and processes (Cornoldi, Lucangeli, & Bellina, 2002). In most children, arithmetic learning difficulties concern only one these abilities: numerical knowledge, the use of procedures in written calculation, or speed and accuracy in mental and written calculations (Cornoldi & Lucangeli, 2004).

Development of arithmetic competence is not always easy for children, who often experience difficulties in the execution of arithmetic tasks. In this regard, Fuchs et al. (2005) found that between 4 and 7% of the school age population experiences some form of math difficulty. Little is known about the development of math skills (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004), and about the cognitive prerequisites of arithmetic performances. Math skills are related to age and cognitive development. Children develop an understanding of early mathematical concepts before start school and begin math learning during primary school. The majority of the studies that have analyzed the role of cognitive processes in math learning have focused on working memory (Baddeley, 1986). These studies showed that working memory plays a role in the performance of arithmetic operations (De Rammelaere, Stuyven, & Vandierendonck, 2001; De Rammelaere & Vandierendonck, 2001; Furst & Hitch, 2000; Seitz & Schumann-Hengsteler, 2000; D'Amico & Guarnera, 2005) and other mathematical tasks (Raghubar, Barnes, & Hecht, 2010). Although it is well-established that working memory is closely linked to mathematical skills, this relationship is mediated by the characteristic of the task and the child's age (Alloway & Passolunghi, 2011). However, considerable controversy remains about whether working memory is causally implicated in mathematical development and disabilities (Butterworth & Reigosa, 2007; Geary, Hoard, Nugent, & Byrd-Craven, 2007).

Working memory models vary on the number of dimensions (Baddeley & Hitch, 1974; Engle, Tuholski, Laughlin, & Conway, 1999; Raghubar et al., 2010). Despite these differences, all models consider attention intimately related to working memory. The central executive component of working memory is an attentive controlling system involved in coordinating performance of separate tasks. The processes that have been attributed to the central executive component include inhibition of irrelevant information, task switching, information updating and goal management.

These processes are also the main aspects of attention. Moreover, simple immediate span of attention is not only a form of working memory but also an integral component of attentive functioning (Howieson & Lezak, 1994).

Fuchs et al. (2005) found that attention, rather than working memory, is a significant predictor of arithmetic, algorithms and mathematical problem solving. In particular, the inability to block out extraneous stimulus from working memory seemed to be significant. In addition, Fuchs et al. (2006) found a relation between arithmetic skill, attentive behavior, processing speed, and phonological decoding.

1.2. Research aim

On the basis of the evidence that attention plays a pivotal role in scholastic learning, this cross-sectional study aimed at analyzing the relationships between attention and calculation skill in children. In particular, the study investigated 1) the differences in attention and calculation skills in children who present different level of formal math learning, 2) the contribution of the main components of attention on calculation skill, and 3) the role of the different components of attention on calculation skills in children who were at different levels of math formal learning.

Calculation and attention skills in children attending the first, third and fifth grades of primary school were measured. The choice to assess children who went to the first, third and fifth grades of primary school depends on the characteristics of Italian scholastic system. In Italy, children begin to study math at the first grade; they might be able to correctly execute the four arithmetic operations in the third grade. At the end of the third grade, a child can be diagnosed as affected by dyscalculia. In the fifth grade (last grade of primary school) children acquire more complex aspects of math skills.

Although previous studies have analyzed the involvement of attention in math performances, the majority of these studies analyzed only single aspects of attention. This study aimed at overcoming this limitation using a measure which assesses all the components of attention.