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Review

Working memory and mathematics in primary school children: A meta-analysis

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ABSTRACT

Working memory, including central executive functions (inhibition, shifting and updating) are factors thought to play a central role in mathematical skill development. However, results reported with regard to the associations between mathematics and working memory components are inconsistent. The aim of this meta-analysis is twofold: to investigate the strength of this relation, and to establish whether the variation in the association is caused by tests, sample characteristics and study and other methodological characteristics. Results indicate that all working memory components are associated with mathematical performance, with the highest correlation between mathematics and verbal updating. Variation in the strength of the associations can consistently be explained by the type of mathematics measure used: general tests yield stronger correlations than more specific tests. Furthermore, characteristics of working memory measures, age and sample explain variance in correlations in some analyses. Interpretations of the contribution of moderator variables to various models are discussed.

Contents

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1. Introduction

Solving mathematical problems is an important activity in the lives of children. From an early age onwards, learning to count, acquiring number skills, and performing mathematical operations become part of children's daily activities. These activities remain important throughout a person's life. Research concerning the underpinnings of success and deficiencies in mathematical skills has expanded during the past two decades. A number of cognitive mechanisms underlying these mathematical skills have been proposed and their contribution to the development of mathematical skill has been investigated. A factor that is thought to play a central role in mathematic skill development is the capacity and the efficiency of working memory and the executive functions: inhibition, shifting and updating (e.g., Bull and Scerif, 2001; Geary, Hoard, Byrd-Craven, & DeSoto, 2004; Passolunghi, Mammarella, & Altoè, 2008; St Clair-Thompson and Gathercole, 2006). Working memory capacity is frequently used as a predictor of skills in mathematics at a later point in time (see: LeFevre, DeStefano, Coleman, & Shanahan, 2005). The number of studies in which the predictive value of working memory and executive functions for mathematical performance is investigated has increased sharply, but the pattern of results is inconsistent: mathematics performance is not consistently predicted by one or all working memory components. Therefore, the present study serves as a meta-analysis of studies in which this relationship was investigated, to investigate whether each working memory component is related to mathematics performance. Moreover, to find an explanation for conflicting results, we investigated the influence of various moderator variables: the type of mathematics measurement used, characteristics of the working memory tasks, children's ages, the population (typical or atypical), the inclusion of control variables and the country and year of origin of the study.

1.1. Working memory

The most widely used model of working memory is the multi-component model originally proposed by Baddeley and Hitch (1974). This model comprises different subcomponents, each with its own function and capacity. Two slave systems, the visuospatial sketchpad and the phonological loop, are responsible for temporary storage of visual and spatial information, and phonological and auditory information, respectively. Capacity of the slave systems is usually measured through simple span tasks, in which increasingly longer strings of information must be replicated (e.g., a dot appearing in different consecutive locations for the visuospatial sketchpad and word lists for the phonological loop). A third component, the central executive, coordinates information stored within the slave systems. Capacity of the central executive is traditionally measured with complex span tasks. In these tasks, a series of items must also be replicated, but this information must first be manipulated: e.g., the items must be recalled backwards, or must be counted first. In other words, the slave systems require only storage of information, while the central executive also requires coordination of information (Oberauer, Süß, Wilhelm, & Wittman, 2003).

Since the formulation of the working memory model, it has been used extensively to inform research, but also educational practise, and it has been applied widely to a wide range of aspects of human thought (see: Baddeley, 2007).The three-factor model including the central executive, the visuospatial sketchpad, and the phonological loop (Baddeley and Hitch, 1974) provided good fit to working memory data of children of various ages (Gathercole, Pickering, Ambridge, & Wearing, 2004).