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Numerical competence in young children and in children with mathematics learning disabilities

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Abstract

A longitudinal study was conducted on 82 children to investigate, firstly the numerical competence of young children and the predictive value of (pre)-numerical tests in kindergarten, and, secondly, whether children's knowledge of the numerical system and representation of the number size is related to their computation and logical knowledge and to their counting skills. In an additional cross-sectional study on 30 children with a clinical diagnosis of mathematical learning disability (MLD) of 8,5 years, age- and ability-matched with 2 × 30 children the same parameters of numerical competence were assessed. The longitudinal data showed individual differences in numerosity, as well as the relationship between a delay in arithmetics in grade 1 and problems on numerosity in kindergarten. In the cross-sectional results some evidence was found for the independence of numerical abilities in MLD-children. About 13% of them had still severe pre-numerical processing deficits (in number sequence production, cardinality skills and logical knowledge) in grade 3. About 67% had severe difficulties in executing calculation procedures and a lack of conceptual knowledge. A feature of 87% of the MLD-children was severe translation deficits, with a significantly worse knowledge of number words compared with the knowledge of Arab numerals. Finally a severe deficit in subitizing was found to be present in 33% of the MLD children. On a group level the processing deficits were linked to understanding numerosity, since the ability-matched younger children and the MLD-children had the same pre-numerical and numerical profile. Implications for the assessment of mathematical disabilities and the value of TEDI-MATH® as an instrument in this process are discussed.
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1. Introduction

1.1. Components of numerical competence

Several components (see Fig. 1) were found important for young children to develop numerical competence and to solve arithmetical problems adequately (Fuson et al., 1997; Gelman & Gallistel, 1978; McCloskey & Macaruso, 1995; Piaget & Szeminska, 1941; Sowder, 1992). We focus on five of these components underlying numerical competence of young children up to grade 3.

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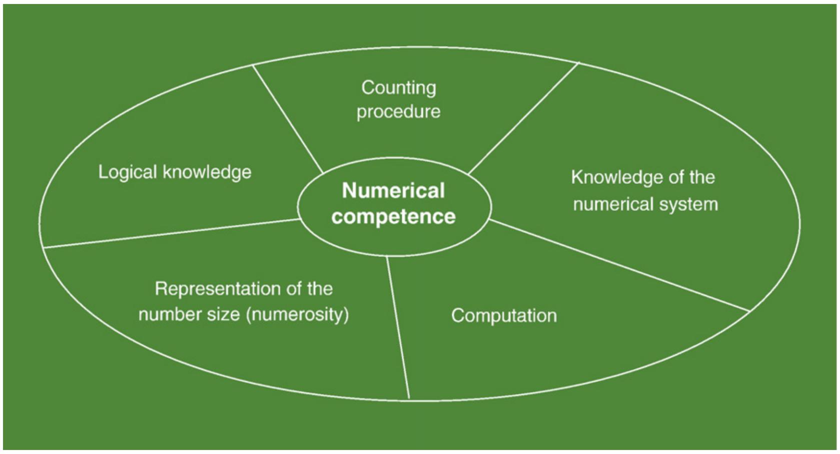

Fig. 1. Theoretical framework integrating several components of mathematical problem solving.

Numerical competence depends on adequate *logical operations on numbers*. Piaget and Szeminska (1941) specified the logical abilities that children progressively acquire to master the concept of number. Co-ordination of classification (gathering items in a set) and seriation (ordering sets of items according to their size) are important for logical thinking on numbers. Although the work of Piaget remains an essential reference for practitioners working with children with mathematical problems, recent studies in the area of mathematics added insights on pre-numerical competence of young children (Donaldson, 1978; Grégoire, 2005; Grégoire, Van Nieuwenhoven, & Noël, 2004; Ruijssenaars, Van Luit, & Van Lieshout, 2004; Van Luit, 2002). In these studies the pragmatic context of studies, language and counting became more important.

The second pre-numerical skill has to do with the *counting procedures*. There are two skills involved in these procedures: number word sequence production and cardinality skills. Firstly, counting depends on the pre-numerical competence and *knowledge of the number word sequences* (e.g., Gelman & Butterworth, 2005). In addition, counting can be seen as a tool to *know the cardinal of a set* (Briars & Siegler, 1984; Gelman & Meck, 1986; Kaye, 1986). According to Gelman and Gallistel (1978) counting is a procedure based on five principles: (1) the stable-order principle according to which the number words have to constitute a stable sequence; (2) the one–one principle according to which every items in a set must be assigned a unique tag; (3) the cardinal principle according to which the last number word pronounced represents the cardinal of the set; (4) the abstraction principle according to which any kind of object, taken as a unit, can be gathered to be counted; (5) the order-irrelevance principle according to which the elements of a set can be counted in any sequence as long as the other counting principles are respected. If these principles are acquired, children can count a linear or random pattern or heterogeneous set of items (e.g., Fuson, 1988).

Furthermore, numerical competence depends on the insight in the number structure or on the knowledge of the position of decades and units and the ability to establish base-ten structure relationships (e.g., McCloskey & Macaruso, 1995). *Knowledge of the numerical system* is required to judge which of two Arab numerals or number words is the larger, to know how many decades and units are for example in 17 and to transcode (write a dictated number or read a number written in Arab code). The understanding and the production of numerical symbols is performed by two components, each one divided into a subsystem for Arab number processing and another one for verbal number processing. The transcoding procedure relates to the transformation for example of Arab representation into verbal representation, and vice-versa (Hüttemann, 1998; McCloskey & Macaruso, 1995).

Numerical competence also depends on knowledge and *computation* skills to calculate and to solve arithmetical operations referring to objects, presented in a number problem format (e.g., $6+3=\_$ or $9-5=\_$ or $2\times4=\_$) or in a verbal format (e.g., Denis had 2 marbles. He won two others. How many marbles had Denis in all?) (Carpenter, Franke, Jacobs, Fennema, & Empson, 1987; Riley, Greeno, & Heller, 1983; Siegler, 1987).

The representation of number size (numerosity) is the fifth skill involved in numerical competence. This numerical skill is involved in subitizing (rapid apprehension of small numerosity) and in estimation of size (Gersten & Chard, 1999; Hannula & Lehtinnen, 2005; Sowder, 1992; Trick & Pylynshyn, 1994). There are even some arguments that problems encountered by pupils with mathematical learning disabilities may be due to a deficit in this skill (Butterworth, 2003).

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