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Mathematical problems in children with developmental coordination disorder

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ABSTRACT

Developmental coordination disorder (DCD) is a heterogeneous disorder, which is often co-morbid with learning disabilities. However, mathematical problems have rarely been studied in DCD. The aim of this study was to investigate the mathematical problems in children with various degrees of motor problems. Specifically, this study explored if the development of mathematical skills in children with DCD is delayed or deficient. Children with DCD performed significantly worse for number fact retrieval and procedural calculation in comparison with age-matched control children. Moreover, children with mild DCD differed significantly from children with severe DCD on both number fact retrieval and procedural calculation. In addition, we found a developmental delay of 1 year for number fact retrieval in children with mild DCD and a developmental delay of 2 years in children with severe DCD. No evidence for a mathematical deficit was found. Diagnostic implications are discussed.

1. Introduction

Developmental coordination disorder (DCD) is defined in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR; American Psychiatric Association [APA], 2000) as a significant impairment in the development of motor coordination, which interferes with academic achievement or activities of daily living. A prevalence of 1.7% in school-aged children has been reported with a higher prevalence among boys than girls (Lingam, Hunt, Golding, Jongmans, & Emond, 2009).

It is well-known that children with DCD often have co-morbid learning disabilities (Alloway & Archibald, 2008; Dewey, Kaplan, Crawford, & Wilson, 2002; Jongmans, Smits-Engelsman, & Schoemaker, 2003; Visser, 2003) including mathematical learning disabilities. Whereas co-morbidity with reading and spelling problems has frequently been investigated (e.g., Cheng, Chen, Tsai, Shen, & Cherng, 2011; Dewey et al., 2002; Fletcher-Flinn, Elmes, & Strugnell, 1997; Lingam et al., 2010), mathematical problems have only been studied indirectly in DCD (Alloway & Archibald, 2008). However, didactical principles such as starting with the manipulation of concrete materials before asking to solve semi-concrete or abstract tasks in a number problem format, illustrate the importance of motor skills to develop mathematical skills. Moreover motor activities such as seriation and classification (Nunes et al., 2007; Piaget & Inhelder, 1956; Stock, Desoete, & Roeyers, 2010)

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and counting (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Gersten, Jordan, & Flojo, 2005; Hannula, Räsänen, & Lehtinen, 2007; Stock, Desoete, & Roeyers, 2009) seem necessary for early mathematics and the mental representation of number concepts. Mental representations lead to the understanding of simple operations such as additions and subtractions (Geary, 1994; Luo, Jose, Huntsinger, & Pigott, 2007).

The existing research about mathematics in children with DCD mainly investigated working memory. These studies established how working memory affects learning in DCD (e.g., mathematics) in comparison to children with other developmental disorders, such as learning disabilities or speech and language disabilities (Alloway, 2007; Alloway & Archibald, 2008; Alloway & Temple, 2007). They found that children with DCD had problems with both working memory as well as short-term memory which was significantly associated with literacy and numeracy. Another approach to study learning in DCD is to look at the automatization of children. The automatization deficit hypothesis states that deficits in the cerebellum could lead to general automatization and balance problems (Fawcett & Nicolson, 1992; Nicolson, Fawcett, & Dean, 2001). One might argue that the problems that children with DCD are confronted with, are due to deficits with automatization (see Visser, 2003) explaining the co-morbidity between motor and mathematical problems. Automatization problems are also described in the semantic memory subtype of mathematical learning disabilities (MLD), focusing on deficits in number fact retrieval (Geary, 1993, 2004). Besides the semantic memory subtype of MLD, there is also evidence for a procedural subtype in MLD (Geary, 1993, 2004; Temple, 1991; Wilson, Revkin, Cohen, Cohen, & Dehaene, 2006). A differentiation in mathematical skills between semantic memory skills (number fact retrieval) and procedural knowledge, seems indicated when exploring mathematical problems in children with DCD. Furthermore, some important similarities between the profile of children with MLD and younger children were described (Chan & Ho, 2010; Geary, 2004; Torbeyns, Verschaffel, & Ghesquiere, 2004). It might be interesting to investigate if this can be extended to children with DCD: are the mathematical problems of children with DCD the result of a developmental delay or rather a deficit? To the best of our knowledge, this has not yet been investigated.

Until recently, there was little consensus about the clinical cut-off scores to diagnose DCD. Recently, two different recommendations appeared, suggesting two different cut-off scores. Whereas the Leeds Consensus Statement (Sugden, Chambers, & Utley, 2006) proposed percentile 5 as the cut-off point, the European Academy of Childhood Disability (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012) was less restrictive and recommended percentile 15. Given these differences, questions arise about whether the characteristics of DCD vary as a function of different performance criteria used by clinicians or researchers. As it concerns children with heterogeneous motor deficits, it might be that these children have a different cognitive profile. One might expect that children with mild DCD have better mathematical skills in comparison to children with severe DCD as previous research has been shown that (fine) motor skills predicts mathematics achievement over time (Luo et al., 2007; Pagani, Fitzpatrick, Archambault, & Janosz, 2010) and an increasing severity of motor problems also increases the range and severity of co-morbid problems (e.g., Jongmans et al., 2003; Rasmussen & Gillberg, 2000). However, we need to be careful with overgeneralization, as it might be that not all children with DCD, regardless of the degree, have problems with mathematics. Therefore, analyses of group and individual differences will be conducted as recommended by Geuze (2010) and Lachance and Mazzocco (2006).

To conclude, we aim to investigate whether (a) children with DCD have problems on the domains of number fact retrieval and procedural calculation; (b) problems can be described as a deficit or as a mild/severe developmental delay; (c) there is a difference on mathematics between children with mild and severe DCD; (d) individual differences besides group differences exist.

2. Methods

2.1. Participants

Forty-three 9-year-old children (14 girls) with DCD participated in this study. Children were recruited by purposeful sampling and reputational case selection through referral by psychologists, speech therapists and physicians in multidisciplinary rehabilitation, special education and centres for developmental disorders and through newsletter advertisements and letters to teachers and parents distributed in special education schools. Children were classified as having DCD if they met the four diagnostic criteria as described in the DSM-IV-TR (American Psychiatric Association [APA], 2000). They all had poor motor coordination substantially below expected (criterion A) confirmed by testing with the Movement Assessment Battery for Children 2 (M-ABC 2; Henderson & Sugden, 2007; Smits-Engelsman, 2010). In some of the subsequent analyses, the group of children with DCD was divided in two groups depending on their motor abilities. Children with mild DCD ($n = 17$) scored between percentile 6 and 15 (i.e., having a total test score between 62 and 68) and children with severe DCD ($n = 26$) scored $\leq$percentile 5 (i.e., having a total test score ≤ 61) on the Movement Assessment Battery for Children 2 (M-ABC 2; Henderson & Sugden, 2007). Functional impairment in daily life or in academic achievement (criterion B) was confirmed for both groups of children, since all of them received physiotherapy for their clumsiness or scored at or below percentile 15 for writing quality or writing speed on the Systematic Screening of Handwriting Difficulties (Smits-Engelsman et al., 2005). Moreover, the motor problems of the children with DCD were not due to a general medical condition or epilepsy (criterion C), which was confirmed by a questionnaire filled out by the parents. Finally (criterion D), all children were typically achieving on intelligence (IQ $\geq$ 80) measured with the short version of the Wechsler Intelligence Scale for Children (WISC-III; Kort et al., 2002; Wechsler, 1991).