

Introduction to the Special Issue: Mathematical abilities in developmental disabilities

Annemie Desoete^{1,2}, Petra Warreyn¹

1. Research in Developmental Disorders Lab, Department of Experimental Clinical and Health Psychology, Ghent University, Belgium

2. Artevelde University College, Ghent, Belgium

Abstract

This special issue includes 11 contributions discussing mathematical abilities and related factors in individuals with developmental disabilities such as dyslexia, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD), Developmental Coordination Disorder (DCD), Intellectual Disability (ID), Williams and Down syndromes and spina bifida, but also in first and second language learners. All studies explore, illustrate and scrutinize available research evidence in the field of understanding mathematical (dis)abilities in neurodevelopmental disorders. They reflect on individual differences versus subtypes, on comorbidity in children with neurodevelopmental disorders, on the extent to which individual differences are related to domain-specific or domain-general factors (such as language and visuospatial factors), on factors that appear promising and positively influencing the learning process of students' learning of mathematics, and on interventions that aim to improve mathematics performance in children with developmental disabilities.

Introduction

Mathematical abilities are needed in all kinds of everyday situations (e.g., calculating prices, measuring distances, estimating amounts and many more). There is also increasing evidence that mathematical ability is not a unitary construct, but instead it is composed of many different subcomponents. Individuals can show marked discrepancies between different components.

Although mathematical abilities seem to be learned quite effortlessly in most people, some children have persisting problems with acquiring and/or applying these abilities, with some problems persisting even into adulthood. This is problematic because mathematical ability is an important predictor of later academic achievement, and since poor mathematical skills in children and adults may lead to decreased perceived competence and increased emotional and behavioral disengagement. In addition, poor mathematical abilities often result in gaining employment in low paid professions during adulthood and have negative consequences for mental health (Ritchie & Bates, 2013). Mathematical disabilities thus have a substantial societal impact.

Up till now research in relation to the mathematical abilities of children and adults with neurodevelopmental disorders remains an underrepresented area of research. As a result of the limited studies, it remains unclear which components of mathematical ability show strengths or difficulties, what predicts typical and atypical achievement and how mathematical under- or high achievement can be detected, understood, and addressed in individuals with neurodevelopmental disorders.

This special issue brings together original papers and reviews about mathematical abilities in neurodevelopmental disorders that may have an impact on policy and/or practice. In this way the issue aims to gain knowledge about the development and pathogenesis of mathematical disabilities and to map mathematical ability and its subcomponents in individuals with

neurodevelopmental disorders. This may advance the understanding of the cognitive architectures that sub-serve human abilities to perceive, represent, learn, and manipulate mathematical information.

The various contributions in this special issue

First, several papers explore mathematical (dis)abilities and subcomponents in children with neurodevelopmental disabilities. **Dowker** reviewed arithmetical strengths and weaknesses in children with dyslexia, DLD, ADHD, and ASD. They concluded that arithmetical weaknesses were more common in children with any of these disorders than in controls, except for ASD, which may also be associated with arithmetic strengths, albeit less frequently than with weaknesses. She also reviewed possible genetic reasons for this increased prevalence of mathematical weaknesses and stressed the importance of other factors related to the comorbid disorders that may influence specific aspects of mathematical abilities more than a genetic overlap. **Gomez** and colleagues studied subitizing and counting in 7-10 year-old children with and without DCD, and showed that, while children with DCD seem to grasp the basic counting rules, they were atypical in both counting and subitizing. However, **Reynvoet** and colleagues focused on word-problem solving, numerosity comparison, arithmetic verification, inhibition and working memory and reported no mathematical problems in 14-16 year-old adolescents with DCD compared to their peers. **Orbach** and colleagues explored the relation between ADHD symptoms, core executive functions (EF), and basic number skills and arithmetic fact retrieval. They reported lower math scores in children with high levels of ADHD symptomatology compared to children with moderate or low levels of symptoms.

Second, two papers explore (predictors of) mathematical skills in children with other disabilities. **Attout** and colleagues focused on the role of visuospatial skills and working memory abilities to explain the differences between participants with and without spina-bifida aged between 7 and 16 years old, in comparison and estimation tasks. They revealed a global magnitude processing deficit for nonnumerical and numerical comparison tasks, but not in symbolic magnitude tasks, compared to the participants without developmental disorders, pointing to the fact that magnitude processing difficulties in children with spina bifida might be due to higher cognitive factors such as visuospatial and working memory processes. **Ranzato** and colleagues explored enumeration and subitizing in Williams and Down syndrome, using eye-tracking technology. They found no significant differences between the groups in accuracy and reaction time, suggesting that individuals with Williams and Down syndrome have no general problems in counting and subitizing. The eye-tracking technology however revealed that they did use atypical scanning strategies for their chronological age.

The next three contributions focus on individual differences or subtypes within Specific Learning Disorders (SLD) and the role of language-related skills. **Kleemans** and colleagues focused on the role of language as precursor of arithmetic skills, geometry and fractions in first-language and second-language learners aged 8-10 years. **Peters** and colleagues investigated numerical magnitude, phonological processing, spatial and verbal skills in children with dyslexia, dyscalculia, or both. **Huijismans** and colleagues explored subtypes in mathematical learning disability through profiles of basic and advanced arithmetic as well as word decoding, number sense, phonological awareness, rapid naming, working memory and reasoning.

Finally, this special issue also includes interventions focusing on mathematical ability (or subcomponents) in children with neurodevelopmental disorders. These contributions suggest some good practices focusing on mathematical ability (or subcomponents) in children with neurodevelopmental disorders. Two contributions focus on the challenge of improving mathematical skills in children with ID and ASD. **Bouck** and colleague) explored the effect of supporting the acquisition, fluency, maintenance, and generalization of life skills math to 14-year old students with ID and/or ASD via schematic diagrams in conjunction with the system of least prompts. **Cox** and colleague performed a literature review in order to provide advice for practitioners searching for empirically validated interventions when dealing with children with ASD and/or ID. To do so, they synthesized literature reviews of mathematics interventions to provide an updated analysis of what we know works for which students under what conditions. Finally, **Reynvoet** and colleagues showed that providing a visual structure (or scaffolding) in word problems reduced the required cognitive load, making the problem solvable for adolescents with **DCD** who have reduced executive functioning skills.

Some preliminary observations concerning the factors influencing math in children with neurodevelopmental disabilities

Mathematical abilities **depend on multiple interacting factors** such as domain-specific knowledge, domain-general or higher cognitive skills and non-cognitive factors.

Dowker concluded that specific aspects of arithmetic in children with neurodevelopmental disorders are often influenced by factors related to these disorders, such as **language comprehension, phonological awareness, verbal and spatial working memory and long-term memory**, and **executive functions**. Genetic aspects may play a more limited role. The involvement of all these factors was indeed confirmed in one or more papers in this special issue.

The importance of **language** for the development of mathematical skills was reported by Kleemans and Segers, who studied 153 first-language (L1) and 80 second-language (L2) learners (10 to 12 years of age). All L1 learners were monolingual speakers of Dutch. The group of L2-learners consisted of Turkish-Dutch and Moroccan-Dutch children. The study revealed that basic linguistic skills indirectly predicted the growth in advanced mathematics via arithmetic skills, whereas advanced linguistic skills directly predicted the growth in geometry and fractions.

Attout, Noël and Rousselle described their study on magnitude processing in 23 individuals, aged between 7 and 16 years old, with spina bifida. They looked at the same processing in 23 participants without developmental disorders, matched one to one with a child with spina bifida at +/- 4 months of chronological age. Their study revealed that higher cognitive factors such as **visuospatial skills** and **working memory** abilities could partially explain the differences between groups in comparison and estimation tasks.

Reynvoet, Marinova and Sasanguie focused on the domain-general factor of executive functions in DCD. They revealed that children with DCD performed worse on several executive functioning tasks compared to children without DCD. In addition, they

revealed that providing a visual structure reduced the required **cognitive load**, making the problem solvable for DCD children, pointing to the contribution of **executive functioning** skills in mathematical problem solving.

Orbach, Herzog, and Fritz also focused on the association between **executive functioning** and math achievement, in children with ADHD. They demonstrated that the association between executive functioning and math achievement varies according to specific math skill and test type. While arithmetic fact retrieval was only predicted by **inhibition** and working memory, next to certain ADHD characteristics, basic number skills were predicted by all EF measures.

Peters and colleagues investigated phonological processing, spatial and verbal skills as possible cognitive correlates of dyslexia, dyscalculia, and their comorbidity. They confirmed the relation between lower **spatial skills** and dyscalculia, and showed that children with comorbid dyslexia – similar to children with isolated dyslexia – had weaknesses in **phonological processing**, providing support for an additive model.

Huijsmans and colleagues revealed that in elementary school it was difficult to distinguish children with mathematical learning disabilities from low-achieving typical developing children solely based on mathematical characteristics. The researchers suggested the importance to understand children's mathematics performance at the individual level, while considering **individual differences** in the cognitive strengths and weaknesses associated with their mathematics performance.

Concluding remarks

The papers included in this special issue demonstrate that arithmetical weaknesses and mathematical disability (or dyscalculia) are common in children with neurodevelopmental disorders, such as dyslexia, DLD, ADHD, DCD and ASD. The latter group however, may also show specific arithmetic strengths.

Mathematical abilities depend on multiple factors such as domain-specific knowledge (e.g., subitizing, counting, magnitude processing, basic number skills and fact retrieval), domain-general or higher cognitive skills (e.g., working memory, language, attention, visuospatial learning) and non-cognitive factors (e.g., motivation, math anxiety, environment) that also interact with one another. The papers in the special issue show that this is also the case in children with (neuro)developmental disorders, who may show specific impairments in one or more of these factors, for instance higher order cognitive factors such as visuospatial and working memory processes.

This special issue also provides recommendations for practitioners. We conclude that there have been several positive outcomes from intervention studies. However, not every attempt or program was equally successful, stressing the need for empirical research that systematically and thoroughly deals with the conditions needed to address the development of mathematical abilities.

To conclude, it is clear that, even in the absence of a comorbid learning disorder, children with neurodevelopmental disorders may also be at risk for a study delay in mathematics. Increased vigilance for emerging problems is therefore strongly advised, and specific support may be needed for these children.

References

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