Early Childhood Research Quarterly 43 (2018) 62–72

Contents lists available at ScienceDirect

Early Childhood Research Quarterly

# Individual differences in basic arithmetic skills in children with and without developmental language disorder: Role of home numeracy experiences

Tijs Kleemans*, Eliane Segers, Ludo Verhoeven

*Behavioural Science Institute, Radboud University, Montessorilaan 3, P.O. Box 9104, 6500 HE Nijmegen, The Netherlands*

ARTICLE INFO

*Article history:*
Received 12 May 2017
Received in revised form
23 November 2017
Accepted 17 January 2018

*Keywords:*
Basic arithmetic skills
Home numeracy experiences
Parent–child activities
Parents' expectations
Developmental language disorder

ABSTRACT

The present study investigated the role of kindergarten home numeracy experiences in predicting individual differences in second-grade basic arithmetic (i.e., small problem sizes and large problem sizes) among children with developmental language disorders (DLD) and their peers with normal language achievement (NLA), after controlling for kindergarten cognitive and linguistic capacities and first-grade basic arithmetic. Forty children with DLD and 103 children with NLA were tested on cognitive, linguistic, and basic arithmetic skills, and their parents filled in a questionnaire on home numeracy activities and numeracy expectations. The results showed that children with DLD scored below their peers with NLA on basic arithmetic skills, with larger group differences on arithmetic with large problem sizes than small problem sizes. Furthermore, for both groups of children, home numeracy experiences were positively related to arithmetic with large, but not small problem sizes, suggesting that the role of home numeracy in basic arithmetic might be restricted to those arithmetic skills that children have not fully mastered yet.



## 1. Introduction

Experiences at home impact children's academic abilities. This goes for both home literacy experiences (Sénéchal & LeFevre, 2014) as well as home numeracy experiences (Skwarchuk, Sowinski, & LeFevre, 2014). Children with learning problems may have a dual risk; besides having a learning problem, their home environment (in terms of informal learning experiences) is often below that of children without learning problems (Martin, Volkmar, & Lewis, 2007). With regard to the development of numeracy, children with developmental language disorder (DLD) form an interesting group. These children show significant delays within the domains of receptive and/or expressive language, as well as phonological working memory skills (Bishop, Snowling, Thompson, & Greenhalgh, 2016), which hinders them to form adequate representations of counting words and number facts (Fazio, 1994, 1996). As a consequence, they also lag behind in early numeracy and basic arithmetic skills (e.g., Durkin, Mok, & Conti-Ramsden, 2013). Furthermore, the home numeracy experiences of children with DLD have been found to be poorer than that of normal language achieving (NLA) children, and this has been found to impact their basic arithmetic skills in first grade (Kleemans, Segers, & Verhoeven, 2013). In second grade, arithmetic starts to rely more on phonological working memory as well as language-based fact retrieval, and the impact of linguistic skills on arithmetic in this phase is well established (e.g., Durkin et al., 2013; LeFevre, Fast et al., 2010). It remains unclear, however, to what extent home numeracy experiences continue to play a role in predicting individual differences in basic arithmetic skills in second grade. In the present study, we investigated this in a longitudinal design, in which children with DLD and NLA were compared.

### 1.1. Child factors of basic arithmetic skills

Basic arithmetic skills comprise the addition and subtraction of single digits (i.e., 1–9) in first and second grades, and are preceded by the acquisition of early numeracy skills in kindergarten (Desoete & Grégoire, 2006; Jordan, Kaplan, Locuniak, & Ramineni, 2007). Evidence from neurocognitive research suggests that a distinction can be made between arithmetic with small problem sizes (i.e., arithmetic with sums and minuends below 10) and arithmetic with large problem sizes (i.e., arithmetic with sums and minuends above 10 and less than 20, including carryover operations) (e.g., Stanescu-Cosson et al., 2000). The solution process of arithmetic

* Corresponding author.
*E-mail address:* m.kleemans@bsi.ru.nl (T. Kleemans).

https://doi.org/10.1016/j.ecresq.2018.01.005
0885-2006/

with small problem sizes relies on having access to arithmetic facts that are stored in long-term memory (De Smedt, Taylor, Archibald, & Ansari, 2010). For arithmetic with large problem sizes, phonological working memory (i.e., phonological loop) is required as well, as such problems exceed the 10, and a solution procedure needs to be carried out before the correct answer can be given (e.g., 7 + 5 = 7 + 3 = 10 + 2 = 12). This solution procedure relies on verbal strategies that may vary from using verbal counting (e.g., seven plus three is "seven,",' "eight," "nine," "ten") to temporarily maintaining arithmetic facts during the solution process (e.g., seven plus three is ten), which are both assumed to rely on phonological codes (Dehaene, Piazza, Pinel, & Cohen, 2003) and are supported by the phonological loop (Lee & Kang, 2002).

From the literature on individual differences in basic arithmetic skills in children with DLD and NLA, a theoretical framework can be derived that includes cognitive as well as linguistic child factors that influence the development of these skills (see e.g., Kleemans, Segers, & Verhoeven, 2016; LeFevre, Fast et al., 2010). To begin with, both general intelligence and working memory as cognitive factors have been found to predict the development of basic arithmetic skills. The role of general intelligence in basic arithmetic skills has been identified in both children with DLD (Cowan et al., 2005) and children with NLA (De Smedt et al., 2009; Stock, Desoete, & Roeyers, 2009). For working memory, three related systems can be identified (Baddeley, 1996): one is a primary system (i.e., central executive functioning) that is responsible for the control and regulation of cognitive processes, and two slave systems that are involved in processing verbal (i.e., phonological loop) and visual–spatial information (i.e., visual–spatial sketchpad). In a *meta*-analysis by Friso-van den Bos, Kroesbergen, Van der Ven, and Van Luit (2013), it was found that the central executive (as measured by a backward digit span) was a strong predictor of mathematical achievement throughout primary school, whereas the role of the slave systems was related to children's strategy use. To be more precise, the visual–spatial sketchpad was found to be associated with finger counting (Rasmussen & Bisanz, 2005), whereas the phonological loop was found to be related to more mature strategies that relied on verbal counting or fact retrieval (De Smedt, Holloway, & Ansari, 2011; Hecht, Torgesen, Wagner, & Rashotte, 2001; Siegler, 1996).

Next to cognitive factors, linguistic factors such as phonological awareness and grammatical ability also predict the acquisition of basic arithmetic. Phonological awareness was uniquely related to small additions and small subtractions in both children with NLA (Hecht et al., 2001; Simmons & Singleton, 2008) and children with DLD (Kleemans, Segers, & Verhoeven, 2012), as the quality of verbal codes (e.g., counting words) relies on phonological representations that are stored in long-term memory (De Smedt et al., 2010). Furthermore, grammatical ability and basic arithmetic skills are based on the same underlying rules and develop on the principle of recursion (e.g., Hauser, Chomsky, & Fitch, 2002). For example, the order of words in a sentence determines its meaning ("The boy chased the dog" vs. "The dog chased the boy"), which is also the case in the order of the numbers and operations in an arithmetical problem ("15 – 8 =" vs. "8 – 15 ="). Grammatical ability has been found to predict single-digit addition and subtraction problems (i.e., small and large problem sizes) in children with DLD (Cowan et al., 2005; Durkin et al., 2013) and children with NLA (Kleemans et al., 2014). Finally, naming speed as an additional child factor should be taken into consideration as well, because the solution process of arithmetic in second grade requires fast retrieval of linguistically encoded arithmetic facts (Koponen, Mononen, Rasanen, & Ahonen, 2006). Interestingly, naming speed differentially predicted the numerical skills of children with DLD in kindergarten as well as first grade (Kleemans, Segers, & Verhoeven, 2011; Kleemans et al., 2012); a better naming speed might reduce the problems in basic arithmetic skills.

### 1.2. Home factors of basic arithmetic skills

Not only child factors predict learning outcomes in the early years of primary education, but individual differences in the home environment are also related to academic success (Melhuish et al., 2008). It is well established that home literacy experiences are associated with children's literacy skills (see e.g., Sénéchal & LeFevre, 2014; Sénéchal & Young, 2008). In a similar way, home numeracy experiences relate to children's numeracy skills (Blevins-Knabe, 2016; Huntsinger, Jose, & Luo, 2016; Skwarchuk et al., 2014). Home numeracy experiences can be seen as a multi-componential, but interrelated construct that facilitate numeracy learning. The two main components of home numeracy experiences are parent–child numeracy activities and parents' numeracy expectations.

With respect to parent–child numeracy activities, LeFevre, Clarke, and Stringer (2002) found the frequency of parent–child numeracy activities to be positively related with the counting skills of French- and English-speaking Canadian children. Comparable results have been found in other cultures (e.g., Turkish- and Chinese-speaking children) as well (Cankaya & LeFevre, 2016): the higher the frequency of parent–child numeracy activities, the better the numeracy skills of the children. Furthermore, Skwarchuk (2009) showed that parents' involvement in activities with basic and complex numeracy goals was positively related to children's early numeracy skills. Longitudinal relationships between parent–child numeracy activities and later basic arithmetic have also been reported. To begin with, in a sample of 609 German kindergartners, Niklas and Schneider (2013) showed that the reported frequency of parental engagement in numeracy activities at home was positively associated with basic arithmetic skills one year later. Furthermore, Huntsinger et al. (2000) reported the frequency of parent–child numeracy activities to be positively related to later basic arithmetic. LeFevre et al. (2009) found not only similar results, but also controlled for cognitive (i.e., spatial memory) and linguistic (i.e., vocabulary) child factors. Although most studies found positive relationships between the frequency of parent–child numeracy activities and basic arithmetic skills, negative relationships have been reported in both cross-sectional (Blevins-Knabe & Musun-Miller, 1996) and longitudinal studies (Ciping, Silisinkas, Wei, & Georgiou, 2015) as well. These negative relationships were explained by the fact that when children are starting to lag behind at school, parents may increase the frequency of numeracy activities in the home (Ciping et al., 2015).

With respect to parents' numeracy expectations, it was found that higher expectations on the part of the parent resulted in more numeracy-related practices, which was related to better numeracy achievement on the part of the child (LeFevre, Polyzoi, Skwarchuk, Fast, & Sowinksi, 2010). A more recent line of research combined both components of home numeracy experiences to determine the unique role of each factor in predicting numerical abilities. Cross-sectional evidence has been provided by Kleemans, Peeters et al. (2012), who found both aspects to be positively related with the early numeracy skills of 89 typically developing kindergartners, after controlling for cognitive and linguistic child factors. In a longitudinal study by Skwarchuk et al. (2014), formal home numeracy practices (e.g., the parent practicing simple sums) as well as parents' expectations were positively associated with symbolic number knowledge in first grade. In addition, in children with DLD, the role of home numeracy experiences in first-grade arithmetic was evidenced: both parent–child numeracy activities and parents' numeracy expectations were positively related to arithmetic with small problem sizes in first grade, after controlling for cognitive and linguistic child factors. Those relations were stronger for parents of