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A pilot study of the effects of RightStart instruction on early numeracy skills of children with specific language impairment

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ABSTRACT

This pilot study investigated the effects of an early numeracy program, RightStart Mathematics (RS), on Finnish kindergartners with specific language impairment (SLI). The study applied a pre-test–instruction–post-test design. The children with SLI ($n = 9$, $M_{age} = 82.11$ months) received RS instruction two to three times a week for 40 min over seven months, which replaced their business-as-usual mathematics instruction. Mathematical skill development among children with SLI was examined at the individual and group levels, and compared to the performance of normal language-achieving age peers ($n = 32$, $M_{age} = 74.16$ months) who received business-as-usual kindergarten mathematics instruction. The children with SLI began kindergarten with significantly weaker early numeracy skills compared to their peers. Immediately after the instruction phase, there was no significant difference between the groups in counting skills. In Grade 1, the children with SLI performed similarly to their peers in addition and subtraction skills (accuracy) and multi-digit number comparison, but showed weaker skills in arithmetical reasoning and in matching spoken and printed multi-digit numbers. Our pilot study showed encouraging signs that the early numeracy skills of children with SLI can be improved successfully in a kindergarten small-classroom setting with systematic instruction emphasizing visualization.

1. Introduction

Previous research has shown that children with specific language impairment (SLI) often demonstrate weaker mathematics performance compared to their age peers before the onset of formal schooling (e.g., Kleemans, Segers, & Verhoeven, 2011). Follow-up studies (Fazio, 1996, 1999; Morgan, Farkas, & Wu, 2011), as well as cross-sectional studies conducted with older children with SLI (Fazio, 1999; Koponen, Mononen, Räsänen, & Ahonen, 2006; Pulkkinen-Kantonen, 2012), have indicated that difficulties in mathematics learning are persistent. In SLI, the normal language acquisition patterns are disturbed in the early stages of development, conditions not caused by neurological or speech mechanism abnormalities, sensory impairments, mental retardation, or environmental factors (ICD-10: World Health Organization, 2010). In addition to language impairment, many of these children also show limitations in working memory and processing speed (Montgomery, Magimairaj, & Finney, 2010), all shown in relation to mathematics performance in early childhood (e.g.,

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Friso-van den Bos, van der Ven, Kroesbergen, & van Luit, 2013; Geary, 2011; Purpura, Hume, Sims, & Lonigan, 2011). In this light, children with SLI in early childhood are already at risk for low performance in mathematics. Mathematics intervention research has provided evidence that pedagogical interventions can improve the early numeracy skills of children with initially low performance (e.g., Jordan, Glutting, Dyson, Hassinger-Das, & Irwin, 2012), but such research on children with SLI is lacking. In this study, we investigated the effects of RightStart Mathematics instruction (Cotter, 2001) on the development of early numeracy skills among kindergartners with SLI.

1.1. Early numeracy skills in children with SLI

A review of the literature concerning the development of early mathematics skills of children with SLI (Appendix A) showed that children with SLI have severe deficits in counting (Arvedson, 2002; Cowan, Donlan, Newton, & Lloyd, 2005; Donlan, Cowan, Newton, & Lloyd, 2007; Fazio, 1994, 1996; Kleemans et al., 2011) and arithmetic skills (Cowan et al., 2005; Donlan et al., 2007; Jordan, Levine, & Huttenlocher, 1995; Kleemans, Segers, & Verhoeven, 2012; Mainela-Arnold, Alibali, Ryan, & Evans, 2011). However, these children have demonstrated similar performance to their age peers and above their language peers in skills that seem to require less language processing, such as single-digit number comparison (Donlan, Bishop, & Hitch, 1998; Donlan & Gourlay, 1999) and number line estimation (Kleemans et al., 2011).

More specifically, counting difficulties seem to be present when oral counting is involved, such as in rote counting forward and backward, where number word sequence errors often surface (Cowan et al., 2005; Fazio, 1994, 1996). In object-counting tasks, children with SLI have generally demonstrated weaker performance when compared to their age peers (Fazio, 1994; Kleemans et al., 2011), unless they were operating in the number range within which they were confident (Fazio, 1996), or if oral counting was not required, such as in reproducing the same set of objects without oral expressions or through gestured counting (Arvedson, 2002; Fazio, 1994). Young children with SLI usually seem to understand conceptual counting principles, such as cardinality and one-to-one correspondence, similarly to their age peers (Arvedson, 2002; Fazio, 1994, 1996).

In arithmetic skills, children with SLI have demonstrated weaknesses in basic single-digit addition and subtraction tasks, regardless of the presentation format (written or spoken), and in accuracy and fluency, as well as in word-problem contexts (Cowan et al., 2005; Donlan et al., 2007; Fazio, 1996; Jordan et al., 1995; Kleemans et al., 2012; Samelson, 2009). Fazio (1996) noted that children with SLI often used more immature counting strategies (e.g., using fingers as memory aids and counting all) compared to their age peers, who were able to recall facts more often from memory. Furthermore, Mainela-Arnold et al. (2011) found that children with SLI showed delays in their understanding of mathematical equivalence (e.g., 5 + 3 + 2 = 5 + __). Despite their weaknesses in arithmetic skills, children with SLI seem to have as strong conceptual understanding of arithmetic principles (Donlan et al., 2007). In nonverbal arithmetic problems (i.e., those in which an oral or written response is not required), children with SLI have performed with results similar to those of their age peers (Arvedson, 2002; Jordan et al., 1995; Samelson, 2009).

In addition to difficulties in counting and arithmetic skills, children with SLI show difficulties in the range of age- and grade-related mathematics tasks compared to their age peers in elementary school, according to a large-scale follow-up study conducted by Morgan et al. (2011). Cowan et al. (2005) found that seven- to nine-year-old children with SLI had difficulties operating on multi-digit numbers, transcoding numbers (reading and writing numbers, and matching spoken and printed numbers), and place value (measured as comparing numbers).

1.2. Reasons for weak early numeracy performance of children with SLI

Numerous studies conducted on typically developing children have reported that general intelligence (e.g., Geary, 2011; Li & Geary, 2013) and working memory (WM) (e.g., Friso-van den Bos et al., 2013) are related to children's performance in mathematics. In children with SLI, the children's general intelligence is thought to be within the normal range, but many show significant limitations in WM, merely in the central executive and phonological loop (Montgomery et al., 2010). The central executive is responsible for coordinating and controlling the different activities within working memory (Montgomery et al., 2010), and deficits may be illustrated in mathematics such as choosing wrong calculation operations, not being able to successfully switch between operations, strategies, and quantity ranges, forgetting intermediate results, and making procedural errors (Friso-van den Bos et al., 2013). The phonological loop, however, contributes to performance involving language-based information processing such as encoding and processing number words and numerals and retrieving linguistically stored representations of arithmetic facts from long-term memory (e.g., Krajewski & Schneider, 2009; Östergren & Träff, 2013). Since children with SLI have impaired language skills, the children may not be able to rely as heavily on the phonological system as their peers, and therefore, learning to count and to do arithmetic becomes a slow and error-prone process. These two WM components are related to the mathematics performance of children with SLI (e.g., Cowan et al., 2005; Kleemans et al., 2011).

The third component of WM, the visuospatial sketchpad, supports non-verbal numerical processing such as in tasks related to number magnitude, estimation, and mental number line (e.g., Bull, Espy, & Wiebe, 2008). Children with SLI do not show the same limitations in the visuospatial sketchpad as in the two other WM components (Montgomery et al., 2010), which may explain why these children perform similarly to their age peers on number comparison (Donlan & Gourlay, 1999; Donlan et al., 1998) and number line estimation tasks (Kleemans et al., 2011). The role of the visuospatial sketchpad is related