Basic Numeracy in Children With Specific Language Impairment: Heterogeneity and Connections to Language

Purpose: This study examined basic numerical skills in children with specific language impairment (SLI) and how well linguistic factors explain the variance in these children’s number skills.

Method: The performance of children with SLI \((n = 29)\) was compared with that of typically developing children along a continuum ranging from preschool to 3rd grade \((n = 20, 47, 40, \text{and } 33)\). This facilitated both linguistic and educational age comparisons. To study number skills within the SLI group more closely, this group was divided into subgroups on the basis of their performance in verbal and nonverbal numerical skills. The performance of the different SLI subgroups on the linguistic and nonverbal reasoning task was analyzed.

Results: As a single group, the children with SLI lagged behind their educational age controls in both verbal and nonverbal numerical skills. Subgroup analyses revealed that the ability to retrieve arithmetic facts from the memory was connected to naming fluency, whereas the differences in nonverbal numerical skills were not explained by the cognitive skills measured (nonverbal reasoning skill, verbal short-term memory, vocabulary, comprehension, and naming fluency).

Conclusions: This study demonstrates that children with SLI form a very heterogeneous group in their numerical skills, and thus specific hypotheses concerning the influence of linguistic deficits on developing numerical skills are required. The cognitive components of serial naming speed present a promising domain for further exploration.

KEY WORDS: numerical skills, language impairment, cognitive skills

Only a few studies have been carried out on the mathematical skills of children with specific language impairment (SLI). These studies show that children with SLI lag significantly behind their age peers in several tasks in this academic area (Arvedson, 2002; Fazio, 1999; Tieche, Christie, Conne, & Gaillard, 1995). However, there are indications that, in some mathematical tasks, children with SLI may perform as well as their age peers (Arvedson, 2002; Donlan, 1993; Donlan & Gourlay, 1999). This interesting finding is supported by clinical studies of acquired and developmental dyscalculia. Research on number processing in normal and brain-damaged adults has revealed that basic numerical skills can be divided into at least two different processing categories: verbal and nonverbal (e.g., Lemer, Dehaene, Spelke, & Cohen, 2003). Rourke and colleagues (Rourke & Conway, 1997; Rourke & Finlayson, 1978) examined the number skills of children with verbal and nonverbal learning disabilities. Children
with nonverbal learning disabilities showed good reading skills but impairments in visuospatial skills, which affected their ability to represent numerical information spatially and to understand the meaning of numerical representations (place value), while children with verbal learning disabilities showed difficulties in reading and fact-retrieval deficits in arithmetic. Likewise, children with SLI have been shown to perform better in nonverbal than in verbal numerical tasks. However, because these studies have used small sample sizes, have investigated differing age groups, and have used different kinds of tasks to measure the skills in question, more studies are required to confirm the results. The aim of this study is to replicate previous findings using a larger sample of 9–11-year-old children with SLI. Earlier studies have used linguistic-age and chronological-age comparison groups. We also compared the numerical performance of children with SLI with that of their peers matched to language and education.

Furthermore, although considerable heterogeneity has been reported in the numerical skills of children with SLI (Donlan & Gourlay, 1999; Tieche Christinat et al., 1995), previous studies have not (mostly because of small sample sizes) analyzed whether all children with SLI show the verbal versus nonverbal dichotomy in their numerical skills. We analyzed the variance in numerical skills within the SLI group to ascertain whether differences in children’s linguistic skills explained the differences in their numerical skills.

### Numerical Cognition and Specific Language Impairment

The main findings to date with regard to earlier studies on the numerical skills of children with SLI are summarized in Table 1. These studies have been conducted among children with SLI at different ages, and each study has focused to partially different numerical skills. Despite the differences, the findings of group studies clearly show that impaired language is strongly associated with difficulties in number processing when the explicit verbal processing and expression of numerals are demanded, as, for example, in verbal counting, retrieving arithmetical facts from memory, and number transcoding (going from one numerical code to another;

<table>
<thead>
<tr>
<th>Age</th>
<th>Study</th>
<th>N</th>
<th>Number transcoding</th>
<th>Counting</th>
<th>Enumeration (set sizes 5 or larger)</th>
<th>Calculation</th>
<th>Conceptual knowledge (cardinality, conservation of number)</th>
<th>Number comparison</th>
<th>Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4–5</td>
<td>Arvedson (2002)</td>
<td>19</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>+/-</td>
<td>+/-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fazio (1994)</td>
<td>20</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>+/-</td>
<td>+/-</td>
<td></td>
</tr>
<tr>
<td>6–7</td>
<td>Donlan (1993)</td>
<td>13</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>+/-</td>
<td>_</td>
<td>+/-</td>
</tr>
<tr>
<td></td>
<td>Fazio (1996)</td>
<td>14</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>+/-</td>
<td>+/-</td>
<td></td>
</tr>
<tr>
<td>7–8</td>
<td>Donlan and Gourlay (1999)</td>
<td>13</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>+/-</td>
<td>+/-</td>
<td></td>
</tr>
<tr>
<td>9–11</td>
<td>Tieche Christinat et al. (1995)</td>
<td>10</td>
<td>_</td>
<td>_</td>
<td>+/-</td>
<td>_</td>
<td>+/-</td>
<td>+/-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fazio (1999)</td>
<td>10</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>_</td>
<td>+/-</td>
<td>+/-</td>
<td></td>
</tr>
</tbody>
</table>

Note. Age is in years. _ = abilities are under the age-appropriate level; +/- = abilities are at least at the age-appropriate level.
i.e., from Arabic numerals to spoken/written number words, as in $5 \rightarrow \text{five}$ or vice versa, as in $\text{twenty-five} \rightarrow 25$). When a more approximate representation of magnitude or numbers is required, as with number comparison and estimation, the performance of individuals with language impairments seems to improve. Earlier results for the same numerical skills as those investigated in the present study are described in more detail below.

Verbal counting. Words representing numbers constitute a strictly sequential organized lexicon with exactly defined syntax (Delazer & Bartha, 2001; Seron, 2001). The amount of single-number words is limited, but using the rules of number syntax, it is possible to generate an infinite amount of number words. Learning the single-number words, number syntax, and/or the correct sequence of number words may be difficult for individuals with language impairment (Delazer & Bartha 2001; Fazio 1994; Seron, 2001).

Arvedson (2002) found that compared with their age peers, children between the ages of 3;5 (years;months) to 5 years with SLI retrieved shorter sequences of number words. Likewise, Fazio (1994) found that in counting, the primary difficulty of 4–5-year-old children with SLI was remembering and retrieving the words in the correct order. In her follow-up study 2 years later (Fazio, 1996), she found that when the children were 6–7 years old, they had difficulties retrieving the correct sequence of numbers when counting numbers over 20. At the age of 9 to 10, the same children with SLI recited significantly shorter sequences of numbers compared with their chronological-age peers (Fazio, 1999). Tieche Christinat et al. (1995) found that in counting 3 by 3 from 1 to 21, 9–11-year-old SLI children made more errors than their chronological-age controls. In single-digit multi-

Comparing and estimating numbers. Children with SLI have not been found to perform any worse than age-matched controls in number comparison tasks (Donlan, 1993; Donlan & Gourlay, 1999). Children age 6 to 7 years with SLI performed at an age-appropriate level in a comparison task with written Arabic numbers (e.g., “Which is bigger, 15 or 51?”, Donlan, 1993). In his later study with Gourlay (Donlan & Gourlay, 1999), 7–8-year-old children with SLI were compared with LC and age control groups. The children with SLI performed better than their younger, language-matched controls and at the same level as their age-matched peers on the number comparison task. Donlan and Gourlay proposed that the ability to relate pairs of numbers to their relative values seems to depend predominantly on nonverbal skills. The only study to investigate the estimation of numbers was carried out by Tieche Christinat et al. (1995), who showed that controls had no failures when positioning numbers on a 1–100 scale. Only 2 out of 10 of the children with SLI required lengthy training in the test method and had difficulties in positioning numbers.

These results from earlier studies are in line with the current models of number processing (e.g. Butterworth, 1999; Dehaene, 1992) that support the idea that presentations of magnitude are independent of verbal processing. According to Dehaene’s triple-code model, a participant is able to relate numerical information given in Arabic numerals in relation to other numerical quantities using two codes: a visual Arabic numerical code and an analogical representation of magnitude. Quantities and magnitudes are represented by local distributions of activation on an oriented number line (e.g., “48 is bigger than 40, and it is about halfway between 0 and 100”; Dehaene & Cohen, 1995). Thus, according to this model, it is possible that processing Arabic numerals can be achieved without the third code: the verbal word frame. Butterworth (1999) and Landerl, Bevan, and Butterworth (2004) have proposed that numerical basis rather than other cognitive domains is central in disabilities of calculation skill.

This Study

In the first section of this study, the performance of children with SLI in verbal and nonverbal number skills is compared with that of their language- and educational-age controls. The second section focuses on the within-group differences found among the SLI children and how well linguistic factors explain the variance in these children’s number skills.

SLI versus controls. On the basis of the previous research on numerical skills and SLI described above,
numerical skills were divided into two categories: verbal and nonverbal numerical skills. The battery of verbal numerical skills consisted of verbal counting and fluency and accuracy of single-digit calculation. The battery of nonverbal numerical skills included comparison and estimation of numbers and comprehension of numbers presented in Arabic numerals and as play money. Earlier studies have used comparison groups matched for chronological age and language. The present study used a continuum from preschool to third grade to match the performance of children with SLI with that of their educational agemates. The group of preschool children also functioned as a language-matched comparison group. The performance in various numerical tasks of children with SLI was compared with that of normally achieving children. Whether children with SLI would perform better in comparing and estimating numbers and comprehension of numbers presented in Arabic numerals than in counting or retrieving arithmetical facts was investigated.

SLI subgroups. The number skills of children with SLI have been shown to vary from persistent difficulties in arithmetic to close to average performance in number comparison. However, previous studies have found that even in arithmetic and approximate magnitude comparison tasks, there are large differences between children with SLI. This is the first study to analyze this variance in more detail. The analysis of the within-group differences in children with SLI was carried out with the aim of obtaining a better understanding of the heterogeneity found in their performances. To study number skills within the SLI group more closely, this group was divided into subgroups. A particular point of interest was whether some of the children with SLI who had reached a certain level of performance in their number skills would be found to differ in their linguistic skills from those who had not reached the same level.

As a result, we divided the children with SLI into subgroups according to qualitatively different performing levels in the two dimensions studied: verbal and nonverbal number skills. Previous research has shown that on average, children with SLI are dysfluent in single-digit calculations but show strengths in nonverbal number skills. We show that the average performance spreads to create a more heterogeneous profile of strengths and weaknesses. Some of the children with SLI show poor overall performance in number skills and some surprising strengths in verbal number skills irrespective of their language deficit.

Studies on arithmetic learning disabilities have shown that these children exhibit a variety of cognitive deficits (e.g., working memory deficits; Geary, Brown, & Samaranayake, 1991; Hitch & McAuley, 1991; McLean & Hitch, 1999) and slow access to number and word names stored in the long-term memory (Geary, Hamson, & Hoard, 2000; Geary et al., 1991; Temple & Sherwood, 2002). Special interest was in whether linguistic variables, for example, rapid automatic naming and sentence comprehension, would explain the variance in numerical performance of children with SLI.

Method

Participants

The target group consisted of twenty-nine 9–11-year-old Finnish-speaking children (6 girls, 23 boys; age: M = 10;3, range = 9;3–11;2) with SLI as diagnosed by a pediatrician or phonetician. In Finland, the International Classification of Diseases, 10th edition (ICD–10; World Health Organization, 1993) diagnostic criteria are used. These criteria are briefly described below. To satisfy a diagnosis of expressive, receptive, or mixed receptive/expressive disorder, a child must have language skills falling at least 2 standard deviations below the average for his/her age. Language skills also are required to be at least 1 standard deviation below nonverbal IQ as assessed on standardized tests. Cases with neurological, sensory, or physical impairments that directly affect the use of spoken language and pervasive developmental disorder are excluded. The most commonly used exclusionary criterion is a nonverbal IQ score below 70 on a standardized test.

The children’s average standard scores for language comprehension, word retrieval, verbal short-term memory, and nonverbal reasoning abilities at the time of the study are presented in Table 2. In the vocabulary test (Word Finding Vocabulary Test; Renfrew, 2001), no Finnish norms were available; however, the average mean score and deviation matched those of 7-year-old American children. On nonverbal reasoning (assessed via Raven’s Coloured Progressive Matrices; RCPM; Raven, 1993), all of these children performed above the ICD–10 exclusionary criterion (nonverbal IQ below 70). Twenty-two of the 29 children produced a nonverbal standard score of 80 or above, which has been used as a criterion in previous studies (Donlan, 1993; Donlan & Gourlay, 1999). Four of the 7 children who failed to reach a nonverbal standard score above 80 (but over 70) on the RCPM (Raven, 1993) had achieved such a score previously on the WISC–III (Wechsler, 1991).

Most of the children had both receptive and expressive language problems. According to the sentence comprehension test used in this study (the Developmental Neuropsychological Assessment; Finnish version; NEPSY; Korkman, Kirk, & Kemp, 1997), only 1 of the children achieved an average-level score, and 22 of 29 had moderate-to-severe receptive difficulties.

In Finland, children diagnosed with SLI have extended education, and they start school at the age of...
6 years (1 year earlier than other children). All of the children with SLI attended special state schools for children with SLI (n = 19 in Jyväskylä; n = 10 in Tampere, Finland). Mathematics was studied according to each child's individual educational plan, and the curricular level in mathematics was estimated from the textbook the child was using at the time of inclusion in the study. Education for these children generally follows the textbooks of the standard curriculum, although, for a smaller group of children, special education textbooks, which are concise versions of the standard books, are used. The textbooks varied from those intended for the autumn term of the second grade to those for the spring term of the third grade. The mean mathematical educational level of the SLI group (M = 2.89 years of education) was close to that of the second-grade control children (M = 2.75 years), all of whom were using textbooks intended for the spring term of that grade.

The SLI group was compared with linguistic-age controls (LC) and educational age controls (EC, Grades 1–3). LCs consisted of 20 preschool children (8 boys and 12 girls; age: M = 6;7, range = 6;3–7;2) who were attending a regular preschool in the city of Jyväskylä, Finland. The language matching was based on verbal short-term memory, vocabulary, comprehension, and naming speed. These were assessed using the auditory Digit Span task (WISC–III; Wechsler, 1991), Word Finding Vocabulary Test (Renfrew, 2001), Sentence Comprehension Test (NEPSY, Finnish version; Korkman et al., 1997), and Rapid Automatized Naming Test (RAN; Colors and Objects; Denckla & Rudel, 1974; the Finnish version; Ahonen, Tuovinen, & Leppäsaari, 1999). The LC group's performance was within the norms for their age. The mean raw scores of the LC group for each subtest were matched with the scores of the SLI group (see Table 2). No significant differences (p > .05) between the LC and SLI groups were found in these subtests. In addition to the assessment of verbal skills, the RCPM (Raven, 1993) was used to examine the nonverbal skills of the children with SLI and the LC group. The LC group reached the age norms for 7-year-olds. A significant difference (p < .001) was found between the mean raw score of the RCPM for the LC and SLI groups (see Table 2). The mean standardized score was 98 (SD = 15) for the LC group and 92 (SD = 13) for the SLI group. No significant difference (p > .05) was found between the standardized scores of the LC and SLI groups.

The continuum for the EC group was formed from 47 first-grade (EC1 group; 26 boys and 21 girls; age: M = 7;7, range = 7;3–8;2), 40 second-grade (EC2 group; 21 boys

### Table 2. The mean performance score of the LC and SLI groups on cognitive tasks and numerical skills.

<table>
<thead>
<tr>
<th>Task</th>
<th>LC (n = 20)</th>
<th>SLI (n = 29)</th>
<th>F(1, 47)</th>
<th>(\eta^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw score M</td>
<td>SD</td>
<td>Raw score M</td>
<td>SD</td>
</tr>
<tr>
<td>Linguistic skills</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit Span(^a)</td>
<td>8.45</td>
<td>1.32</td>
<td>10.30</td>
<td>2.02</td>
</tr>
<tr>
<td>Comprehension(^b)</td>
<td>12.30</td>
<td>1.72</td>
<td>9.00</td>
<td>2.96</td>
</tr>
<tr>
<td>Vocabulary(^c)</td>
<td>39.05</td>
<td>3.99</td>
<td>39.93</td>
<td>4.69</td>
</tr>
<tr>
<td>Naming(^d)</td>
<td>65.28</td>
<td>9.93</td>
<td>61.57</td>
<td>15.24</td>
</tr>
<tr>
<td>Nonlinguistic skill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCPM (IQ)(^e)</td>
<td>20.10</td>
<td>6.49</td>
<td>27.14</td>
<td>5.07</td>
</tr>
<tr>
<td>Numerical skills</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counting(^f)</td>
<td>16.15</td>
<td>3.92</td>
<td>15.83</td>
<td>4.44</td>
</tr>
<tr>
<td>Calculation accuracy(^g)</td>
<td>.59</td>
<td>.28</td>
<td>.91</td>
<td>.05</td>
</tr>
<tr>
<td>Calculation speed(^h)</td>
<td>9.19</td>
<td>3.87</td>
<td>4.06</td>
<td>1.85</td>
</tr>
<tr>
<td>Nonverbal(^i)</td>
<td>28.10</td>
<td>5.64</td>
<td>36.16</td>
<td>7.85</td>
</tr>
</tbody>
</table>

Note. LC = language control; SLI = specific language impairment.

\(^a\)Digit Span task (Wechsler Intelligence Scale for Children, Finnish version; Wechsler, 1991), raw score and standard score (M = 10, SD = 3).
\(^b\)Sentence Comprehension (Developmental Neuropsychological Assessment, Finnish version; Korkman, Kirik, & Kemp, 1997), raw score and standard score (M = 10, SD = 3).
\(^c\)Word Finding Vocabulary Test (Renfrew, 2001), raw score.
\(^d\)Rapid Automatized Naming Test (Denckla & Rudel, 1974), time and standard score (M = 10, SD = 3).
\(^e\)Raven’s Coloured Progressive Matrices (Raven, 1993), raw score and standard score (M = 100, SD = 15).
\(^f\)Verbal counting (Diagnostic Tests 3: Motivation, Metacognition and Mathematics; Salonen et al., 1994), raw score (max = 20).
\(^g\)Simple additions and subtractions (correct/attempted).
\(^h\)Mean calculation response time in simple additions and subtractions in seconds.
\(^i\)Sum score (max = 55). Analyses done by using the raw scores.

***p < .001.
and 19 girls; age: $M = 8;8$, range = $8;2–9;4$), and 33 third-grade (EC3 group; 18 boys and 15 girls; age: $M = 9;7$, range = $9;3–10;2$) children, who were attending a regular school in the city of Jyväskylä. The reason for the use of several EC groups was twofold: First, the simple information that children with SLI perform more poorly than chronological-age controls on numerical tasks is not very informative as we already know that the content of their mathematics curriculum is less advanced than that of their age peers. Despite their older age and longer school history, the children with SLI were studying at the same curricular level as the EC2 and EC3 groups. Second, we used tasks in which the children were required to use the spatial position of numerals or linguistic syntax to understand the magnitude of numbers. Thus, it is reasonable to suppose that matching with the children’s experience of numbers of a certain magnitude gives a better picture of their skills than chronological-age matching.

**Procedure**

The preschool children (LC group) and the children with SLI were assessed individually in two testing sessions ($2 \times 45$ min). In each session, 30 min was spent completing computer-administered numerical tasks followed by approximately 15 min completing paper-and-pencil tasks. The first-, second-, and third-grade children were assessed in groups of 6 to 9 pupils on computer-administered numerical tasks in a single session lasting approximately 45 min. Three examiners, who ensured that each child understood the task instructions and the computer operations, supervised each group.

The computer tasks consisted of three nonverbal tasks, two verbal numerical skill tasks, and one task used to control for number key knowledge. In all the computer tasks, the child heard instructions through headphones and viewed examples of the task on the screen. The computer recorded the answers and time taken for each trial of every task. The computer-administered tasks were constructed and carried out using NEURE, a graphical experiment generation tool (Niilo Mäkö Instituutti, 2002; see http://www.nmi.jyu.fi/neure/).

**Measures**

**Verbal Tasks**

- **Verbal counting.** LC and SLI children’s skills in counting were measured using the five subtests taken from the Diagnostic Tests for Motivation, Metacognition and Mathematics (Salonen et al., 1994). The test was not administered to the first-, second-, and third-grade children as, according to the norms of this counting test, normally developed first-grade children will have already achieved the maximum performance level on the chosen tasks.

  Three of the five subtests required forward-counting skill. In the first subtest, the child was asked to count as far as he or she could. If the child reached 50, the test was stopped. The subtest was scored as follows: 5 points were given if the child could count correctly to 50, 4 points if the child made only one counting error, 3 points if the child made two errors, 2 points if the child made three errors, 1 point if the child made four errors, and 0 points if the child made five or more errors. If the child did not reach number 50, 0 points were given even if no errors were incurred. In the second subtest, the child was given a starting number and asked to count forward from this number. One point was awarded if the child was able to count correctly at least the first four successive numbers. The subtest consisted of four different tasks (starting values: 3, 8, 12, and 19). In the third subtest, the child was asked to count forward from a given number to another given number. One point was awarded for counting a correct sequence of numbers. The subtest consisted of four different tasks (2–7, 6–11, 18–25, and 39–51). The remaining two subtests required backward-counting skill. In the first, the child was given a starting number and asked to count backward from this number. One point was awarded if the child was able to count correctly at least the first four successive numbers backward. This subtest consisted of four different levels (starting values: 4, 8, 12, and 23). In the second subtest, the child was asked to count backward from a given number to another given number. One point was awarded for counting the correct sequence of numbers. This subtest consisted of three different levels (6–3, 13–8, and 20–17).

- **Addition task.** Single-digit additions using permutations from 1 to 9 were presented one at a time in horizontal format on the computer screen. The additions were in a quasi-random order so that each successive item had different addends. The child was instructed to answer as quickly as possible by pressing a number key on the keyboard for the answer and, when confident the answer was correct, to mouse-click an on-screen “OK” button. The child was required to calculate as many of the additions as possible within a time limit of 3 min. To begin with, there were 24 items, which did not include carrying operations. The remaining 58 items included additions with or without carryover operations. Two measures were derived: accuracy and rate of calculation. Accuracy was computed by dividing the sum of correct answers by the sum of attempted items. Speed of calculation was computed as the median of the time taken to provide a correct solution. The median was selected because it is less sensitive to outlying values than the mean.

- **Subtraction task.** The subtraction items were constructed, ordered, and presented to the child in the same way as for the addition task. The minuend was the sum of the addition, and the subtrahend was the first addend of
the same addition (e.g., $4 + 1 = 5$). Accuracy of calculation was computed by dividing the sum of correct items by the sum of attempted items. Calculation speed was again the median time taken to provide a correct solution.

**Nonverbal Tasks**

Comparing two-, three-, four-, and five-digit numbers. Three numbers were presented on-screen, and the child was required to choose the largest by clicking on the relevant number with the mouse. A blue frame subsequently surrounded the selected number. The child was able to change his/her selection by clicking another number. When the child was confident that the answer was correct, he or she mouse-clicked on a large on-screen “OK” button that triggered the presentation of the next trial. This subtest consisted of 3 practice items and 15 test items. One point was awarded for each correct answer to each test item.

Moneybag task. The aim of this computerized task was to measure comprehension of the structure of numbers. This novel task consisted of two parts, both of which comprised 10 items. In Part 1, the child viewed a moneybag. Displayed above the moneybag was the amount of money contained in the bag, written in Arabic numerals. Below the moneybag, three piles of play money were displayed. Each pile consisted of yellow coins (units) and notes of different colors and denominations (tens, fifties, hundreds, thousands). The child was required to select the pile, which contained exactly the same amount of money as the moneybag. The second part was the same with the exception that one pile of money and three moneybags were displayed with the requirement to select the bag containing the same amount of money as the pile depicted above the bags. The amount of money varied from 7 to 1,500 units. One point was awarded for each correct answer.

Estimation task. This task consisted of two parts, each with 10 items (see Figure 1). A vertical line starting at 0 formed the sidewall of a building containing an elevator. The elevator in the building was depicted as a line. The child had to choose from four numerical alternatives (given under the building) the correct floor at which the elevator had stopped by clicking on the corresponding number. The height of the building ranged from 10 to 1,000 floors (10, 20, 100, 700, and 1,000), each height appearing two times. The number of the top floor was marked next to the building. A prompt was presented on the screen when the number of floors changed. The second part was the inverse of the first. Four floors were marked by lines in the building, and the child was instructed to click on the correct floor for the elevator according to the floor number shown on-screen. For each part of the test, 1 point was awarded for each correct answer.

Number Key–Finding Task

This task was used to control for the time taken to complete the tasks involving time as a variable. The children differed in their experience with the computer keyboard, and a key-finding task was used to control for this difference. In this task, a number appeared on-screen with the requirement to press the corresponding number key on the keyboard as quickly as possible. Each number from 1 to 9 appeared three times in random order. There
was a 2,500-ms interval between the end of one item and the onset of the next. Each child completed this task twice: once at the beginning and once at the end of the assessment session. The mean of the median number location times in those two sessions was computed.

**Variables**

Composite scores for verbal and nonverbal number skills were computed for the analyses. Verbal number skills comprised three scores: verbal counting, accuracy of calculation, and speed of calculation. Verbal counting was computed from the sum of the scores of the five subtests (maximum = 20 points; Cronbach’s α = .77). Accuracy of calculation was the mean number of correct answers in the addition (accuracy close to ceiling in both SLI and EC groups) and subtraction tasks (Cronbach’s α = .58). Speed of calculation was the mean of the median addition and subtraction speed subtracted by the median time taken by the child to locate the numbers on the computer keyboard in the number key–finding task (Cronbach’s α = .80). A composite score for the children’s nonverbal numerical skills was constructed by summing the scores of the three subtests (comparing and estimating numbers and comprehension of numbers presented in Arabic numerals and as play money; maximum = 55 points; Cronbach’s α = .79; Pearson’s product–moment correlation for the verbal and nonverbal numerical skills tests = .65, p < .001). To validate the division into verbal and nonverbal numerical skills, Spearman’s correlations between the linguistic and numerical tasks were calculated (see Table 3).

The number comparison task has been the most commonly used indicator of nonverbal number skill (e.g., Dehaene & Cohen; 1995, Donlan & Gourlay, 1999). Thus, to confirm our results obtained with the nonverbal sum variable, additional analyses with the number comparison task only were done.

**Results**

The analyses and results are presented in four sections. The first two analyses present the data on the performance of the children with SLI in verbal and nonverbal number skills compared with the LC and EC groups. The next two focus on the within-group differences among the SLI children. We analyzed, first, the differences in numerical performance within the group and, second, whether linguistic factors or nonverbal reasoning explained the variance in these children’s number skills.

**SLI Group Versus LC Group**

The results for the children with SLI and the LC group are presented in Table 2. The scores for verbal and nonverbal number skills were subjected to a multivariate analysis of covariance (MANCOVA; controlling for nonverbal IQ), which yielded a significant group effect, F(1, 47) = 19.59, p < .001, Wilks’s Λ(47) = .35, p < .001. The groups did not differ in verbal counting skills, and the covariate did not reach statistical significance. In simple addition and subtraction, the covariate reached significance (p < .05 for accuracy and p < .001 for fluency). However, after controlling for nonverbal IQ, a significant group effect remained. Children with SLI were better at simple addition and subtraction than was the LC group. They had more correct answers (p < .001, ηp² = .49), and they produced the correct answers more quickly (p < .001, ηp² = .53). Likewise, in the nonverbal number skills tasks, the children with SLI performed significantly better than the children in the LC group (p < .001, ηp² = .27). The covariate did not reach statistical significance.

<table>
<thead>
<tr>
<th>Cognitive task</th>
<th>Additionf</th>
<th>Subtractiong</th>
<th>Countingh</th>
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<th>Estimation</th>
<th>Moneybag</th>
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<tr>
<td>Digit Spana</td>
<td>.282</td>
<td>.203</td>
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<td>.095</td>
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<tr>
<td>Comprehensionb</td>
<td>.501**</td>
<td>.442*</td>
<td>.320</td>
<td>.367*</td>
<td>.182</td>
<td>.362</td>
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<td>Vocabularyc</td>
<td>.186</td>
<td>.209</td>
<td>.541**</td>
<td>.312</td>
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<td>.354</td>
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<tr>
<td>Namingd</td>
<td>-.635**</td>
<td>-.638**</td>
<td>-.429*</td>
<td>.022</td>
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<td>RCPMe</td>
<td>.322</td>
<td>.341</td>
<td>.117</td>
<td>.088</td>
<td>-.067</td>
<td>.237</td>
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Note: aDigit Span task (Wechsler Intelligence Scale for Children, Finnish version; Wechsler, 1991), raw score. bSentence Comprehension (Developmental Neuropsychological Assessment, Finnish version; Korkman, Kirk, & Kemp, 1997), raw score. cWord Finding Vocabulary Test (Renfrew, 2001), raw score. dRapid Automatized Naming Test (Denckla & Rudel, 1974; time). eRaven’s Coloured Progressive Matrices (Raven, 1993), raw score. fSimple additions. gSimple subtractions. hVerbal counting (Diagnostic Tests 3: Motivation, Metacognition and Mathematics; Salonen et al., 1994), raw score (max = 20). iNumber comparison.

*p < .05. **p < .01.
The scores for verbal and nonverbal number skills were subjected to a multivariate analysis of variance (MANOVA), which yielded a significant group effect between the SLI and EC groups, \(F(3, 145) = 6.74, p < .001\), Wilks’s \(\Lambda(145) = .68, p < .001\) (MANOVA was used instead of MANCOVA because nonverbal IQ scores were not available for the educational controls). The verbal and nonverbal performances were analyzed as a function of group using the general linear analysis of variance model and post hoc Fisher’s least significant difference multiple comparison test at \(p < .05\). The results for the verbal and nonverbal number skills of the children in the SLI and EC groups are presented in Table 4.

In the verbal number skills, no significant group effect was found in simple calculation accuracy \((p > .05)\). However, there was a significant difference in calculation speed, \(F(3, 145) = 16.93, p < .001, \eta^2_p = .26\). Post hoc comparisons revealed that the calculation speed of the SLI group was significantly slower than that of the EC2 \((p < .001)\) and EC3 groups \((p < .001)\). No significant difference was found between the SLI and the EC1 group \((p > .05)\). The EC3 and the EC2 groups were also significantly faster than the EC1 group \((p < .001)\), and the EC3 group was faster than the EC2 group \((p < .05)\).

There was a significant main effect in the nonverbal number skills, \(F(3, 145) = 14.29, p < .001, \eta^2_p = .23\). Post hoc comparisons revealed that the SLI group had a lower mean score than either the EC2 \((p < .001)\) or EC3 groups \((p < .001)\). There were no differences between the SLI and the EC1 groups \((p > .05)\). Furthermore, the EC3 and the EC2 groups performed better than the EC1 group \((p < .001)\). The mean score of the EC3 group was higher than that of the EC2 group, the difference being close to significant \((p < .06)\). Additional analyses with only number comparison as a measure of nonverbal number skills revealed similar results: On average, the children with SLI performed at the level of first graders.

Table 4. The mean performance score of SLI group and educational control groups in verbal and nonverbal numerical skills.

| Task                   | Group       | M     | SD    | M     | SD    | M     | SD    | F (3, 145) | \(\eta^2_p\) | Difference
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<tr>
<td>Calculation accuracy(^a)</td>
<td>SLI (n = 29)</td>
<td>.91</td>
<td>.05</td>
<td>.91</td>
<td>.05</td>
<td>.93</td>
<td>.06</td>
<td>.91</td>
<td>.05</td>
<td>1.00</td>
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<tr>
<td>Calculation speed(^b)</td>
<td>EC1 (n = 47)</td>
<td>4.06</td>
<td>1.85</td>
<td>3.99</td>
<td>1.22</td>
<td>2.98</td>
<td>0.71</td>
<td>2.40</td>
<td>0.63</td>
<td>16.93**</td>
</tr>
<tr>
<td>Nonverbal skills(^c)</td>
<td>EC2 (n = 40)</td>
<td>36.16</td>
<td>7.85</td>
<td>36.79</td>
<td>6.27</td>
<td>41.43</td>
<td>4.63</td>
<td>44.09</td>
<td>4.84</td>
<td>14.29**</td>
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<td></td>
<td>EC3 (n = 33)</td>
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\(^a\)Simple additions and subtractions (correct/attempted). \(^b\)Mean calculation response time in simple additions and subtractions in milliseconds. \(^c\)Sum score, max = 55. A general linear model analysis of variance with Fisher’s least significant difference post hoc analyses.

**\(p < .001\)**

The second aim of the present study was to investigate the heterogeneity in the numerical skills of children with SLI. To study number skills within the SLI group more closely, the group was divided into subgroups. Subgrouping was motivated by the fact that there are qualitatively different levels of performance in number skills. However, the same factors were also analyzed as continuous variables to confirm the findings (see Table 3). In verbal number skills, the key dimension was the difference between children who mainly use retrieval and those who use counting-based strategies in single-digit calculations. The cutoff point was the response time of 3,000 ms for single-digit calculations, which has been shown to be a good estimate of this strategic change (e.g., Temple, 1998). In nonverbal number skills, the division was made between those children who have been able to develop a representation of the magnitude of Arabic numerals up to the magnitude that they have been exposed to at school and those who had not achieved this. The cutoff point was set to 1 SD below the mean score for the EC2 group, which corresponds to the mean educational age of the SLI group. The use of the performance of the control group as a yardstick was motivated by the fact that the results of the SLI group must be compared with the average skills of children who have been exposed to equally high numbers.

As a result, three subgroups, from the four possible, were found: Twelve children showed difficulties in both verbal and nonverbal number skills \((V^-/N^-)\), 8 children showed difficulties in verbal skills only \((V^-/N^+)\), and 9 children showed no difficulties in either verbal or nonverbal number skills \((V^+/N^-)\). No child experienced difficulties solely in nonverbal number skills.

To minimize the influence of occasional outliers on the results of this rather small and very heterogeneous group, the analyses were conducted using the nonparametric
Kruskal–Wallis test. In addition, Spearman’s correlations between the numerical and linguistic tasks were calculated.

Number skills performance. The calculation speed variable for the verbal and the sum score of the nonverbal number skills were subjected to the nonparametric Kruskal–Wallis test to validate the theoretical classification of the SLI group into subgroups. The means and standard deviations of the subgroups in calculation speed and in nonverbal number skills are shown in Table 5. The analyses yielded a significant group effect between the groups, both in verbal, \( \chi^2(2, N = 29) = 18.01, p < .001 \), and nonverbal, \( \chi^2(2, N = 29) = 20.96, p < .001 \), number skills. The Mann–Whitney test was used for further analyses. It was confirmed that in calculation speed, the subgroup V+/N+ was significantly faster than the V–/N– \( (p < .001) \) and V–/N+ subgroups \( (p < .001) \). These latter two groups did not differ in calculation speed \( (p > .05) \). In nonverbal number skills, the V+/N+ subgroup was significantly better than the V–/N– subgroup \( (p < .001) \) but did not differ from the V–/N+ subgroup \( (p > .05) \). In addition, other verbal numerical skills were analyzed. There were no significant differences between the groups in verbal counting \( (p > .05) \) or in calculation accuracy \( (p > .05) \).

The performance of the SLI subgroups in comparison with the control groups is shown in Figure 2. In addition, analyses were carried out using the nonparametric Mann–Whitney test to ascertain whether the observed differences reached statistical significance. Figure 2 shows that in verbal numerical skills, the SLI subgroup V+/N+ performed at the level of the third graders. The V–/N– and V–/N+ subgroups were compared with the first graders. The V–/N– subgroup had a slower speed of calculation than the first graders (\( U = 173, p < .05 \)), and the V–/N+ subgroup did not differ significantly from the first graders \( (U = 118, p = .098) \).

In nonverbal numerical skills, the SLI V+/N+ subgroup performed at the level of the third graders, and the V–/N+ subgroup performed at the level of the second graders. This result matched these two subgroups’ level of education. On average, members of the V+/N+ subgroup were studying third-grade mathematics textbooks, and members of the V–/N+ subgroup were studying second-grade mathematics textbooks. The V–/N– subgroup was compared with the first graders. The results showed that they performed more poorly than the first graders \( (U = 173, p < .05) \) despite the fact that they were, on average, studying second-grade mathematics textbooks.

Performance on linguistic and nonverbal reasoning tasks. The SLI groups’ scores on the Auditory Digit Span task (WISC–III); Sentence Comprehension (NEPSY); Word Finding Vocabulary Test; RAN, Colors and Objects;
and the RCPM were analyzed to examine any differences between the subgroups. The mean scores and standard deviations for the subgroups are shown in Table 5. The Kruskal–Wallis test was applied to all the linguistic and nonverbal reasoning variables. The test for an effect of group on the RAN showed a close to significant \( \chi^2 \) value of 5.83 (\( p = .054 \)). No other significant values were found.

A follow-up test for rapid serial naming, using the Mann–Whitney test, showed a significant difference between the V-/N+ and V+/N+ subgroups, \( U = 12.5, p < .05 \), the V+/N+ subgroup being more rapid in naming. The difference between the V+/N- and V+/N+ subgroups was close to significant (\( U = 27.0, p = .055 \)), the V+/N+ group being more rapid in naming. No significant differences between subgroups were found in sentence comprehension: 83% of subgroup V-/N-, 75% of V-/N+, and 67% of subgroup V+/N+ had severe or moderate difficulties. Likewise, no significant differences between subgroups were found in nonverbal IQ, where 42% of children in the V-/N- subgroup had a nonverbal IQ above 100, which was a higher proportion than in the other two subgroups (V-/N+ 38%; V+/N+ 33%).

The subgroup analyses were corroborated by the analyses with continuous variables. Spearman’s correlations between the numerical tasks and the cognitive variables are presented in Table 3. Addition and subtraction speed correlated strongly with rapid serial naming (both \( ps < .01 \)) and less with sentence comprehension (\( p < .01 \) and \( p < .05 \), respectively). Verbal counting correlated significantly with rapid serial naming (\( p < .05 \)) and vocabulary (\( p < .01 \)). The comparison task had a small correlation with sentence comprehension (\( p < .05 \)). The moneybag task and estimation task failed to correlate significantly with any language or nonverbal reasoning task.

Because serial naming speed discriminated the subgroups and correlated strongly with arithmetic retrieval speed, the partial correlations between naming and arithmetic, controlled for age, vocabulary, and comprehension, were analyzed. The covariates did not have effects on the correlations: For addition, the correlation was .58 (\( p < .01 \)), compared with .64 without covariates, and for subtraction, the correlation was .63 (\( p < .01 \)), compared with .64.

### Discussion

The discussion is presented in two sections. The first section discusses the findings of the performance of the children with SLI on verbal and nonverbal number skills compared with the LC and EC groups. The second section focuses on the within-group differences found among the SLI children and how the linguistic factors explained the variance in these children’s number skills.
The primary focus of this study was to examine the influence of language impairment on various number skills. We were interested in whether children with SLI would do better in those tasks where explicit expression of numerical information or verbal processing of numbers was not required (nonverbal number skills) compared with those tasks where verbal processing has been found to be central (verbal number skills). Donlan and Gourlay (1999) found that curriculum level explained the differences in mathematics performance better than, for example, the group itself (e.g., SLI or age controls). Therefore, in contrast to previous studies, we used educational age controls instead of chronological age controls. This must be taken into consideration when interpreting the results and comparing them with those of previous studies. Our control groups formed a continuum from preschool to third grade, which made it possible to define more precisely the level of numerical skills of the children with SLI.

As a group, the children with SLI lagged behind the EC group, both in verbal and nonverbal mathematics. They performed at the level of first graders in both skills. This result differs from what has been found in previous studies (see Table 1) and what was hypothesized in this study. In verbal number skills, the children with SLI performed as expected. In verbal counting, they performed at the level of the LC group, and likewise, their level of fluency in performing calculations was weak considering that they had been taught and had practiced simple calculations for several years (i.e., 1 to 2 years more than the EC group). This finding is the same as reported by Fazio (1999) in her study of 9–10-year-old children with SLI and a standard nonverbal IQ score of 85 or above. However, children with SLI calculated as accurately as did the EC group. This finding agrees with that of Tieche Christinat et al. (1995), who did not find group differences in accuracy in the case of simple oral additions, subtractions, and divisions (by 2 and 3) between children with SLI and their 9–11-year-old age controls. Even though older children (9 to 11 years) with SLI seem to use slower counting-based calculation strategies more frequently than peers matched for education or age, at least, when given a longer time to practice, they are able to learn to perform almost error-free single-digit calculations.

Contrary to expectations, the SLI group as a whole performed at the level of first graders in nonverbal number skills, despite the fact that according to their average curriculum level, they have had more exposure than first graders to numbers above 100. The number comparison task has been previously used as an indicator of nonverbal number skill (e.g., Dehaene & Cohen, 1995, Donlan & Gourlay, 1999). To make our results more comparable with those of previous studies, additional analyses were undertaken in which number comparison only was used as the dependent variable. However, the results were the same: The children with SLI performed at the level of first graders. There are, at least, three possible explanations for this finding: group differences in nonverbal reasoning skills, the different number range used, and the heterogeneity of the SLI group.

The first possible explanation is that the SLI group had poorer nonverbal reasoning skills (mean standard score = 92). However, the current models of number processing do not support the idea (e.g. Butterworth, 1999; Dehaene, 1992) that nonverbal reasoning and representations of magnitude would share the same processing origins. In accordance with this, we found no significant correlations between nonverbal reasoning and nonverbal numerical skills within either the SLI group or LC group, and neither did nonverbal IQ attain significance as a covariate when the two groups were compared in nonverbal numerical skills. Second, the nonverbal reasoning skills of the children with SLI were on average close to the level of their chronological age, while their nonverbal numerical skills were clearly below the level of our oldest control group, who were younger than the children with SLI. Unfortunately, as RCPM data were not collected for the EC group, it was not possible to confirm that nonverbal reasoning and nonverbal number skills did not correlate across the whole age range of the study.

A more likely explanation for the weak performance of the SLI group in nonverbal numerical skills compared with previous findings (Donlan, 1993; Donlan & Gourlay, 1999) could be the different number range used. Donlan and Gourlay studied the understanding of double-digit numbers (10–99) in 8-year-old children with and without SLI. Eight out of 13 children with SLI and 10 out of 12 age-matched controls reached at least the 85% accuracy criterion in the task, which may indicate a ceiling effect. The numbers used in the present study ranged from 1 to 12,000. A detailed look at the data shows (and this is visible also in the mean and standard deviation) that in our study first graders (mean age 7.7 years) demonstrated that they had mastered number comparisons with double digits and most of them also with three digits. Even most of the preschool children seemed to have mastered the comparison of double-digit numbers. In the light of these results, the question is, if the previous studies had used larger numbers with more complex syntax, would the findings have been the same as those of the present study?

Could the influence of a more general deficit in processing syntax explain this finding? It is assumed that there is a domain-specific area of the brain for quantity processing, which is activated whenever a comparative operation that needs access to a numerical scale is called for (Dehaene, 1992; Dehaene & Cohen, 1995; Dehaene, Piazza, Philippe, & Cohen, 2003). However, studies have
only been carried out with single- and double-digit numbers and the influence of syntactic complexity (e.g., three- and four-digit numbers) on the identification process and on the whole comparison process has not been studied. As Arabic numerals advance in magnitude, it becomes more difficult to process quantity using only the visuospatial structure of the printed number; hence, using verbal decoding may serve as an aid in the process of numerical comparison. The finding of a small but significant correlation between the number comprehension task and the Sentence Comprehension Test partly supports this suggestion. However, the general deficit in processing syntax cannot fully explain the children’s performance in the number comparison task. First, there were no differences between the V–/N– and V–/N+ subgroups in verbal comprehension even though the groups differed in number comparison. The post hoc analyses revealed that the correlation was caused by the differences between the V–/N– and V–/N+ subgroups (i.e., between those who were good or poor in both verbal and nonverbal number skills).

The third explanation could be the considerable heterogeneity in the numerical skills of the children with SLI, which was also mentioned, but not analyzed, in previous studies (Donlan & Gourlay, 1999; Tieche Christinat et al., 1995). As our subgrouping analyses show, children with SLI cannot be treated as a uniform group from the perspective of number skills, because of the large variance in both verbal and nonverbal number skills. Less than one third of the children with SLI (V–/N+ group) showed clearly the previously described “poor verbal/better nonverbal” number skills profile.

Why did some of the children with SLI seem to acquire better numerical skills than others? To look for a possible answer to this question, we examined the differences in number skills within the SLI group and whether such differences in these children could be explained by linguistic or nonverbal reasoning factors. The children with SLI were divided into three subgroups according to their performance in verbal and nonverbal numerical skills. The V+/N+ subgroup used fact retrieval as their main strategy in simple calculation, and they also showed intact number comprehension and estimation skills compared with the EC group. The V+/N+ subgroup did not have fluent calculation skill but used counting as the main strategy in simple calculation. However, they showed intact number comprehension and estimation skills compared with the EC group. The V–/N+ subgroup had neither fluent calculation skill nor average number comprehension and estimation skills compared with the EC group.

Most of the children with SLI had difficulties in calculating simple additions and subtractions fluently (69%; V–/N+ and V+/N+ subgroups). In keeping with previous studies (e.g. Fazio, 1999), children with SLI have more problems with arithmetic fact retrieval, and they more often use slower strategies in performing simple calculations. Dehaene and Cohen (1995) proposed that simple facts are stored as verbal associations and can be retrieved only when the problem is modified into a verbal form (e.g. 3 + 2 = “three plus two”). Thus, it is hardly surprising that children with SLI perform poorly on these tasks. However, some of the children with SLI not only performed rather well on the nonverbal number skills tasks but also had no problems on the verbal number task (31%; V+/N+ subgroup). This group differed from the other two subgroups (V–/N–, V+/N+) in the RAN, where they were faster. The two subgroups, which calculated simple additions and subtractions slowly, likewise named colors and objects more slowly than the V+/N+ group. Naming speed was the only measure of the linguistic variables that explained the differences found in verbal number skills. As can be seen in Table 3, there were strong correlations between rapid serial naming and addition as well as between rapid naming and subtraction. This finding is in line with that of Temple and Sherwood (2002), who found that a group of children with arithmetic difficulties were slower at color and object naming than controls, although the authors did not explain it as a causal relationship between rapid naming and fact retrieval difficulties.

It has been proposed that naming speed could be the factor that explains the fairly high comorbidity found between learning disabilities in reading and mathematics (White, Moffitt, & Silva, 1992). There is considerable evidence that slow naming speed is a good indicator of reading disabilities (Grigorenko, 2001; Wolf, Bally, & Morris, 1986). Both skills, fluent reading and fluent calculation, require the fast retrieval of the appropriate names or sounds of either letters/words or numbers and of the associated answer. Difficulties in storing or accessing verbal material in or from long-term memory can lead to problems in learning to read fluently (Denckla & Cutting, 1999) as well as retrieving arithmetical facts (Geary & Hoard, 2001; Räsänen & Ahonen, 1995).

In nonverbal number skills, more than half (59%; V–/N+ and V+/N+ subgroups) of the children with SLI reached the level of the EC group. As was found in the previous study by Donlan and Gourlay (1999), despite language impairment, children with SLI can acquire numerical information related to the magnitudes of Arabic numerals and the quantitative relations between them. The rest of the children with SLI (41%; V–/N– subgroup) as a group had only reached the level of the LC group in nonverbal number skills. Donlan (1993) reported that five out of thirteen 8-year-old children with SLI failed to reach the 85% accuracy criterion in comparison of double-digit numbers. The weak performance of three of them was explained by their curricular experience. However, the percentage of failed children is about the same as that of the poor achievers (V–/N+) in
the present study with a larger group of children. Because of this subgroup, who performed very poorly in nonverbal number skills, the average performance of the SLI group as a whole reached only the first-grade level.

We found no significant differences between the SLI subgroups in nonverbal reasoning. In fact, the V^-/N^- subgroup contained a higher percentage of children with a nonverbal IQ above 100 than the other two subgroups (V^-/N^- 42%, V^-/N+ 38%, V+/N^- 33%). In addition, none of the measured language factors explained their poor performance in nonverbal number skills compared with the other two subgroups. In particular, the subgroup with poor performance in both verbal and nonverbal number skills (V^-/N^-), and the subgroup with only poor verbal number skills (V^-/N+) were very similar across all the language factors. The number-specific processing skills theory (Butterworth, 1999) could explain the weak performance of subgroup V^-/N^- in both calculation and nonverbal number skills, as well as the intact performance of subgroup V+/N+ in verbal and nonverbal number skills. However, the theory does not explain the performance of subgroup V^-/N+, who had intact non-verbal number skill but weak calculation fluency. Their good performance in number comprehension tasks would suggest intact numerical processing skills. If so, then their slow performance in calculation cannot be due to a number-specific processing deficit (see Landerl, Bevan, & Butterworth, 2004; Temple & Sherwood, 2002), and therefore other explanations are required.

Conclusions

We conclude that the numerical skills of children with SLI cannot be fully explained only by reference to their language skills or nonverbal reasoning skills, or to the theories of a number-specific module (Butterworth, 1999; Landerl, Bevan, & Butterworth, 2004). We propose that some language factors are associated with the development of number skills. The results obtained from this study suggest that the development of calculation fluency seems to share some of the underlying processing abilities required for accessing the long-term memory in order to recall the names of objects or colors rapidly. From a cognitive perspective, the naming task used in this study (RAN) is multicomponential in nature and is composed of, at least, phonological skills, processing speed, verbal fluency, and inhibition within verbal working memory factors (Närhi et al., 2005). Additional studies are thus required to determine which of these components are critical in the achievement of fluent calculation skills. Analyses of the developmental connections between calculation skills and different cognitive profiles, as well as specific number skills, are required. Children with specific language impairment provide a good possibility for studies of this kind. Rehabilitation studies would provide the strongest evidence concerning the influence of a number-specific module and various language factors on the development of number skills. It would be interesting to explore whether children with severe naming difficulties but intact numerical comprehension are able to learn arithmetical facts if they are taught to use their conceptual understanding.

In comparing our results with previous results, a few important observations should be made. The first concerns the format in which tasks were presented and the answers produced. In our study, both numerals and signs were presented visually in the calculation tasks and answers were given by pressing number keys. Hence, the task itself did not load so heavily on auditory comprehension, working memory, or verbal production, as did the counting itself. It may be that, had the calculation task been presented verbally and an answer also required verbally, the performance of the SLI children would have been poorer. However, requiring verbal answers from children with SLI can contaminate the results so that it becomes impossible to ascertain whether the poor performance is due to difficulties in processing numbers or to producing the answer verbally.

The second concerns the age and schooling experience of both the controls and the children with SLI. In this study, the children in the LC group were preschool, without any formal school experience of performing calculations. Had the SLI group been older, the LC group would also have been somewhat older, for example, first graders with 1 year’s school experience; the results might then have indicated different levels of performance. A promising design modification would be to have several age groups, each with its own LC group. The third and most important point is that our study demonstrates that children with SLI form a very heterogeneous group in their number skills. Instead of using SLI children as a whole group, more specific hypotheses concerning the influence of specific language skills and other cognitive skills on number skills are required. Our results suggest that the cognitive components of serial naming speed would be one of the most promising areas for further exploration.

Acknowledgments

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