*Reading and Writing: An Interdisciplinary Journal* **14:** 757–799, 2001.



# Correlates of early reading performance in a transparent orthography

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**Abstract.**
A cross-sectional study was conducted with 83 first – and 81 fourth graders at the end of the school year to examine factors accounting for early reading performance in Finnish, a transparent orthography with a clear mapping of phonemes onto graphemes. Measures for both grades included reading comprehension, phoneme awareness, and object- and digit naming. Additionally measures of skills in morphology, spelling and a screening battery were administered to the first graders. The sets of measures accounted for 56% of the variance in reading performance in first grade and 64% in fourth grade. Phoneme awareness was strongly related to reading performance and spelling at the end of first grade, but only for less-skilled readers in fourth grade. These results suggest a larger role for phoneme awareness for children learning a transparent orthography than has been suggested in earlier studies. At the same time, listening comprehension contributed more strongly to first-grade reading performance than has been reported for children learning to read English.

**Keywords:** Cross-language, Listening comprehension, Morpheme awareness, Phoneme awareness, Rapid naming, Regular orthography, Screening, Shallow orthography

## Introduction

Most studies examining what accounts for individual differences in learning to read have been carried out with English speaking subjects. These show that phoneme awareness, decoding skill, spelling, underlying phonological processes, comprehension, and intelligence are associated with reading proficiency in English (for reviews, see Blachman 1997). A growing number of studies in orthographies other than English address the importance of the characteristics of the reader's orthography and her/his linguistic environment on reading acquisition (Frost 1989, 1993). Cross-language studies suggest, for example, that reading skill develops at a different pace in different orthographies (e.g., Cossu, Shankweiler, Liberman, Katz & Tola 1988; Öney & Durgunoglu 1997).

According to the degree of phoneme-grapheme correspondence, orthographies can be put on an orthographic depth continuum from transparent, or shallow orthographies, with an almost perfect mapping of phonemes onto graphemes, to deep orthographies where, depending on its context, the same letter can represent different phonemes and the same phoneme can be represented by different letters (Frost, Katz & Bentin 1987). The English orthography, designed to capture morphologic as well as phonologic information, and the phonetically regular Finnish orthography, with an almost perfect transparency, lie on the two ends of this continuum.

If the depth of the orthography affects the rate of reading acquisition for the beginning reader, this should result in two related consequences: First, the depth of the orthography should be reflected in the correlates of early reading. Because a transparent orthography is easier to decode than a deep orthography, it might be anticipated that decoding, and phonological factors related to decoding, will account for less of the variance in learning to read. Second, differences in orthographic depth should also influence the pattern of reading development from beginning stages to fluent reading. If a transparent orthography is easier to master for the beginning reader than, for example, the English writing system, more cognitive resources may be available for beginning readers for higher-level processes of text integration and comprehension (Stanovich 1993). Being able to focus on the meaning of text may in turn be a rewarding experience more likely to encourage further reading and development of cognitive skills related to reading and intelligence (i.e., the Matthew Effect, Stanovich 1986).

The goal of the present study was to begin to test these predictions by examining the correlates of beginning reading for children learning Finnish. Finnish was chosen because this writing system is a transparent orthography with a high regularity between phoneme and letter correspondences. In addition, Finnish students are known to be highly successful in reading: a study conducted in 32 countries examined reading comprehension scores for children at ages 9 and 14 and found Finnish students, despite their late school start at the age of seven, to have the highest literacy levels for both age groups (Elley 1992). Because the characteristics of Finnish orthography are thought to play an important role in the reading success of Finnish students, questions about reading acquisition were studied in a cross-sectional study of Finnish children in grades one and four.

## *Prior studies of reading development for languages with alphabetic writing systems*

The results of international and cross-linguistic studies confirm the strong relation between phoneme awareness and reading acquisition found in English for other writing systems as well. The degree of regularity of grapheme-phoneme correspondances, however, seems to influence the duration of this relation.

Phoneme awareness has been found to be a good predictor of reading skills in the Scandinavian languages of Swedish, Norwegian, and Danish. These writing systems have opaque orthographies, but Swedish and Norwegian are considered to be more transparent than Danish or English. Phoneme awareness was the strongest predictor of end of first-grade reading skill in Norway (Hoien, Lundberg, Stanovich & Bjaalid 1995). Similarly, phoneme analysis skills successfully predicted reading achievement for the second grade in Danish and until the sixth grade in Swedish (Lundberg 1984; Lundberg, Olofsson & Wall 1980). In addition to the role of phoneme awareness in the gradual mastery of decoding in opaque orthographies, awareness of the morphological structure of words has been shown to make a contribution to reading performance in Danish (Elbro & Arnbak 1996; Olofsson & Niedersoe 1999).

The Hebrew writing system constitutes an interesting case where a deep orthography can be made transparent for instructional purposes. Hebrew has two forms of orthography, unpointed and pointed. The general unpointed orthography is ambiguous and opaque. It represents mostly consonants, omitting vowels that have to be guessed based on context. The pointed version provides information about the vowels by superimposing diacritical marks on the consonants and is found in children's literature. This version is considered a transparent writing system (Frost 1993). Ben-Dror, Bentin and Frost (1995) found that phoneme awareness deficits were significantly related to reading disability in the pointed version. In addition, morphologic skills were an important correlate of reading proficiency in morphologically rich and complex Hebrew.

The Dutch and German orthographies are writing systems rated as midway between Finnish and English (Elley 1992). De Jong and Van der Leij (1999) reported a strong effect of phonological abilities for the initial stages of reading acquisition in Dutch. This effect however disappeared after first grade. In German a relationship between phonological awareness and reading speed was documented by Wimmer, Landerl and Schneider (1994). They assessed preschool phonological awareness with a rhyme and onset oddity task and compared it to subsequent reading and spelling proficiency in German at grades one, three, and four. Early awareness skill was only moderately related to reading speed in first grade, but became more strongly linked to reading in the later grades.

Highly regular languages such as Italian or Turkish have been reported to show a significant relation with phonological awareness only for initial stages of reading acquisition in the beginning of first grade (e.g., Cossu et al. 1988; Öney & Durgunoglu 1997). Turkish children display rapid gains in decoding and spelling when reading instruction begins. One study noted that after basic decoding skills were achieved in the first months of first grade, the importance of phonological awareness in reading proficiency diminished rapidly (Öney & Durgunoglu 1997). Indeed, end of first-grade reading skills were more strongly predicted by listening comprehension than by phonological awareness.

Differences in rate of development of decoding skills have also been linked with orthographic characteristics. A cross-language study comparing the nonword reading skills of English and German-speaking children found that German eight year olds read faster and only made a fifth as many errors as the English-speaking children, yet these differences seemed to level out by the age of twelve (Frith, Wimmer & Landerl 1998). The researchers concluded that phonological decoding skills are mastered earlier in a more consistent orthography like German. This outcome conforms with other evidence of higher error rates in first grade for English-speaking children (i.e., 40% to 80%; e.g., Share, Jorm, MacLean & Matthews 1984; Juel, Griffith & Gough 1986; Treiman, Goswami & Bruck 1990) than for beginning readers of orthographically consistent writing systems (e.g., 10% errors for Greek children, Porpodas 1989; 20% errors for Italian children, Cossu, Gugliotta & Marshall 1996). Thorstad (1991), in a study directly comparing English and Italian children on the effect of orthography on literacy acquisition, confirmed that children learn to read and spell more easily when the orthography is predictable and constant. He concluded that Italian children acquire the same fluency in reading after one year that English children typically achieve after three to five years. Thorstad also noted the benefits of early success: compared to English children, Italian children became confident of their decoding skills more quickly and approached reading tasks more systematically and without anxiety.

Comparison of spelling performance also reveals interesting contrasts for children learning opaque and transparent orthographies. Thorstad (1991) reported that English beginning readers show greater ability in reading than in spelling, whereas their Italian counterparts are able to read and spell on equal levels. Further, consistency of orthographies is reflected in the patterns of errors. Children who learn to read English commit twice as many errors on vowel than consonant spelling (Shankweiler 1994), reflecting differences in the regularity of vowel and consonant coding: vowels have multiple spelling options while consonants in English are mapped in a more regular fashion to graphemes. This error pattern is reversed in the Italian, German, and Serbo-Croatian writing systems in which spoken vowels are represented in print in a consistent one-to-one manner (Shankweiler 1994). In contrast, in these writing systems a consonant name is often a syllable composed of two phonemes (i.e., the phoneme representing the consonant and an additional vowel), potentially inducing intrusions of the associated vowel on the spelling of consonants.

With mastery of basic reading and writing skills, listening comprehension has been proposed to place an upper bound on reading comprehension (Curtis 1980; Royer, Kulhavy, Lee & Peterson 1986). As reading improves, the proportion of variance in reading comprehension explained by listening comprehension increases, whereas the proportion linked to decoding decreases (e.g., Stanovich, Cunningham & Feeman 1984). In terms of Gough and Tunmer's (1986) "simple model" of reading (i.e., reading comprehension equals the product of decoding and listening comprehension), one could interpret this to mean that in a deep orthography the proportion of variance in reading comprehension accounted for by decoding will be noteworthy for beginning readers and will gradually decrease. Accordingly, Curtis (1980) found that the correlations between reading and listening comprehension for learners of English increased from 0.26 in second grade, to 0.66 in third grade, and to 0.74 in fifth grade. A transparent orthography, on the other hand, would be predicted to result in a greater contribution in the early grades from listening comprehension. The results of Öney and Durgunoglu (1997) with children learning to read Turkish confirm this prediction (i.e., $r = 0.87$ for listening comprehension and reading comprehension at the end of first grade).

*Phoneme awareness and decoding skills in poor readers of non-English orthographies*

A relatively small number of studies have explored the nature of language-related reading problems for children learning writing systems that are orthographically less deep than English. Preliminary research suggests that deficits in phoneme awareness and in decoding may be shaped by the demanding phonological features of the language and its writing system.

Similar measures were found to be related to reading difficulties in the morphophonemic writing system of Danish as in English (i.e., deficits in phoneme awareness, naming speed, verbal memory and vocabulary skill, Elbro, Bostrom & Petersen 1998). Additionally, the quality of the pronunciation of unstressed vowels in phonologically complex words seemed to contribute independently to reading skill, pointing to the relevance of underlying abilities to establish and store phonological representations.

For German, some findings suggest less accurate phoneme segmentation and decoding at beginning stages of reading instruction, but not later. For example, Wimmer (1996) reported that early difficulties in phoneme segmentation for dyslexic children were no longer apparent at the end of grade four. Likewise, when assessing decoding, the children were accurate at reading nonwords, though not able to do so as rapidly as their peers. Wimmer, Mayringer, and Landerl (in press) conclude that an early phonological awareness deficit may not be detrimental for reading mastery in the context of a consistent orthography. These authors propose that reading group differences in children learning a more transparent orthography may be limited to differences in automaticity.

Supporting the argument that reading difficulties in German might be primarily related to fluency in phonological processing, Wimmer (1993) found that speed of digit naming in a rapid naming task was the best predictor of nonword reading speed among dyslexic children learning to read German. The data of Wimmer et al. (in press) also showed large deficits in naming speed among German dyslexic readers in third grade. Having classified dyslexic participants into three groups according to the double-deficit hypothesis (Wolf 1997) (i.e., awareness/decoding deficit; naming speed deficit; both), Wimmer et al. found that naming speed corresponded with reading performance regardless of the dyslexic subtype. Similarly, other studies with cross-linguistic data also suggest that when the phonological demands placed on young readers are lower, as in a regular orthography, a naming-speed deficit is a dominant diagnostic indicator for at-risk readers (Wolf 1997). Slow naming speed among eight-year-olds also predicted more resistant forms of dyslexia in Finland (Korhonen 1991).

Countering this line of reasoning, Landerl, Wimmer and Frith (1997) found persistent phonological awareness deficits on a spoonerism task (e.g., man and hat become han and mat) among German dyslexic students eleven to thirteen years old. The spoonerism task was selected to be more sensitive to individual differences in awareness skills at a point when initial measures of awareness generally have reached ceiling levels. Likewise, examination of the performance of German dyslexic children on nonword decoding tasks reveals not only slower reading, but also a higher occurrence of errors (Wimmer 1996). A separate study by Wimmer and Hummer (1990) also found that reading-delayed German first-graders made approximately 35% errors reading words and nonwords, in contrast to the 10% error rate noted above for their average-reading peers. Interestingly, accuracy deficits by German dyslexic students are particularly evident in spelling tasks rather than on reading measures, perhaps because of the greater orthographic demands when phonemes are translated into graphemes than vice versa (Wimmer & Landerl 1997).

Evidence supporting deficits in the quality of phonological representations comes from a study of adult dyslexic readers compared with normal adult readers in Finland. In addition to reading at a slow pace, the dyslexic subjects also had greater problems with certain phoneme contrasts (Lyytinen, Leinonen, Nikula, Aro & Leiwo 1995). Error analysis of a pseudoword reading task showed insensitivity to the duration of phonemic segments. Dyslexics mistakenly lengthened short consonants to the corresponding long consonant an average of 30.2 times more often than normal readers and lengthened vowels an average of 6.6 times more often (see Appendix A for characteristics of the Finnish language). These findings of reduced accuracy raise questions about the claim that differences in reading ability in shallow orthographies are limited largely to rate.

In sum, there is a need to better understand the sources of individual differences in different orthographies[1] and to explore the nature of difficulties for children who have reading problems even when the writing system is transparent. In spite of the highly regular orthography of Finnish, six percent of the adult Finnish population are found to be dyslexic (Lyytinen et al. 1995). The authors suggest that orthographic regularity results in an earlier timepoint for acquiring functional reading skills, but should not affect the incidence of severe reading problems.

*Research goals*

The present study was designed to evaluate and extend the evidence on correlates of reading acquisition for a transparent orthography. As noted earlier, Finnish children in first and fourth-grades were studied. For the first-grade sample, one goal was to test whether ceiling effects are obtained on phoneme awareness tasks in the first-grade year, as Oney and Durgunolu (1997) reported, or whether phonological awareness continues to be associated in Finnish with literacy acquisition beyond the beginning stages of reading in the fall. Here, for the awareness measures used at the end of first grade, an effort was made to design tasks that were sufficiently demanding to tap individual differences (e.g., by including subtle phonological contrasts in Finnish such as phoneme duration). A further goal with the first-grade sample was to use a broad array of measures, in addition to phoneme awareness, to investigate other potential factors in reading acquisition and to examine whether a larger role for listening comprehension would be obtained than is seen for beginning readers of English (c.f., Oney & Durgunolu 1997). Memory span, morphological awareness, rapid naming speed, and visuo-motor coordination were assessed, in addition to measures of letter knowledge, decoding accuracy and speed, reading and listening comprehension, and estimates of IQ. Some of these measures were assessed as part of this study, others were available from a screening procedure administered at school entry.

Because few studies in languages other than English have looked at the development of literacy skill beyond the early stages, we also wanted to examine the presence of reading problems for readers of a transparent orthography in the middle grades. Fourth-grade children were studied and were tested on phoneme awareness, and rapid naming speed, as well as on reading and cognitive measures. Central questions were whether poorer reading performance in these older children would be associated with weaknesses in phoneme awareness if sufficiently demanding measures were administered and on correspondence of reading performance with naming speed.

## Method

### *Participants*

After excluding children who were outliers in cognitive functioning or who displayed neurological, behavioral or sensory difficulties, 159 participants (74 girls and 85 boys) from two urban elementary schools in Southern Finland were selected for this study. All Students spoke Finnish as their first language. They included 80 first graders (mean age = 91, 1 months; SD = 3, 7 months; range = 89–103, 3 months) and 79 fourth graders (mean age = 125, 7 months; SD = 3, 8 months; range = 125, 7–140, 0 months).

### *Measures*

#### *Measures of reading*

*Reading comprehension.* The tasks for reading comprehension were selected from the "Comprehensive School Reading Test" (CSRT) (Lindeman 1998a). The first graders were presented one passage and the fourth graders two passages (i.e., the amount that could be administered during a one hour session.) The reading comprehension tests were group administered following the standard procedure. Each portion consisted of a short story with twelve related written multiple choice questions. The subject's score was the number of correct answers achieved (first graders, maximum score = 12; fourth graders, maximum score = 24). The estimates of internal consistency for the reading comprehension texts, calculated with the K-R 20 formula, were 0.80 for the first grade and 0.86 for the fourth grade in the present sample.

*Decoding speed and accuracy.* Speed and accuracy for reading a twenty item pseudoword text were assessed for each grade (see Appendix B). The texts were derived from grade appropriate text books for the first and the fourth grades. One or two graphemes per word were altered so that the pseudowords still conformed with phonological patterns of Finnish. Most of the first-grade words were mono- or bisyllabic, whereas word patterns were more varied for the fourth-grade text. Two scores were calculated for each child: 1) A speed score obtained by dividing the duration it took to read the passage (measured in tenths of a second with a stop watch) by the number of syllables in the passage (i.e., 31 for the first grade, 63 for the fourth). 2) An accuracy score consisting of the number of correctly read pseudowords (maximum = 20). The estimate of internal consistency (K-R 20) for the pseudoword accuracy variable was 0.89 for the first-grade sample and 0.55 for the fourth-grade sample.[2]

*Spelling (first grade only).* A group-administered spelling test consisting of 14 words was given to assess spelling skills (see Appendix B). The score was the number of correctly spelled items. The test had an estimate of internal consistency of 0.90 (K-R 20).

*Measures of intelligence*

*Nonverbal cognitive ability.* The Block Design subtest from the Wechsler Intelligence Scale for Children Revised (WISC-R) was used as a measure of nonverbal cognitive ability (Wechsler 1974). The subtest has a median internal consistency reliability of 0.90 within the Finnish population (Wechsler 1984).

*Verbal ability and vocabulary knowledge.* The Vocabulary subtest of the Finnish version of the WISC-R was administered (Wechsler 1974). Within the Finnish population, the subtest has a median internal consistency reliability of 0.95.

*Estimate of IQ.* An estimate of IQ was obtained by combining the standard scores for the WISC-R vocabulary and block design tasks according to Sattler (1982). In United States samples, this IQ-estimate correlates 0.90 with the Full Scale IQ scores of the WISC-R (Sattler 1982).

*Listening comprehension.* No standardized listening comprehension tests were available. In order to be comparable with the reading comprehension test, one first-grade and one fourth-grade passage from the Comprehensive School Reading Test, and the related multiple choice questions for each, were transformed into a listening comprehension test recorded on audiotape (note: The passages selected for this purpose were not used to assess reading comprehension). Participants listened first to the entire passage, then each paragraph was presented individually along with the corresponding multiple choice questions. Children marked their responses on an answer sheet. Each correctly answered item was given one point (maximum score = 12). The estimate of internal consistency of the listening comprehension tests (K-R 20) was 0.72 for the first-grade and 0.70 for the fourth-grade sample.

*Measures of phonological awareness and of morphological knowledge*[3]

*Oddity task (first grade only).* The procedure was adapted from a sound categorization task by Bradley and Bryant (1985). Eighteen trials of four words were created in which three contained a common phoneme (see Appendix C.1). Because of the small number of monosyllabic words in Finnish (i.e., around 50; see Kyöstiö 1980), it was necessary to use mainly bisyllabic words. To reduce the memory load, the children were told the position of the phoneme they were to focus on (initial position for the first six trials, final position for the next set of six trails, and second position for the last set). Two of the six trials for each set contained items for which duration of the phoneme was the criterion for discrimination. The total number of correct answers was the score for each child (maximum = 18 points). The estimate of internal consistency of the sample was 0.76 (K-R 20).

*Phoneme Deletion (first and fourth grade).* The first graders were presented three sets of five words (see Appendix C.2). In each set the participant was to delete the designated phoneme (Set One – initial; Set Two – final; Set Three – second). If done correctly, a new word remained (e.g., English example: pill without the /p/ is ill). The total number of correct answers was the child's score (maximum = 15 points). The estimate of internal consistency of the sample was 0.81 (K-R 20).

The fourth graders also were presented with three sets of five words each (see Appendix C.3) in which a specified phoneme was to be deleted (Set One – initial phoneme (with different words than the first graders had); Set Two – second phoneme (same words as Set Three for the first graders); Set Three – next to last phoneme)). The participants score was the total number of correct answers (maximum = 15 points). The estimate of internal consistency of the sample was 0.50 (K-R 20). Steps to improve the reliability of the fourth-grade phoneme deletion task are described in the results section.

*Piglatin (fourth-grade only).* In this task, the participants were presented twelve words, one at a time (see Appendix C.4). For each item they were to shift the first "sound" from the word to its end (e.g., talo → alot) and then to add the "-in" syllable (e.g., alot-in). The total of correctly spoken "piglatin" responses was the score for each person (maximum = 12 points). The estimate of internal consistency of the sample was 0.69 (K-R 20).

*Morphological awareness (first grade only).* The task used subtests of a measure of the mastery of inflectional forms developed by Lyytinen (1988) mainly for preschool and first-grade children (see Appendix D). The test measures children's skills at inflecting old Finnish words no longer in use. Each word is orally presented together with a drawing showing the activity or ability corresponding to the word. The child is then to attempt to generate a specified inflection for the item. Three of six subtests were selected for this study (i.e., present tense, comparative and superlative). Each item was scored on a 3 to 0 point scale: 3 = correct inflection of the whole word; 2 = correct inflection of at least the last syllable; 1 = an alternative response (e.g., a synonym for the targeted word); 0 = all other responses. Thus, the maximum score per subtest was 15, with a total maximum score of 45. The estimate of internal consistency (K-R 20) of the test in the sample was 0.79.

*Measures of naming speed*

*Digit naming speed.* The children were asked to name as quickly as possible a set of 30 randomly selected single digit numbers presented on three rows on a computer screen. The items were identical for both grades. When the matrix first appeared on the screen, a "click" sound was produced. The time between the "click" sound and the moment when the last number on the list was named was measured with a stop watch. The average number of digits per second was the score for each child. Due to incidental naming errors, the digit naming scores of three first graders and of one fourth grader were dropped from the data set.

*Object naming speed.* The participants were asked to name as quickly as possible 20 small pictures of unambiguous high frequency objects (ball, umbrella, watch, squirrel, etc.) that were presented in four rows on a computer screen. The 20 stimuli selected for this task were chosen out of a pool of 50 items based on pilot work showing that these stimuli elicit very consistent naming responses by children. The task was identical for both grades. Naming time was measured as for the digit naming task. The average number of items per second was the score for each participant. Due to incidental naming errors, the object naming scores of seven first graders and of six fourth graders were dropped from the data set.

*Additional screening measures (first grade only)*

Four additional measures from a screening procedure related to literacy acquisition were included. This screening procedure was developed by reading teachers of the town of Vantaa, Finland (E. Kokko, personal communication, May 20, 1997), to identify children at risk for reading failure among incoming first graders. The tests had been administered at the beginning of the first school year to all entering first graders in both participating schools.

*Letter knowledge.* In this group-administered task, the examiner said a lettername and the students were told to write it on their answer sheets. The score was the number of correctly written letters (8 vowels, 12 consonants; maximum = 20). The variance on this measure turned out to be low: 66% of the incoming first graders knew all letters, another 18% knew all but one letter.

*Identification of initial letter.* In this measure, the child was asked to name the first letter or sound that would be used to spell a word. Ten words were presented orally, five beginning with a vowel and five with a consonant. The score was the number of correctly identified letters or sounds (maximum = 10).

*Digit span.* Each first grader was tested on five sequences of digits. The first trial had three digits, the second and third had four digits, and the fourth and fifth sequences had five digits. The numbers were read at a rate of one digit per second. The participant was told to repeat the sequence immediately after the experimenter had completed saying it. If a child failed on both trials with four digits, the trials with five digits were omitted. The score was the number of correctly recalled sequences (maximum = 5).

*Visuomotor coordination skill.* The child had to copy four different figures or shapes (e.g., triangle, diamond) with a pencil. For each of the four items, two one-inch areas with three rows of three dots (i.e., nine dots), equally spaced, were presented to the student. The figures to be copied were drawn upon an identical nine dot pattern on the left side of the page and had to be copied on the nine dots on the right side. In order to perform the task correctly, the lines of the copied figure had to touch the equivalent dots as in the example. The child's score was the number of correctly copied figures (maximum = 4).

### *Procedure*

All measures were administered by the first author and by a literacy teacher. In first grade the four screening measures (i.e., letter knowledge, identification of initial letter, digit span and visuomotor coordination skill) were administered in September, at the beginning of the school year. Spelling was assessed during March. The remainder of the testing in first grade and all testing in fourth grade began in May and continued until August. Four of the measures were administered in the classrooms: reading comprehension, listening comprehension, spelling and letter knowledge. All other measures were administered individually in a fixed order occurring over two sessions for the first and one session for the fourth graders. Practice trials were included for tasks, and for subsets of tasks if appropriate for all measures except spelling, letter knowledge, identification of initial letter and visuomotor coordination skill.

There was full participation for all measures, except for absences during the screening measures that were administered at the beginning of the school year for the first graders. In addition, as mentioned earlier, a small number of naming speed scores had to be dropped from the data set due to incidental naming errors.

## Results

For each grade, correlational analyses between all variables were conducted and multiple hierarchical regression analyses were performed to examine the variance accounted for by these variables for the outcome measures of reading comprehension, decoding, and spelling. Some results were compared to results of a U.S. sample in Stanovich et al. (1984). Prior to these analyses, descriptive statistics were calculated and the variables were examined for normality of distribution and adequacy of the variance. A summary of the descriptive statistics for the reading and intelligence measures is provided in Table 1. Means, standard deviations and ranges of the other variables are summarized in Table 2. In the first-grade sample, distributions of only three of the variables were nonnormal, but were improved by logarithmic transformations. These were decoding accuracy and listening comprehension (Table 1), and letter knowledge on the screening battery (Table 2). All scores for measures administered to the fourth-grade sample were normally distributed.

### *Combining measures of phoneme awareness*

The measures administered to the first graders to assess phoneme awareness (i.e., the phoneme deletion and oddity tasks) were highly correlated ($r = 0.69$). Because the goal of both measures was to assess skill in phoneme awareness, a principal component analysis was performed on all items in both tasks, and a combined score (combined phoneme awareness) was created based on the results. Map-rule (Velicer 1976) retained one factor. Based on factor loadings of 0.3 or more on the sole factor, 30 items were selected for the combined measure. The estimate of internal consistency of the combined first-grade phoneme awareness measure was 0.87 (K-R 20). Scores for this combined

*Table 1.* Means, standard deviations and ranges for measures of reading and intelligence in first and fourth grade samples[a]

| | First grade (n = 80) | | Fourth grade (n = 79) | |
|---|---|---|---|---|
| | Mean (SD) | Range | Mean (SD) | Range |
| *Measures of reading* | | | | |
| Reading comprehension max = 12/24[b] | 7.71 (2.78) | 1–12 | 16.69 (4.26) | 7–23 |
| Decoding speed[c] | 1.15 (0.55) | 0.17–2.56 | 1.87 (0.59) | 0.82–3.89 |
| Decoding accuracy max = 20/20[b] | 18.06 (3.32) | 0–20 | 18.52 (1.72) | 13–20 |
| Decoding accuracy (revised) max = na/13[d] | NA | | 11.61 (1.65) | 6–13 |
| Spelling max = 14 | 11.28 (3.58) | 0–14 | NA | |
| *Measures of intelligence* | | | | |
| Estimate of IQ Standardized score M = 100 | 96.00 (12.77) | 71–120 | 105.73 (11.52) | 80–135 |
| Block design (Wisc-R) Standardized score M = 10 | 9.83 (2.62) | 5–19 | 10.80 (2.49) | 6–17 |
| Vocabulary (Wisc-R) Standardized score M = 10 | 8.80 (2.96) | 3–16 | 11.15 (2.42) | 7–18 |
| Listening comprehension max = 12/12[b] | 10.04 (2.08) | 2–12 | 8.95 (2.04) | 2–12 |

[a]The particular test items for first and fourth graders differed on all measures except Estimate of IQ, Block Design and Vocabulary. These three measures used Standardized Scores. Other values reflect raw scores.
[b]Maximum scores for first/fourth grades.
[c]Syllables per second.
[d]Revised score.

measure were calculated for all subjects (see phoneme awareness (combined) in Table 2).

The fourth-grade sample was tested on two measures of phoneme awareness: phoneme deletion and piglatin. Again, because both measures were designed to assess skills in phoneme awareness, Principal Component Analysis was performed on all items of both. Map-rule (Velicer 1976) retained one factor. Based on factor loadings of 0.30 or higher, ten items from the piglatin task and three items from the phoneme deletion task were grouped to form a phoneme awareness measure for the fourth-grade sample (combined phoneme awareness) (see Table2). The estimate of internal consistency for this measure of phoneme awareness was 0.72 (K-R 20).

*Table 2.* Means, standard deviations and ranges for first and fourth graders for measures[a] of phonological awareness and morphological knowledge, naming speed and for the screening tasks administered to first graders at school entry

| | First grade (n = 80) | | Fourth grade (n = 79) | |
|---|---|---|---|---|
| | Mean (SD) | Range | Mean (SD) | Range |
| *Measures of phonological awareness and morphological knowledge*: | | | | |
| Oddity task max = 18 | 12.73 (3.20) | 6–18 | NA | |
| Phoneme deletion max = 15/15[b] | 11.38 (3.02) | 2–15 | 12.85 (1.59) | 7–15 |
| Piglatin max = 12 | NA | | 8.18 (2.46) | 2–12 |
| Phoneme awareness (combined) max = 30/13[b] | 21.94 (5.39) | 9–29 | 8.73 (2.80) | 1–13 |
| Morphological awareness max = 45 | 33.19 (6.55) | 15–42 | NA | |
| *Measures of naming speed* | | | | |
| Digit naming[c] (n = 77/78) | 1.40 (0.32) | 0.5–2.1 | 2.15 (0.37) | 1.3–2.9 |
| Object naming[c] (n = 74/74) | 0.91 (0.21) | 0.4–1.6 | 1.15 (0.27) | 0.6–1.8 |
| *First-grade screening tasks* | | | | |
| Letter knowledge max = 20 (n = 77) | 18.71 (3.32) | 2–20 | NA | |
| Initial letter identification max = 10 (n = 78) | 8.69 (1.92) | 4–10 | NA | |
| Digit span max = 5 (n = 63) | 3.54 (1.24) | 0–5 | NA | |
| Visuomotor coordination max = 4 (n = 77) | 2.81 (1.20) | 0–4 | NA | |

[a]The particular test items for first and fourth graders differed on all measures except digit and object naming.
[b]Maximum scores for first/fourth grades.
[c]Items per second.

## *Improving the reliability of fourth-grade decoding accuracy*

The estimate of internal consistency of fourth-grade decoding accuracy was low (.55, K-R 20). In order to improve the variance per item ratio (2.89/20 items for the fourth grade), seven words with no or very low variance were removed (see Table 1, Decoding Accuracy (revised)). The variance per item ratio improved to 2.72/13 items. The revised decoding accuracy measure correlated 0.97 with the original measure; its estimate of internal consistency improved to 0.63. Skewness and kurtosis were not affected.

### *Correlational analyses*

In order to examine the relationships between the variables used in this study, and the occurrence of multicollinearity, correlational analyses were performed for the first (see Appendix E) and fourth-grade samples (see Appendix F).

#### *First-grade correlational patterns*

Significant correlations were obtained between all measures of first-grade literacy performance (i.e., reading comprehension, decoding accuracy, decoding speed, spelling), of phoneme awareness (i.e., phoneme deletion, the oddity task and the combined score for these), and digit naming, and of initial letter identification at school entry.

Reading comprehension and decoding speed also were significantly related to both the estimate of IQ, listening comprehension, morphological awareness and object naming. This outcome suggests that morphological skills, in addition to phoneme awareness and digit naming, may play an important role in Finnish reading performance.

Of the other measures administered at school entry, letter knowledge was significantly related to reading comprehension, and digit span to decoding accuracy, decoding speed and spelling. Visuomotor skill, however, was not significantly related to any of the reading outcome measures.

Listening comprehension was significantly correlated with reading comprehension, decoding speed, spelling, Block Design, Vocabulary, IQ estimate, all measures of phonological awareness, the naming tasks, and the screening measures done at school entry except for visuomotor coordination skill.

#### *Fourth-grade correlational patterns*

Fourth-grade reading comprehension was significantly correlated with decoding accuracy, estimate of IQ, Vocabulary, listening comprehension, measures of phonological awareness (i.e., piglatin and phoneme deletion) and object naming. However, decoding speed, Block Design and digit naming speed were not significantly related to reading comprehension at the end of grade four.

Decoding speed was significantly correlated with decoding accuracy, phoneme deletion and the combined measure of phonological awareness, and both naming speed measures. Decoding accuracy was correlated, in addition to reading comprehension and decoding speed, with all measures of phonological awareness and with digit naming.

Listening comprehension correlated significantly with reading comprehension, estimate of IQ, Vocabulary, and both measures of naming speed but was not, in contrast to the first graders, significantly related to decoding or phoneme awareness.

*Pattern for less-skilled readers*

In order to examine the relationships among the variables for less-skilled readers, students whose score on the reading comprehension measure was lower or equal to one standard deviation below the mean of the corresponding normative sample of the CSRT reading test (Lindeman 1998b) were assigned to the less-skilled reader groups (i.e., 16 first graders and 22 fourth graders).

Due to the relatively small number of students in the less-skilled reader samples, only correlations of about 0.5 or more are significant. For the less-skilled readers in the first-grade, reading comprehension was significantly related to phoneme deletion and digit naming (see Appendix G). For this group, decoding speed was related significantly to decoding accuracy, spelling, phoneme deletion, oddity task, the combined measure of phoneme awareness, and digit naming. Decoding accuracy was related significantly to the same phoneme awareness and spelling measures as decoding speed, additionally to letter knowledge. However, unlike for decoding speed, decoding accuracy was not related to digit naming speed. Spelling was significantly correlated to the decoding measures, phoneme deletion, the combined measure of phoneme awareness and to digit naming. No significant correlations emerged for listening comprehension.

In the sample of less-skilled fourth grade readers, phoneme deletion, as well as the combined phoneme awareness measure, correlated significantly with reading comprehension (see Appendix H). Object naming and decoding accuracy were both related to decoding speed. Listening comprehension correlated significantly with digit naming and, in contrast to the entire sample, with the combined phoneme awareness measure.

In order to compare the development of the relation between reading comprehension and listening comprehension, as well as between reading comprehension and vocabulary skill in the Finnish sample of this study and in the American sample used by Stanovich et al. (1984), the amount of shared variance between the variables was calculated based on the correlation coefficients. The comparisons are tentative because different measures were used. Figure 1 shows that listening comprehension and reading comprehension in the Finnish sample shared roughly one third of their variance in both grades, whereas American children reached a similar level of association between listening and reading comprehension in the fifth grade, but not at younger

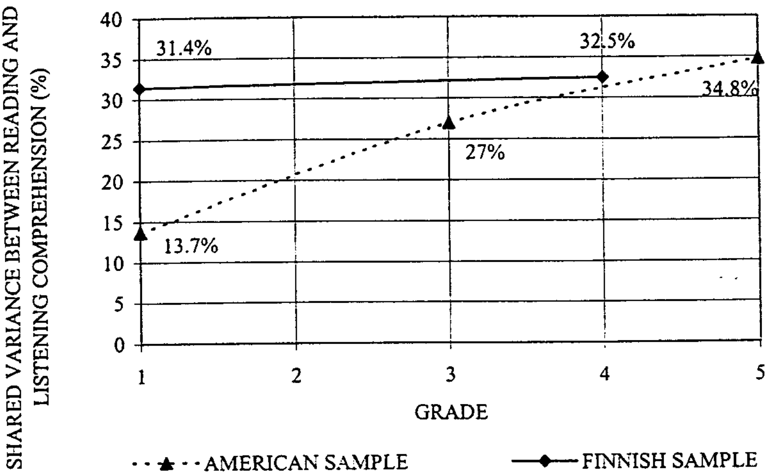


*Figure 1.* Percentage of shared variance between reading comprehension and listening comprehension in the Finnish and American sample at different grades (Stanovich et al. 1984).

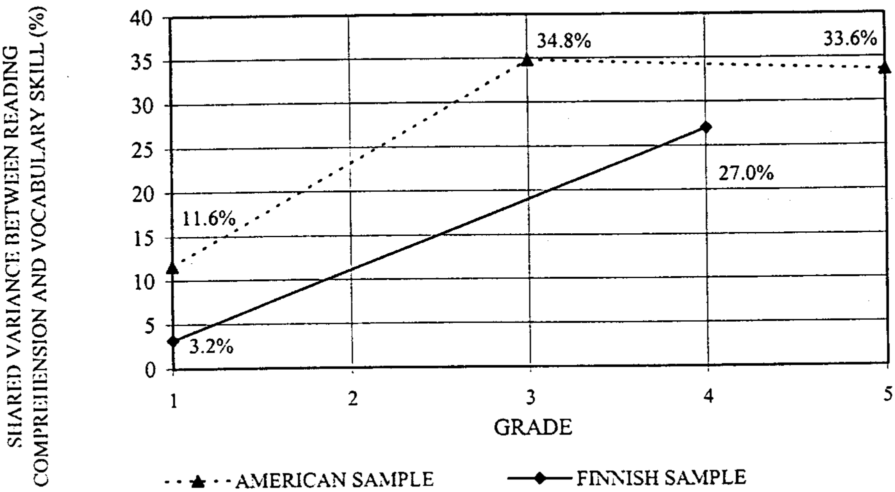


*Figure 2.* Percentage of shared variance between reading comprehension and vocabulary skill in the Finnish and American sample (Stanovich et al. 1984) at different grades. *Note.* Measure used in the American sample: Peabody Picture Vocabulary Test.

grades, especially in first grade. Figure 2 reveals that vocabulary skill seems to have a similar developmental association to reading comprehension in both languages and writing systems, however the association in English appears to be relatively earlier and somewhat stronger for beginning readers.

*Table 3.* Outcomes of hierarchical regression analyses of predictors of reading comprehension for entire first and fourth grade samples

| | | First grade | | | Fourth grade | | |
|---|---|---|---|---|---|---|---|
| Step | Measure | $R^2$ | $R^2$ change | ß | $R^2$ | $R^2$ change | ß |
| 1 | Age (months) | 0.013 | 0.013 | 0.115 | 0.058 | 0.058 | 0.241* |
| 2 | Block design (raw) | 0.098 | 0.085 | 0.292* | 0.126 | 0.068 | 0.261* |
| 3 | Vocabulary (raw) | 0.119 | 0.021 | 0.151 | 0.423 | 0.297 | 0.584*** |
| 4 | Object naming | 0.173 | 0.054 | 0.237* | 0.537 | 0.114 | 0.341*** |
| 5 | Digit naming | 0.210 | 0.037 | 0.233 | 0.538 | 0.001 | 0.047 |
| Reversing the order of steps 4 and 5 | | | | | | | |
| 4 | Digit naming | 0.200 | 0.081 | 0.294* | 0.477 | 0.054 | 0.238 |
| 5 | Object naming | 0.210 | 0.010 | 0.121 | 0.538 | 0.062 | 0.313*** |
| 6 | Listening compreh. | 0.373 | 0.163 | 0.469*** | 0.604 | 0.066 | 0.316** |
| 7 | Phoneme awareness | 0.470 | 0.097 | 0.370*** | 0.616 | 0.011 | 0.125 |
| 8 | Decoding accuracy | 0.501 | 0.031 | 0.239 | 0.636 | 0.020 | 0.158 |
| 9 | Decoding speed | 0.534 | 0.033 | 0.261* | 0.641 | 0.006 | −0.092 |

*Note.* *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

### *Hierarchical multiple regression analyses*

Hierarchical multiple regression analyses were carried out for both grades to examine in each the variance in reading performance accounted for by phoneme awareness and other variables. Prior to each analysis, the sample was examined for multivariate outliers using the $p < 0.001$ criterion for Mahalanobis distance (Tabachnick & Fidell 1996). No multivariate outliers were identified.

The first series of analyses for both grades determined which measures accounted for individual differences in reading comprehension (see Table 3). Phoneme awareness contributed significantly to first-grade reading comprehension, even after effects of several other variables had been accounted for (age, Block Design, Vocabulary, the naming speed measures (i.e., Object and Digit Naming) and listening comprehension).

At both grade levels, listening comprehension contributed significantly to reading comprehension after accounting for age, Block Design, Vocabulary and naming speed. Digit naming was more related to first-grade reading comprehension than object naming, whereas object naming contributed more strongly to fourth-grade reading comprehension. Reading comprehension in first grade was predicted significantly by decoding speed after all other variables had been accounted for.

*Table 4.* Outcomes of hierarchical regression analyses of predictors of decoding speed for entire first and fourth-grade samples

| | | First grade | | | Fourth grade | | |
|---|---|---|---|---|---|---|---|
| Step | Measure | $R^2$ | $R^2$ change | ß | $R^2$ | $R^2$ change | ß |
| 1 | Age (months) | 0.009 | 0.009 | 0.094 | 0.043 | 0.043 | 0.208 |
| 2 | Block design (raw) | 0.073 | 0.064 | 0.254* | 0.062 | 0.019 | 0.137 |
| 3 | Vocabulary (raw) | 0.117 | 0.044 | 0.216 | 0.064 | 0.002 | −0.045 |
| 4 | Object naming | 0.168 | 0.051 | 0.232* | 0.201 | 0.138 | 0.374*** |
| 5 | Digit naming | 0.264 | 0.097 | 0.372** | 0.216 | 0.015 | 0.158 |
| Reversing the order of steps 4 and 5 | | | | | | | |
| 4 | Digit naming | 0.263 | 0.146 | 0.396*** | 0.167 | 0.103 | 0.329** |
| 5 | Object naming | 0.264 | 0.002 | 0.047 | 0.216 | 0.049 | 0.281* |
| 6 | Phoneme awareness | 0.491 | 0.227 | 0.553*** | 0.226 | 0.010 | 0.120 |
| 7 | Decoding accuracy | 0.501 | 0.010 | 0.134 | 0.297 | 0.070 | 0.293* |
| Reversing the order of steps 6 and 7 | | | | | | | |
| 6 | Decoding accuracy | 0.410 | 0.146 | 0.397*** | 0.296 | 0.080 | 0.302** |
| 7 | Phoneme awareness | 0.501 | 0.091 | 0.457*** | 0.297 | 0.001 | 0.034 |

*Note.* $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

A second series of analyses examined predictors of decoding speed. After accounting for individual differences in age, Block Design, Vocabulary and naming speed (i.e., object and digit naming), phoneme awareness contributed significantly to first-grade decoding speed even after decoding accuracy had been accounted for (see Table 4). No significant contribution of phoneme awareness emerged for fourth-grade decoding speed.

Digit naming speed received a higher beta-weight than object naming speed, regardless of order of entry, indicating a stronger relation to decoding speed in first grade. The picture was almost reversed for the fourth graders, where object naming speed turned out to be a stronger predictor of decoding speed than did digit naming speed.

A third series of analyses examined predictors of decoding accuracy for both grades and of spelling skill for first grade (see Table 5). Phoneme awareness was significantly related to first-grade spelling and to both first- and fourth-grade decoding accuracy. Phoneme awareness entered the regression equations significantly for first-grade spelling and decoding accuracy, as well as for fourth-grade decoding accuracy even after effects of age, cognitive ability, naming speed and decoding speed were accounted for. Digit naming was significantly related to first-grade spelling only.

*Table 5.* Outcomes of hierarchical regression analyses of predictors of first-grade spelling and of decoding accuracy for entire first and fourth-grade samples

| | | First grade (Spelling) | | | First grade (Decoding accuracy) | | | Fourth grade (Decoding accuracy) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Step | Measure | $R^2$ | $R^2$ change | ß | $R^2$ | $R^2$ change | ß | $R^2$ | $R^2$ change | ß |
| 1 | Age (mo) | 0.030 | 0.030 | 0.174 | 0.001 | 0.001 | 0.037 | 0.003 | 0.003 | 0.053 |
| 2 | Block des. (raw) | 0.052 | 0.021 | 0.147 | 0.037 | 0.036 | 0.190 | 0.052 | 0.049 | 0.222 |
| 3 | Vocabulary (raw) | 0.089 | 0.037 | 0.199 | 0.038 | 0.001 | 0.028 | 0.054 | 0.002 | 0.043 |
| 4 | Object naming | 0.115 | 0.026 | 0.166 | 0.044 | 0.006 | 0.081 | 0.072 | 0.018 | 0.135 |
| 5 | Digit naming | 0.211 | 0.096 | 0.371* | 0.076 | 0.032 | 0.213 | 0.123 | 0.051 | 0.299 |
| Reversing the order of steps 4 and 5 | | | | | | | | | | |
| 4 | Digit naming | 0.211 | 0.122 | 0.362** | 0.075 | 0.037 | 0.200 | 0.121 | 0.068 | 0.267 |
| 5 | Object naming | 0.211 | 0.000 | −0.018 | 0.076 | 0.001 | −0.025 | 0.123 | 0.001 | −0.037 |
| 6 | Phonol. awaren. | 0.490 | 0.279 | 0.614*** | 0.459 | 0.383 | 0.720*** | 0.185 | 0.062 | 0.294* |
| 7 | Decoding speed | 0.564 | 0.074 | 0.382** | 0.469 | 0.010 | 0.142 | 0.259 | 0.074 | 0.309* |
| Reversing the order of steps 6 and 7 | | | | | | | | | | |
| 6 | Decoding speed | 0.481 | 0.270 | 0.606*** | 0.259 | 0.183 | 0.499*** | 0.212 | 0.089 | 0.338** |
| 7 | Phonol. awaren. | 0.564 | 0.083 | 0.403** | 0.469 | 0.210 | 0.641*** | 0.259 | 0.047 | 0.257* |

*Note.* $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

The fourth set of analyses examined the significance of morphological awareness with first-grade reading comprehension and decoding speed as outcome measures (see Table 6). Morphological awareness was significantly related to reading comprehension and decoding speed after effects of age, Block Design, Vocabulary, naming speed and listening comprehension were accounted for. When phoneme awareness was entered in the equation first, morphological awareness remained a significant predictor for reading comprehension, but not for decoding speed. Because morphological awareness was highly correlated with listening comprehension ($r = 0.48$), this outcome was not surprising.

A fifth set of analyses examined the predictive contributions of the screening measures (i.e., visuomotor coordination, digit span, letter knowledge and initial letter identification) administered to first graders at the beginning of the school year (see Tables 7 and 8). The outcome measures were reading comprehension, phoneme awareness, spelling, decoding accuracy and decoding speed. Initial letter identification skill, a measure of phoneme awareness and letter knowledge turned out to be the best predictor of all outcome measures, even though it was entered last into the equation. Digit span contributed significantly to phoneme awareness, spelling, decoding accuracy and decoding speed. Visuomotor coordina-

*Table 6.* Outcomes of hierarchical regression of predictors of reading comprehension and decoding speed for entire first-grade sample with emphasis on morphological awareness

| | | Reading comprehension | | | Decoding speed | | |
|---|---|---|---|---|---|---|---|
| Step | Measure | $R^2$ | $R^2$ change | ß | $R^2$ | $R^2$ change | ß |
| 1 | Age (months) | 0.013 | 0.013 | 0.115 | 0.009 | 0.009 | 0.094 |
| 2 | Block design (raw) | 0.098 | 0.085 | 0.292* | 0.073 | 0.064 | 0.254* |
| 3 | Vocabulary (raw) | 0.119 | 0.021 | 0.151 | 0.117 | 0.044 | 0.216 |
| 4 | Object naming | 0.173 | 0.054 | 0.237* | 0.168 | 0.051 | 0.232* |
| 5 | Digit naming | 0.210 | 0.037 | 0.233 | 0.264 | 0.097 | 0.372** |
| 6 | Listening compreh. | 0.373 | 0.163 | 0.469*** | 0.320 | 0.056 | 0.274* |
| 7 | Morphol. awareness | 0.443 | 0.070 | 0.316** | 0.366 | 0.046 | 0.257* |
| 8 | Phoneme awareness | 0.506 | 0.063 | 0.309** | 0.522 | 0.156 | 0.486*** |
| Reversing the order of steps 7 and 8 | | | | | | | |
| 7 | Phoneme awareness | 0.470 | 0.097 | 0.370*** | 0.512 | 0.192 | 0.519*** |
| 8 | Morphol. awareness | 0.506 | 0.036 | 0.234* | 0.522 | 0.011 | 0.129 |
| 9 | Decoding accuracy | 0.536 | 0.030 | 0.236* | 0.534 | 0.012 | 0.146 |
| 10 | Decoding speed | 0.560 | 0.024 | 0.226 | | | |

*Note.* *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

*Table 7.* Outcomes of hierarchical regression analyses with screening measures administered at school entry as predictors of reading comprehension and phoneme awareness at end of first grade

| | | Reading comprehension | | | Phoneme awareness | | |
|---|---|---|---|---|---|---|---|
| Step | Measure | $R^2$ | $R^2$ change | ß | $R^2$ | $R^2$ change | ß |
| 1 | Age (months) | 0.006 | 0.006 | 0.080 | 0.001 | 0.001 | 0.026 |
| 2 | Visuomot. coord. skill | 0.067 | 0.060 | 0.246 | 0.053 | 0.052 | 0.228 |
| 3 | Block design (raw) [a] | 0.088 | 0.021 | 0.161 | 0.093 | 0.041 | 0.226 |
| 4 | Vocabulary (raw) [a] | 0.111 | 0.023 | 0.158 | 0.142 | 0.048 | 0.228 |
| 5 | Digit span | 0.141 | 0.030 | 0.181 | 0.218 | 0.077 | 0.290* |
| 6 | Letter knowledge | 0.199 | 0.058 | 0.248 | 0.223 | 0.005 | 0.073 |
| 7 | Initial letter identif. | 0.268 | 0.070 | 0.311* | 0.530 | 0.306 | 0.652*** |

*Note.* *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
[a]Administered at end of school-year.

tion skill did not contribute significantly in predicting any of the outcome measures.

In order to compare the relation among the predictors of first-grade reading comprehension between the Finnish sample of the present study and the American sample used by Stanovich et al. (1984), variables were entered in hierarchical regression analyses with four different orders of entry (Table

*Table 8.* Outcomes of hierarchical regression analyses with screening measures administered at school entry as predictors of spelling, decoding accuracy and decoding speed at end of first grade

| | | Spelling | | | Decoding accuracy | | | Decoding accuracy | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $R^2$ | $R^2$ | ß | $R^2$ | $R^2$ | ß | $R^2$ | $R^2$ | ß |
| Step | Measure | | change | | | change | | | change | |
| 1 | Age (months) | 0.007 | 0.007 | 0.082 | 0.001 | 0.001 | 0.030 | 0.004 | 0.004 | 0.061 |
| 2 | Visuomot. coord. skill | 0.025 | 0.018 | 0.135 | 0.049 | 0.048 | 0.218 | 0.052 | 0.048 | 0.219 |
| 3 | Block design (raw) [a] | 0.032 | 0.007 | 0.096 | 0.059 | 0.010 | 0.113 | 0.088 | 0.036 | 0.212 |
| 4 | Vocabulary (raw) [a] | 0.062 | 0.030 | 0.179 | 0.059 | 0.000 | −0.009 | 0.119 | 0.031 | 0.182 |
| 5 | Digit span | 0.253 | 0.191 | 0.456*** | 0.141 | 0.082 | 0.299* | 0.225 | 0.106 | 0.340** |
| 6 | Letter knowledge | 0.253 | 0.000 | 0.007 | 0.143 | 0.003 | −0.052 | 0.244 | 0.020 | 0.143 |
| 7 | Initial letter ident. | 0.578 | 0.325 | 0.671*** | 0.453 | 0.310 | 0.656*** | 0.442 | 0.198 | 0.524*** |

*Note.* *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. [a]Administered at end of school-year.

9). Although the children in the American sample were one year younger than the children in the Finnish sample and different measures were used in both countries to address the same concepts (i.e., prediction of reading comprehension with phoneme awareness, decoding speed, general intelligence and listening comprehension as predictor variables), the combined measures predicted an almost equal amount of variance of reading comprehension in both countries (i.e., 49.5% for the Finnish and 49.4% for the American sample). Interestingly, the variables usually entered the regression equation at similar levels of significance with the exception of listening comprehension in the Finnish sample, which, in contrast to the American sample, predicted reading comprehension significantly even when entered last.

## Discussion

The present study was designed to study correlates of reading acquisition for children learning the transparent Finnish writing system using a sensitive set of phoneme awareness and decoding measures, as well as other measures of language and cognitive abilities. In English, which has a deep orthography, level of reading skill is strongly associated with phoneme awareness and decoding abilities. In turn, expertise in decoding takes a number of years to achieve and sets a limit on reading comprehension until sufficient skill in decoding is achieved. In contrast, in languages with highly transparent orthographies such as Italian and Turkish, phoneme awareness has been reported to be linked with reading attainment only for a brief period at the beginning of first grade (Cossu et al. 1988; Öney & Durgunoglu 1997).

*Table 9.* Comparison of setwise hierarchical regression outcomes for reading comprehension between first graders in Finland and in the USA (Data from Stanovich et al. 1984)

| | | Finnish sample | | US-sample | |
|---|---|---|---|---|---|
| Order | Set of variables | $R^2$ | $R^2$ change | $R^2$ | $R^2$ change |
| A1 | Phoneme awareness | 0.293 | 0.293** | 0.244 | 0.244** |
| 2 | Decoding speed | 0.394 | 0.100** | 0.385 | 0.142** |
| 3 | General intelligence | 0.395 | 0.001 | 0.443 | 0.058 |
| 4 | Listening comprehension | 0.495 | 0.100** | 0.494 | 0.050 |
| B1 | Decoding speed | 0.347 | 0.347** | 0.258 | 0.258** |
| 2 | General Intelligence | 0.356 | 0.009 | 0.376 | 0.091* |
| 3 | Listening Comprehension | 0.461 | 0.105** | 0.444 | 0.068 |
| 4 | Phoneme Awareness | 0.495 | 0.034 | 0.494 | 0.050 |
| C1 | General Intelligence | 0.062 | 0.062 | 0.186 | 0.186** |
| 2 | Listening Comprehension | 0.313 | 0.251** | 0.260 | 0.074 |
| 3 | Phoneme Awareness | 0.448 | 0.135** | 0.365 | 0.106* |
| 4 | Decoding Speed | 0.495 | 0.047* | 0.494 | 0.129** |
| D1 | Listening Comprehension | 0.311 | 0.311** | 0.144 | 0.144* |
| 2 | General Intelligence | 0.313 | 0.002 | 0.260 | 0.115* |
| 3 | Phoneme Awareness | 0.448 | 0.135** | 0.365 | 0.106* |
| 4 | Decoding Speed | 0.495 | 0.047* | 0.494 | 0.129** |

*Note.* $^*p < 0.05$, $^{**}p < 0.01$.
General Intelligence = Wisc-R Block Design and Vocabulary in Finnish sample; Raven's Progressive Matrices and Peabody Picture Vocabulary test in American sample. Phoneme Awareness = Phoneme deletion and oddity task in both samples. Items in Finnish and American measures differ, but appear to have similar task demands.

The results of our study indicated that in first grade, a stronger link with phoneme awareness was found than had been reported by other studies of reading development in transparent orthographies. The measures of phoneme awareness were significantly related to all measures of literacy performance (i.e., reading comprehension, decoding speed, decoding accuracy, and spelling) at the end of first grade even after effects of age, general intelligence, vocabulary skill and naming speed were accounted for. In fourth grade, the combined measure of phoneme awareness explained around 10% of the variance in reading comprehension and decoding accuracy. However, once the effects of general cognitive variables were accounted for, phoneme awareness was only significantly related to decoding accuracy. On the other hand, when only the less-skilled readers in fourth grade were considered, the combined measure of phoneme awareness explained 26% of the variance of reading comprehension. These findings suggest that phoneme awareness skills are related to reading performance among beginning Finnish readers both more than would have been expected based on previous results for transparent Italian and Turkish orthographies and for a longer period of time than could be hypothesized for less-skilled readers of a regular orthography based on findings by Wimmer (1996) or Landerl and Wimmer (2000).

The implication emerging from these findings, consistent with phonological theories of reading acquisition, is that phoneme awareness is an important principle for learners of *all* alphabetic writing systems, regardless of the depth of the orthography. That is, appreciating the phonemic composition of spoken words and how phonemes map onto letters is the foundation for learning to use any alphabetic system of writing.

When there is a systematic correspondence between phonemes and symbols, as for shallow orthographies such as Finnish, it is likely that reading instruction itself fosters discovery of the phonemic composition of words for many children. Even for less-regular writing systems such as Hebrew and English, the facilitation of phoneme awareness by exposure to reading lessons has been well-documented (Bentin & Leshem 1993; Perfetti, Beck, Bell & Hughes 1988). Yet, when the orthography is less transparent in morphophonemic systems like English, the variations in pronunciation of some individual graphemes such as vowels appear to make it more difficult for many children to fully apprehend the phonemic basis for the writing system. The corollary of this gradation in depth of the orthography is that proportionally more children would be expected to have difficulty determining the phonemic structure of words with writing systems that are less transparent, especially when instruction lacks adequate attention to phonemes. Hence more learners of a deep orthography would be impeded at this foundation stage of reading acquisition and would require explicit instruction to facilitate acquisition of phonemic awareness. Nonetheless, the present results demonstrate that even exposure to a shallow orthography does not prompt sufficient insight about the phonemic structure of spoken words for all children. The sensitivity in this study to individual differences in phoneme awareness may stem from the use of stimuli that include phonemes documented to be more difficult to perceive. In any case, the current results support the view of Leong and Joshi (1997) who advocate systematic training in phonemic awareness regardless of the orthographic transparency of the particular writing system, especially for children at-risk for reading failure.

In addition to examining the role of phoneme awareness in learning to read Finnish, a second goal of the study was to examine the relationships of other language abilities to reading acquisition. Our approach built on the logic that the same cognitive requirements hold for all alphabetic systems with differences hinging on the characteristics of the orthography in terms of the time course of when particular elements come to the fore. In this instance, we wanted to examine the relationship between listening comprehension and reading comprehension in learning to read a shallow orthography. The results point to listening comprehension intersecting with reading skills at an earlier stage in reading development in Finnish than for English. In our study, listening comprehension and reading comprehension shared roughly one third of their variance not only in fourth grade, but also in the first grade. As shown earlier in Figure 1, a similar level of association between listening comprehension and reading comprehension was reached by American children in the fifth grade, but not at younger grades (Stanovich et al. 1984). The current results support the hypothesis by Stanovich (1993) that beginning readers of a transparent and regular orthography have more resources available for the comprehension requirements of reading.

An interesting contrast is seen with the relatively earlier association between vocabulary skill and reading comprehension in English as compared to Finnish. Whereas vocabulary skill shared 11.6% of the variance with reading comprehension in first grade in the sample of Stanovich et al. (1984), it shared only 3.2% of the variance with reading comprehension in Finnish in first grade (see Figure 2). Differences in measures and samples across the studies mean that comparisons must be tentative, of course. However, our results may relate to a finding by Frith, Wimmer, and Landerl (1998). In a cross-language study with German and American children, they found that when American children made errors on a pseudoword decoding task, they often said a real word. This tendency to produce real word responses was not seen for the German children. Frith et al. concluded that American children often apply a top-down decoding strategy when trying to read unfamiliar words (c.f., the self-teaching model of Share & Stanovich 1995), while the German children who were used to consistent letter-sound correspondences could rely on bottom-up strategies to decode words phonetically. Top-down processing potentially requires greater vocabulary knowledge for successful word identification than does systematic decoding.

A further focus of this study was to examine the relations in the first-grade sample between reading acquisition and both morphological awareness and verbal memory. Our interest in exploring these constructs stemmed from consideration of the particular cognitive demands that the Finnish writing system might impose (i.e., a rather complex system of inflections (i.e., 16 cases) and numerous long words). In the present study, morphological awareness was significantly related to reading comprehension for the first-grade children even after accounting for influences of age, intelligence, naming speed, listening comprehension and phoneme awareness. Similarly, morphological awareness shared 23% of the variance with first-grade listening comprehension. In contrast, awareness of morphemes did not retain a significant relationship with decoding speed after other variables were accounted for. Nonetheless, a positive relationship was observed between awareness of morphological structures and awareness of phonemes (i.e., 17.6% shared variance), similar to studies of beginning readers of English (Fowler & Liberman 1995), Serbian and Turkish (Fowler, Feldman, Andjelkovic & Oney, in press).

How might these patterns be explained? On the one hand, one might anticipate shared variance for morphological and phonological awareness, reflecting the general analytic demands of linguistic awareness tasks (Carlisle 1988). Yet, the extent to which this correspondence hinges on the phonological demands of morpheme measures remains to be determined. In English, the association of reading ability with morphological awareness is especially apparent when different forms of a word also differ phonologically (e.g., five/fifth as opposed to four/fourth) (Fowler & Liberman 1995). In Serbian and Turkish, recent research similarly links the tie between phoneme and morpheme awareness to phonological complexity (Fowler et al., in press). At the same time, it makes sense that the language units represented by phonemes and by morphemes also would contribute differently, at least in part, to the cognitive demands of reading: phonemes by definition are units of sound, morphemes are units of meaning. While awareness of phonemes clearly is pivotal to appreciation of the phonemic basis of alphabetic writing systems, awareness of morphemes, in contrast, may foster understanding of the correspondence of meanings across inflectional and derivational variants of words, influencing comprehension and reflecting depth of vocabulary knowledge. Thus, a stronger association of morphological awareness with comprehension measures than with decoding measures seems plausible.

In our study a different pattern emerged regarding verbal memory capacity, here assessed by a simple digit span task at school entry. Verbal memory span did not significantly predict reading comprehension, but shared 19.4% of the variance with spelling, 10.9% with decoding speed, and 6.3% with decoding accuracy. Thus memory performance at school entry corresponded at the end of the school year with the analytic abilities associated with discovering the phonemes in words and with learning how they are represented in print. It is plausible that for a beginning reader the challenge of analyzing a long word stresses the temporary storage of verbal input (for discussion of the role of verbal working memory in acquisition of decoding in English see Perfetti 1985). Although longer words have to be decoded and acquired for sight recognition in Finnish, this may be functionally comparable for comprehension purposes to the constructions in non-agglutinated languages with a greater number of short words (e.g., the meaning of a sentence with six English words, "Would we come to your home?," can be expressed with two Finnish words, "Tulisimmeko kotinne?").

The results with morphological awareness and verbal memory invite further investigation. The question of the role of morphological factors in reading acquisition has not been extensively studied (for earlier research see Feldman 1995), and certainly is of interest for a writing system like Finnish with agglutinated structures. The only other study of morphological awareness in a spoken language with these structural properties is a small-scale study in Turkish mentioned earlier (Fowler et al., in press). In that study, conducted with kindergarten children between five and six years of age, verbal IQ was significantly correlated with morphological awareness hinting at a similar link with comprehension, but follow-up evaluation of the relationship to reading was not included for comparison. In future work on agglutinated languages, it would be worthwhile to go beyond the age studied in the current study and to examine the role of morphological awareness in later reading achievement. For example, for older individuals does knowledge of morphological structures account for a significant portion of the variance of reading comprehension and of listening comprehension? In that age group, will there be an association of morphemic awareness with phonological factors as there was for pre-school children in Turkey? By focussing on awareness of derivational versus inflectional morphemes, it might be possible to explore these questions. For example, studying the impact of changes in pronunciation for different forms would speak to phonological influences, while a link with comprehension might be revealed by evidence of stronger effects for derivational changes that make more semantic demands than do inflectional changes (c.f., Fowler et al., in press).

Likewise, the importance of phonological memory abilities for reading development in Finnish bears further study. In English speakers, the link between verbal memory and reading development appears complex. Some have argued that the growing association as readers get older points to improved verbal memory as a consequence of reading experience (e.g., Pennington, Van Orden, Kirson & Haith 1991) and improvements in vocabulary knowledge that may increase the efficiency of phonological processes. At the same time, some forms of memory measures (e.g., sentence memory) appear to have reasonable predictive validity in young children (Scarborough 1998). Future study of the role of verbal memory in Finnish would be of interest in its own right, and would help to test patterns observed in English.

Our final question regarding underlying factors in reading acquisition in Finnish pertains to rapid serial naming of digits and of objects, measures currently receiving much attention in the reading field. In the present study, naming speed contributed significantly to decoding speed at both first and fourth grades. Similar to results by Wolf (1991) rapid serial digit naming was more related to decoding skills in first grade whereas rapid confrontational naming was associated with comprehension in fourth grade. As noted in the introduction, suggestions have been made that for learners of a shallow orthography, deficits in rapid serial naming rather than in phoneme awareness characterize the poor reader (e.g., Wimmer 1996). The current findings make clear that when examined closely, deficits in both rapid naming and phonological awareness are present among poor readers of a regular writing system, though the findings do not question the rationale that phonological awareness and decoding will be easier to acquire in a shallow orthography. The results of prior studies on German already indicated both difficulties in automaticity (Wimmer et al., in press) and persistent weaknesses in phoneme awareness and nonword decoding (Landerl et al. 1997). A recent study in German employing the subgroups of the double-deficit hypothesis also found that poor orthographic spelling characterized all three groups, pointing to phonological coding difficulties in the single phonological naming-speed deficit group, as well as in the single naming awareness deficit group and the double-deficit group. Only the latter two groups were slower in rate of word/nonword reading (Wimmer et al., in press). The implication that all poor readers have some difficulties with acquisition of the written code is also supported by the research of Levy, Bourassa, and Horn (1999) showing that two groups of poor readers, slow namers and fast namers, both learned more easily with instruction that focussed on segmentation of the written word.

With respect to depth of the orthography, it appears that although the ease of a shallow orthography raises the general level of decoding accuracy and lowers the variance of scores in those tasks as compared to a deep orthography, there still seem to be significant accuracy differences between the average and poor reader. This conclusion is not incompatible with individual differences in speed of reading as well. The loci of difficulty for poor readers no doubt depend in part on the effects of the particular orthography on the demands of reading, but also on the degree of severity of the reading deficit, the individual's stage of reading acquisition, and method of instruction, among other variables. Interpreting patterns of difficulty for readers of different kinds of writing systems will have to consider these different factors (e.g., Frith et al. 1998).

As an extra point, the predictive value of the brief screening procedure administered at school entry to the first graders will be commented on briefly. Letter knowledge did not differentiate children in this study. Instead, the ability to specify the initial letter of a spoken word had the highest predictive value for all of the measures of reading performance at the end of the school year. Because this task requires both phoneme awareness and elementary decoding knowledge, it captures the demands of beginning reading. Byrne and Fielding-Barnsley (1990) incorporated this sort of task in a procedure for teaching and evaluating whether a child had acquired the alphabetic principle. The present results indicate that it would be a useful addition to screening batteries for prediction and instructional purposes.

## Closing remarks

Research on cognitive factors associated with reading has been conducted in depth for children learning to read English, a writing system that is a deep orthography. Study of reading development with other orthographies offers at least two benefits. First, one can test the extent to which commonalities exist, independent of unique features of both languages and writing systems, for individuals learning to read and write. Such commonalities highlight the cognitive constraints on acquiring literacy and help to reveal which requirements are universal. Second, specific to each language and writing system, sources of difficulty and differences in the pattern of reading acquisition may be evaluated.

This study served both purposes. The importance of phoneme awareness and decoding was underscored for reading acquisition. Even for transparent orthographies, phoneme awareness still accounts for a noteworthy percentage of variance in first grade and even for older less-skilled readers in fourth grade. Present results question the extreme brevity of an association reported for Turkish (Oney & Durgunolu 1997), a language and writing system with very similar attributes to Finnish.

The results also indicate that even for Finnish, often cited as the language with the highest literacy success levels, a portion of children nonetheless find learning to read to be a challenging task, and they still require assistance in learning and mastering the principles of phoneme awareness and decoding. This outcome points to the value of early screening and of direct instruction on decoding concepts regardless of the orthographic depth of the writing system. A second point of interest was the finding of a greater contribution of listening comprehension in early reading performance in Finnish. The present results conform with Gough and Tunmer's (1986) simple theory of reading acquisition (i.e., reading comprehension is the product of listening comprehension and decoding), but suggest that for the average or skilled Finnish reader the contribution of listening comprehension may reach asymptote earlier than for children learning a deep orthography.

## Acknowledgment

This research was supported by a grant from the national Institute of Child Health and Human Development (Grant HD-01994) to Haskins Laboratories.

## Notes

1. In addition to the depth of alphabetic writing systems, the nature of the phonological system for particular languages may be a further potential factor in learning how spoken language is represented in print. Caravolas and Bruck (1993) examined how characteristics for spoken language in Czech and English influenced young children's phonological awareness. The Czech language includes many words beginning with complex consonant clusters (e.g., spl-, fspl-, fspr-) They found Czech children to be more accurate than English speaking children on tasks requiring manipulation of cluster onsets. In contrast, English speaking children performed better on onset-rime distinctions common in English words (e.g., b-at, s-it). The authors concluded that the frequency of particular structures in a language influence a child's awareness of them. Similarly, French children perform better on syllable segmentation tasks than English speaking children do, presumably because French is syllable-timed whereas boundaries between English syllables often are more difficult to detect (Bruck, Genesee & Caravolas 1997).
2. The reliability of the fourth-grade decoding accuracy measure was improved by removing some of its items. The reliability of the revised fourth-grade decoding accuracy measure is given in the results section.
3. Individual task reliabilities are reported here. In the results section some tasks had items with low variability, therefore a combined measure of phoneme awareness was created. Reliabilities for the new combined task are given in the results section.

## Appendix A

### *Characteristics of the Finnish language*

Finnish has a clear and straightforward phonological structure that can be represented by 21 phonemes (Kyöstiö 1980).

Standard Finnish has only 13 consonants (D, G, H, J, K, L, M, N, P, R, S, T, V) and 8 vowels (A, O, U, E, I, Y, Ä, Ö). Each letter represents one phoneme and is pronounced consistently in the same way. Because of vowel-harmony, A, O and U are never combined in the same word with Y, Ä and Ö, and vice versa. Short versus long quantity of a phoneme is marked by one versus two letters. Since the duration of a sound affects the meaning of the word (*tuli – fire, tuuli – wind, tulli – customs*), it could be argued whether the longer version consists of two different phonemes or just a longer version of the same phoneme.

In Finnish, the accent always occurs on the first syllable. Standard Finnish syllables do not have cluster onsets, but can end with two-consonant clusters.

Syllables can be open, closed or they can consist of a single vowel. The syllable types are: V, VV, VVC, VC, VCC, CV, CVV, CVC, CVVC, CVCC. Some adopted words from other languages might show cluster onsets ("trak-to-ri" for tractor or "strut-si" for ostrich). As compared to English, where syllabification is not fixed but fluid (Treiman & Zukowski 1990), the syllable structure of Finnish is perceived by children as natural and plays an important step in learning how to read or write. Beginning writers find it easy to divide a spoken word into syllables by means of rhythmic tapping and write the word out one syllable at a time.

Finnish is an agglutinating language. Only about 50 words are monosyllabic. Most words begin with the root and add a number of short syllables (each is usually 1-3 letters). The syllables carry semantic information, for example information displayed in English by the functions of prepositions and possessive pronouns (e.g., Finnish "bussi" = English "bus", "bussi-ssa" = "in the bus", "bussi-ni" = "my bus"). Words may therefore become relatively long and they might contain a considerable load of semantic information (Kyöstiö, 1980). Both factors could be related to the low decoding speed exhibited by Finnish poor readers.

## Appendix B

*Decoding and spelling measures*

1. *Decoding speed and accuracy measure for first grade*

The text contains 31 syllables. Syllable-dashes mark syllable boundaries. The text was presented to first graders in capital letters and with syllable-dashes.

KI-KA PYÖ SA MUO.
TÄ-KI AN E-SO IS-TE.
Ä-SÄ NYÖ JAS ES KU-HE AU-SA.
PEE A-MI-AT EI-NA HE-KI TUN MOIT.

2. *Decoding speed and accuracy measure for fourth grade*

Text contains 63 syllables. Text was presented without syllable-dashes. Syllable-dashes are included here to mark syllable boundaries.

Poit väyk-kää la-vin u-le-ras-ta mä-pi-lä-ky-sää pon-tuk-ti-nou-vi-a-kin ju peh-dä saik-ko-pa väp-pe-jä puk-ko-tork-ke-ja lynt-tä-vi-päi-hik-si e-nu-le-si meu-toi. Puk-ti-en ki-lam-me vuot myk-sys-sä ha-ni-ta meh-li-ä.

3. *Spelling measure for first grade*

The following 14 words had to be spelled one at a time Syllable boundaries are marked by dashes.

1. ui
2. maa

3. e-mo
4. ri-su
5. myy-rä
6. met-sä
7. leh-ti
8. lum-me
9. pyrs-tö
10. pur-jeet
11. run-ko
12. laut-ta
13. aal-lot
14. vik-ke-läs-ti

## Appendix C

*Measures of Phoneme Awareness*

1. *Oddity task for first grade*
Items used, correct answers are in parentheses.

Odd sound at the position of the initial phoneme

| | |
|---|---|
| Practice trials: | 1. kynä, (lasi), kumi, kesä |
| | 2. aalto, aate, aarre, (alus) |
| Test trials: | 1. (uni), uusi, uute, uuni |
| | 2. mäki, mato, mela, (nuha) |
| | 3. setä, syli, (teko), siru |
| | 4. pako, (kisa), poni, pesä |
| | 5. runo, reki, raha, (vipu) |
| | 6. aasi, aamu, (asu), aave |

Odd sound at the position of the final phoneme

| | |
|---|---|
| Practice trials: | 1. (rotu), sana, loma, sika |
| | 2. mopo, siro, lato, (kala) |
| Test trials: | 1. sipoo, espoo, (salo), porvoo |
| | 2. mies, (norsu), varis, porsas |
| | 3. (vakio), nopea, kuiva, hurja |
| | 4. ahven, nainen, avain, (kyynel) |
| | 5. kotka, kissa, (lehmä), tamma |
| | 6. paluu, (kipu), takuu, kaipuu |

| Odd sound at the position of the second phoneme | |
|---|---|
| Practice trials: | 1. voi, (suo), koira, nouto<br>2. taakka, kaasu, maali, (pallo) |
| Test trials: | 1. liuska, siemen, piano, (reikä)<br>2. (sakko), paalu, kaari, naama<br>3. öljy, (silmä), alku, ilma<br>4. usva, askel, (neste), osto<br>5. (koukku), munkki, tuoli, suihku<br>6. liitu, (pino), siima, kiire |

2. *Phoneme deletion measure for first grade*
Items used: letters which mark phonemes to be deleted are in parentheses.

| Initial phoneme to be deleted | |
|---|---|
| Practice trials: | 1. (k)ilo, 2. (p)apu |
| Test trials: | 1. (n)auta, 2. (p)aita, 3. (h)osua, 4. (a)ikuistaa, 5. (t)rikki |

| Final phoneme to be deleted | |
|---|---|
| Practice trials: | 1. kato(s), 2. soita(n) |
| Test trials: | 1. käsi(n), 2. tulo(s), 3. solmi(o), 4. keitti(ö), 5. liito(s) |

| Second phoneme to be deleted | |
|---|---|
| Practice trials: | 1. l(e)ima, 2. a(l)ku |
| Test trials: | 1. t(o)ukka, 2. o(t)sa, 3. a(r)vaus, 4. s(u)ola, 5. k(i)oski |

3. *Phoneme deletion measure for fourth grade*
Items used: letters which mark phonemes to be deleted are in parentheses.

| Initial phoneme to be deleted | |
|---|---|
| Practice trials: | 1. (k)ilo, 2. (p)apu |
| Test trials: | 1. (r)ajoittaa, 2. (t)saari, 3. (k)rokantti, 4. (s)trutsi, 5. (o)ivallisesti |

| Second phoneme to be deleted | |
|---|---|
| Practice trials: | 1. l(e)ima, 2. a(l)ku |
| Test trials: | 1. t(o)ukka, 2. o(t)sa, 3. a(r)vaus, 4. s(u)ola, 5. k(i)oski |

| Final phoneme to be deleted | |
|---|---|
| Practice trials: | 1. las(t)i, 2. kiel(t)o |
| Test trials: | 1. tuloskat(s)e, 2. mutakäär(m)e, 3. vesipat(j)a, 4. pääver(h)o,<br>5. eläinvirt(s)a |

4. *Pig Latin measure for fourth grade*
Items used: correct answer in parentheses.

| | |
|---|---|
| Practice trials: | 1. talo (alot-in), 2. pannu (annup-in), 3. kello (ellok-in) |
| Test trials: | 1. maksa (aksamin), 2. roisto (oistorin), 3. uoma (omauin), 4. aukko (ukkoain), 5. tynnyri (ynnyritin), 6. öisin (isinöin), 7. krokotiili (rokotiilikin), 8. uistin (istinuin), 9. grillaus (rillausgin), 10. eilinen (ilinenein), 11. treenata (reenatatin), 12. ientulehdus (entulehdusiin) |

## Appendix D

*Morphological awareness measure used in first grade (Lyytinen 1988)*

The meaning of the old words was revealed through pictures. The bold word is the target word which had to be transformed into the required form. The correct answer is in italics.

*Present tense*

| | |
|---|---|
| Practice trial: | Tämä pitää **puikkaamisesta**. Nytkin se *puikkaa*. |
| English translation: | This creature likes to **throw** the ball. Now it *throws* the ball. |
| Test trials: | 1. **Tiplaaminen** on kovaa työtä. Nytkin tuo *tiplaa*.<br>2. Tämä pitää **kaalaisemisesta**. Nytkin tuo *kaalaisee*.<br>3. **Juoliminen** on tästä mukavaa. Nytkin tuo *juolii*.<br>4. **Hotiseminen** on näistä hauskaa. Nytkin nuo *hotisevat*.<br>5. Nämä pitävät **lorputtamisesta**. Nytkin nuo *lorputtavat*. |

*Comparative and superlative*

| | |
|---|---|
| Practice trial: | Tämä porkkana on näin **pullero**, tuo on vielä *pullerompi* ja tämä on kaikista *pulleroin*. |
| English translation: | This carrot is quite **large**, this one is even *larger* but that one is the *largest* of all. |
| Test trials: | 1. Tämä sieni on näin **tipokas**, tuo on vielä *tipokkaampi* ja tämä on kaikista *tipokkain*.<br>2. Tämä kynttilä on näin **hiilunut**, tuo on vielä *hiiluneempi* ja tämä on kaikista *hiilunein*.<br>3. Tämä ilmapallo on näin **lepero**, tuo on vielä *leperompi* ja tämä on kaikista *leperoin*.<br>4. Tämä nalle on näin **ilakka**, tuo on vielä *ilakampi* ja tämä on kaikista *ilakin*.<br>5. Tämä mato on näin **täkyisä**, tuo on vielä *täkyisämpi* ja tämä on kaikista *täkyisin*. |

**Appendix E** . Correlation matrix for first-grade measures (N = 80, except for correlations with naming measures and digit span).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Reading comprehension | | | | | | | | | | | | | | | | | |
| 2. Decoding speed | 0.59*** | | | | | | | | | | | | | | | | |
| 3. Decoding accuracy (Rev.) | 0.44*** | 0.48*** | | | | | | | | | | | | | | | |
| 4. Spelling | 0.58*** | 0.65*** | 0.62*** | | | | | | | | | | | | | | |
| 5. Estimate of IQ | 0.25** | 0.27* | 0.12 | 0.13 | | | | | | | | | | | | | |
| 6. Block design (Wisc-R) | 0.21 | 0.22 | 0.11 | 0.09 | 0.76*** | | | | | | | | | | | | |
| 7. Vocabulary (Wisc-R) | 0.18 | 0.21 | 0.02 | 0.11 | 0.82*** | 0.24* | | | | | | | | | | | |
| 8. Listening comprehension | 0.56*** | 0.43*** | 0.15 | 0.45*** | 0.39*** | 0.31** | 0.31** | | | | | | | | | | |
| 9. Oddity task | 0.45*** | 0.55*** | 0.54*** | 0.50*** | 0.45*** | 0.36** | 0.36** | 0.38*** | | | | | | | | | |
| 10. Phoneme deletion | 0.53*** | 0.61*** | 0.63*** | 0.68*** | 0.32** | 0.30** | 0.22 | 0.33** | 0.68*** | | | | | | | | |
| 11. Combined phoneme aw. | 0.53*** | 0.62*** | 0.64*** | 0.64*** | 0.40*** | 0.34** | 0.29** | 0.38*** | 0.92*** | 0.90*** | | | | | | | |
| 12. Morphological awareness | 0.50*** | 0.40*** | 0.21 | 0.35** | 0.36*** | 0.13 | 0.43*** | 0.48*** | 0.39*** | 0.36** | 0.42*** | | | | | | |
| 13. Digit naming (n = 77) | 0.31** | 0.42*** | 0.23* | 0.37** | 0.18 | 0.10 | 0.19 | 0.28* | 0.30** | 0.32** | 0.32** | 0.25* | | | | | |
| 14. Object naming (n = 74) | 0.26* | 0.28* | 0.11 | 0.18 | 0.21 | 0.23* | 0.09 | 0.26* | 0.16 | 0.25* | 0.20 | 0.19 | 0.52*** | | | | |
| 15. Letter knowledge | 0.23* | 0.08 | −0.07 | −0.07 | 0.17 | 0.12 | 0.15 | 0.31** | 0.07 | 0.20 | 0.12 | 0.21 | 0.25* | 0.39** | | | |
| 16. Initial letter identification | 0.37*** | 0.46*** | 0.39*** | 0.46*** | 0.38*** | 0.20 | 0.38*** | 0.40*** | 0.49*** | 0.62*** | 0.59*** | 0.39*** | 0.42*** | 0.36** | 0.48*** | | |
| 17. Digit span (n = 63) | 0.18 | 0.33** | 0.25* | 0.44*** | 0.11 | −0.11 | 0.24 | 0.26* | 0.28* | 0.24 | 0.30* | 0.34** | 0.03 | 0.01 | −0.06 | 0.14 | |
| 18. Visuomotor coordination | 0.14 | 0.16 | 0.22 | 0.02 | 0.42*** | 0.42*** | 0.25* | 0.08 | 0.19 | 0.14 | 0.18 | 0.07 | 0.14 | 0.13 | 0.16 | 0.03 | −0.06 |

*Note*. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

**Appendix F**. Correlation matrix for fourth-grade measures (N = 79, except for correlations with naming measures).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Reading comprehension | | | | | | | | | | | |
| 2. Decoding speed | 0.22 | | | | | | | | | | |
| 3. Decoding accuracy | 0.41*** | 0.38*** | | | | | | | | | |
| 4. Estimate of IQ | 0.45*** | 0.08 | 0.13 | | | | | | | | |
| 5. Block design (Wisc-R) | 0.20 | 0.09 | 0.14 | 0.80*** | | | | | | | |
| 6. Vocabulary (Wisc-R) | 0.52*** | 0.03 | 0.06 | 0.79*** | 0.27* | | | | | | |
| 7. Listening comprehension | 0.57*** | 0.21 | 0.18 | 0.31** | 0.09 | 0.40*** | | | | | |
| 8. Phoneme deletion | 0.33** | 0.25* | 0.30** | 0.25* | 0.22 | 0.18 | 0.26* | | | | |
| 9. Piglatin | 0.29* | 0.18 | 0.28* | 0.33** | 0.38*** | 0.14 | 0.17 | 0.35** | | | |
| 10. Combined phoneme aw. | 0.34** | 0.22* | 0.29** | 0.38*** | 0.42*** | 0.18 | 0.21 | 0.50*** | 0.95*** | | |
| 11. Digit naming (n = 78) | 0.20 | 0.36*** | 0.25* | −0.17 | −0.17 | 0.10 | 0.26* | −0.01 | 0.06 | −0.04 | |
| 12. Object naming (n = 74) | 0.38*** | 0.38*** | 0.16 | 0.13 | 0.14 | 0.06 | 0.30** | 0.02 | 0.09 | 0.12 | 0.56*** |

*Note*. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

**Appendix G**. Correlation matrix for first-grade measures among less-skilled readers (reading comprehension score one standard deviation or more below national norming sample mean, N = 16, except for correlations with digit naming and digit span).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Reading comprehension | | | | | | | | | | | | | | | | | |
| 2. Decoding speed | 0.41 | | | | | | | | | | | | | | | | |
| 3. Decoding accuracy (rev.) | 0.33 | 0.65** | | | | | | | | | | | | | | | |
| 4. Spelling | 0.39 | 0.77*** | 0.86*** | | | | | | | | | | | | | | |
| 5. Estimate of IQ | 0.02 | −0.12 | −0.07 | −0.04 | | | | | | | | | | | | | |
| 6. Block design (Wisc-R) | 0.15 | −0.33 | −0.01 | −0.23 | 0.66** | | | | | | | | | | | | |
| 7. Vocabulary (Wisc-R) | −0.10 | 0.15 | −0.08 | 0.16 | 0.72** | −0.05 | | | | | | | | | | | |
| 8. Listening comprehension | 0.43 | 0.21 | −0.03 | 0.10 | 0.48 | 0.31 | 0.36 | | | | | | | | | | |
| 9. Oddity task | 0.13 | 0.63** | 0.57* | 0.46 | 0.40 | 0.24 | 0.32 | 0.31 | | | | | | | | | |
| 10. Phoneme deletion | 0.60* | 0.61* | 0.79*** | 0.72** | 0.07 | 0.06 | 0.04 | 0.09 | 0.54* | | | | | | | | |
| 11. Combined phoneme aw. | 0.42 | 0.73** | 0.80*** | 0.69** | 0.19 | 0.11 | 0.16 | 0.18 | 0.86*** | 0.88*** | | | | | | | |
| 12. Morphological awareness | 0.16 | 0.27 | 0.10 | 0.30 | 0.10 | −0.28 | 0.41 | 0.38 | 0.23 | 0.11 | 0.20 | | | | | | |
| 13. Digit naming (n = 15) | 0.66** | 0.75** | 0.36 | 0.65** | 0.14 | −0.21 | 0.33 | 0.40 | 0.32 | 0.56* | 0.50 | 0.37 | | | | | |
| 14. Object naming | 0.40 | 0.20 | 0.11 | 0.28 | 0.07 | −0.07 | 0.14 | 0.21 | 0.02 | 0.28 | 0.16 | 0.21 | 0.64* | | | | |
| 15. Letter knowledge | 0.12 | −0.36 | −0.56* | −0.41 | 0.27 | 0.12 | 0.25 | 0.43 | −0.21 | −0.11 | −0.23 | 0.25 | 0.06 | 0.42 | | | |
| 16. Initial letter identification | 0.41 | 0.35 | 0.48 | 0.56* | 0.41 | 0.10 | 0.46 | 0.36 | 0.45 | 0.72** | 0.63** | 0.54* | 0.57* | 0.38 | 0.28 | | |
| 17. Digit span (n = 15) | −0.18 | 0.35 | 0.11 | 0.38 | −0.10 | −0.45 | 0.28 | 0.35 | 0.08 | −0.21 | −0.07 | 0.42 | 0.14 | −0.08 | −0.11 | 0.00 | |
| 18. Visuomotor coordination | −0.18 | 0.15 | 0.24 | 0.10 | 0.45 | 0.44 | 0.20 | −0.02 | 0.66** | 0.08 | 0.39 | −0.30 | −0.07 | −0.04 | −0.27 | 0.00 | −0.06 |

*Note*. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

**Appendix H** . Correlation matrix for fourth-grade measures among less-skilled readers (reading comprehension score of one or more standard deviations below the national norming sample, N = 22, except for correlations with object naming).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Reading comprehension | | | | | | | | | | | |
| 2. Decoding speed | 0.24 | | | | | | | | | | |
| 3. Decoding accuracy | 0.42 | 0.46* | | | | | | | | | |
| 4. Estimate of IQ | 0.12 | −0.19 | −0.10 | | | | | | | | |
| 5. Block design (Wisc-R) | 0.06 | −0.03 | −0.06 | 0.95*** | | | | | | | |
| 6. Vocabulary (Wisc-R) | 0.18 | −0.37 | −0.16 | 0.92*** | 0.75** | | | | | | |
| 7. Listening comprehension | 0.12 | 0.28 | −0.02 | 0.33 | 0.27 | 0.34 | | | | | |
| 8. Phoneme deletion | 0.66* | 0.30 | 0.20 | 0.35 | 0.33 | 0.33 | 0.41 | | | | |
| 9. Piglatin | 0.37 | 0.37 | 0.26 | 0.30 | 0.36 | 0.19 | 0.37 | 0.24 | | | |
| 10. Combined phoneme aw. | 0.51* | 0.32 | 0.24 | 0.40 | 0.43* | 0.30 | 0.46* | 0.48* | 0.93*** | | |
| 11. Digit naming | −0.18 | 0.42 | 0.09 | −0.18 | −0.09 | −0.27 | 0.56** | 0.01 | 0.34 | 0.22 | |
| 12. Object naming (n = 19) | −0.13 | 0.54* | 0.08 | −0.38 | −0.21 | −0.52* | 0.39 | −0.02 | 0.26 | 0.15 | 0.54* |

*Note.* $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

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