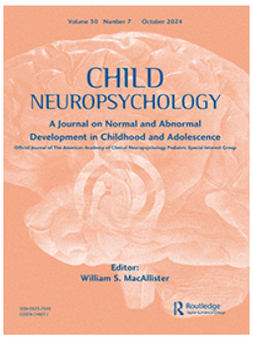

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Finnish children born very preterm have good reading comprehension but weak reading fluency at age 11 years – a longitudinal cohort study

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ABSTRACT

Children born very preterm (<32 gestational weeks and/or birth weight ≤1500 g) are at elevated risk for reading difficulties. This study aimed to investigate reading fluency and reading comprehension at 11 and to analyze the associations between literacy skills at 7 and reading skills at 11 in 134 Finnish-speaking very preterm children. At 11, reading fluency and reading comprehension were evaluated. At 7, pre-reading skills, decoding, and writing were assessed. Results showed that there were more preterm children with weak skills in reading fluency compared to a normative test population. Reading comprehension was age appropriate. Additionally, 62% to 68% of the children with weak literacy skills at 7 had weak reading fluency at 11, compared to those with more advanced skills (43% to 33%, $p < 0.001$ to 0.026). Respectively, 30% to 50% of the children with weak literacy at 7 had weak reading comprehension at 11 compared to those with more advanced skills (13% to 17%, $p < 0.001$ to 0.005). Findings highlight the importance of screening reading fluency until 11 years and providing support for the continuum between literacy skills in the beginning of schooling and reading outcome at later school age.

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KEYWORDS
Reading difficulties; reading fluency; reading comprehension; literacy skills; very preterm children

Children born very preterm (VP, <32 gestational weeks and/or birth weight ≤1500 g) are at elevated risk for developmental and educational difficulties, including problems in reading acquisition (Allotey et al., 2018; Twilhaar, de Kieviet, Aarnoudse-Moens, et al., 2018). Studies concerning reading ability in school-aged children born VP have produced partly inconsistent results. Many studies have reported that these children are outperformed by their full-term-born peers in pre-reading skills such as phonological awareness, letter knowledge, rapid automatized naming and vocabulary (Alanko et al., 2017; Joensuu et al., 2021; Munck et al., 2012), reading (Guarini et al., 2019; Joensuu et al.,

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2021) and word writing (Guarini et al., 2019; Joensuu et al., 2021; Pritchard et al., 2009), while in some studies, the difference between VP born children and full-term controls has not been significant (Aarnoudse-Moens et al., 2011). The findings of meta-analyses regarding the academic performance at school age of children born VP consistently support previously published evidence that these children perform poorer in academic skills, especially in mathematics but also in reading, compared to full-term peers (Aarnoudse-Moens et al., 2011; Kovachy et al., 2015; Allotey et al., 2018; McBryde et al., 2020; Twilhaar, de Kieviet, Aarnoudse-Moens, et al., 2018). For example, 6–18-year-olds have been reported to score 0.71 SD lower on mathematics, 0.44 SD lower on reading and 0.52 SD lower on spelling compared to their full-term controls (Twilhaar, de Kieviet, Aarnoudse-Moens, et al., 2018). Further, some studies have reported that after controlling for general cognitive development, the differences between VP and control groups in reading ability have no longer been statistically significant (Alanko et al., 2017; Frye et al., 2009). In reading performance, the gap with term controls has been found to remain even in the absence of severe cognitive impairment (intelligence quotient IQ < 70) or other neurodevelopmental impairments (NDI), including cerebral palsy, severe hearing impairment, and severe visual impairment (Guarini et al., 2010, Kovachy et al., 2015; Joensuu et al., 2021).

When assessing the reading ability of children born VP, many studies have not investigated the different domains of reading separately. Decoding, fluency, and reading comprehension, which are often considered the three core components of reading (Ecalle et al., 2021; Hoover & Gough, 1990), are rarely differentiated in studies evaluating the reading ability of preterm samples (Kovachy et al., 2015; McBryde et al., 2020). *Decoding* (i.e., single-word reading) refers to the technical ability to translate written words into spoken words by matching graphemes to their corresponding phonemes and forming syllables and words. *Reading fluency* is enhanced when the decoding process becomes automatized and the representations of words are retrieved rapidly and accurately from the orthographic lexicon (Hudson et al., 2008; Landerl et al., 2022; Wolf & Katzir-Cohen, 2001). *Reading comprehension* indicates the ability to understand and construct the meaning of written words and sentences (Hjetland et al., 2020; Hulme & Snowling, 2011), which is the main goal of reading instruction (Leppänen et al., 2008; Virinkoski et al., 2021). For sufficient reading ability, proficiency in decoding, fluency, and reading comprehension is essential. Difficulties in reading can emerge in one or several subskills, and thus it is reasonable to evaluate these domains separately (Ecalle et al., 2021). The studies examining each component of reading individually in VP populations have provided contradictory results (Samuelsson et al., 2006; Leijon et al., 2018; Aarnoudse-Moens et al., 2011, Kovachy et al., 2015; McBryde et al., 2020). To enable targeted support for reading difficulties, more knowledge is needed to clarify whether the deficits establish and persist in one or in several component skills of reading in children born VP.

Reading acquisition is influenced by the linguistic features of the specific language being learned (Borleffs et al., 2019). In the meta-analysis by Kovachy et al. (2015), the authors highlight the fact that existing evidence of the reading ability of children born VP is mainly limited to the English language, and therefore conclusions drawn from these studies might not be generalizable to reading performance in children born VP in other languages. In contrast with the orthographically opaque English language, Finnish is a highly transparent orthographic language

with a regular grapheme – phoneme correspondence. Consequently, the basic decoding skills are often acquired during the first year of school in Finnish-speaking children (Holopainen et al., 2001). More than one-third of Finnish first-graders can already read before entering school at 7 years of age (Leppänen et al., 2004; Lerkkanen et al., 2004b; Soodla et al., 2015). On the other hand, the inflectional system in Finnish morphology is complex. Furthermore, Finnish children must learn to distinguish subtle differences in phoneme duration, since removing a phoneme or adding one often changes the meaning of a word (Korkeamäki, 1997).

The theoretical models of reading, such as the Simple View of Reading (SVR; Hoover & Gough, 1990) are mainly based on English language (Torppa et al., 2016). However, there are some studies supporting the validity of the SVR model in the context of transparent orthographies (see, e.g., Torppa et al., 2016). According to the SVR model, reading comprehension is the product of effective decoding ability and linguistic comprehension. In addition, previous longitudinal studies on general Finnish school populations have shown that pre-reading in kindergarten and decoding skills in the first grade of school have predictive value for reading fluency and reading comprehension in fourth grade (Leppänen et al., 2008). This continuum between pre-reading and decoding skills at the beginning of schooling and reading fluency and reading comprehension later in school in Finnish children born VP has not been investigated before. Further, previous studies of typically developing populations have suggested that reading and writing skills derive from the same linguistic and cognitive processes (Ehri & Wilce, 1987; Lerkkanen et al., 2004b). For example, Lerkkanen et al. (2004b) investigated the prospective relationships between reading and writing performance in Finnish first-graders and suggested that writing skills support reading development during the first grade of primary school. In children born VP acquiring Finnish, these associations have not been investigated previously.

Despite the increased risk for academic problems, including deficits in reading in the VP population, the ongoing clinical monitoring of these children, especially of those without significant neurodevelopmental disorders, rarely continues to school age. Thus, the identification of difficulties in reading acquisition in these children at school age may be delayed or might even fail. In addition, longitudinal studies investigating the acquisition of reading skills in VP-born children are especially sparse (Allotey et al., 2018), and the few existing studies have provided inconsistent results regarding the continuum of reading ability in these children (Leijon et al., 2018; Samuelsson et al., 2006; Twilhaar, de Kieviet, van Elburg, et al., 2018). Parents and healthcare and educational practitioners would benefit from knowledge on whether there is an association between early literacy skills and later reading ability, and whether the difficulties detected in the beginning of schooling persist into later school age in this population.

Based on what has been presented above, the aims of the present study are (1) to investigate the reading-fluency and reading-comprehension skills of a regional cohort of 11-year-old Finnish-speaking children born VP, (2) to analyze the association between pre-reading skills, decoding, and word-writing ability at 7 years of age and reading fluency and reading comprehension at 11 years of age, and (3) to study how much the pre-reading skills, decoding, and word-writing ability at 7 years explain the variance in

reading fluency and comprehension at 11 years of age in these children, when the background factors are controlled for.

Materials and methods

Participants

The participants of the present study are subjects of the prospective multidisciplinary follow-up study PIPARI (Development and Functioning of Very Low Birth Weight Infants from Infancy to School Age). All children born <32 weeks of gestational age and/or with birth weight ≤1500 g in Turku University Hospital, Finland, in 2001–2006 were invited to participate. From 2001 to 2003, the inclusion criteria were birth weight ≤1500 g and prematurity (<37 gestational weeks). From the beginning of 2004, the inclusion criteria were expanded to include all infants born <32 weeks of gestation, regardless of birth-weight. Children with severe congenital anomalies or diagnosed syndromes affecting their development were excluded. The current study sample consisted of 134 children born VP living in Finnish-speaking families who had data available from the reading assessment at 11 years of age. The results at 7 years of age were available for 126 children. A flowchart of the children participating in the current study is presented in Figure 1.

The PIPARI study protocol has been approved by the Ethics Review Committee of the Hospital District of Southwest Finland in December 2000 and January 2012. After receiving oral and written information, all parents who agreed to participate provided written informed consent. At age 11 years, the parents and the children gave their own consent after receiving written information. The participants were able to withdraw from the study at any time, and withdrawal did not affect their normal treatment. The children and their families received the results of the assessments in which they participated. If difficulties requiring treatment were found, the families were informed and advised to contact their managing body, e.g., in schools or in healthcare.

The background characteristics of the children participating in the present study are shown in Table 1. Neurodevelopmental impairment (NDI) was defined if one or more of the following factors was present: cognitive impairment at 11 years (Full-scale IQ [FSIQ] of the Wechsler Intelligence Scale, Fourth Edition, Finnish translation [WISC-IV; Wechsler, 2011a, 2011b], composite score < 70): cerebral palsy by 2 years of corrected age, severe hearing, and/or visual impairment.

Drop-out analysis

The follow-up rate was 72% for the VP group participating in the current study. The background characteristics (Table 1) were compared between the children participating in the present study and the children whose reading data at 11 years of age were unavailable (dropouts, $n = 52$). In the dropout group, there were fewer multiple births compared to the study children (39%, $n = 52$, of study children vs. 23%, $n = 12$, of dropouts; $p = 0.04$) and more children with neurodevelopmental impairment (15%, $n = 19$, of the study children vs. 30%, $n = 10$, of the dropouts had NDI; $p = 0.04$). No other statistically significant difference in the background characteristic between the study children and dropouts was found.

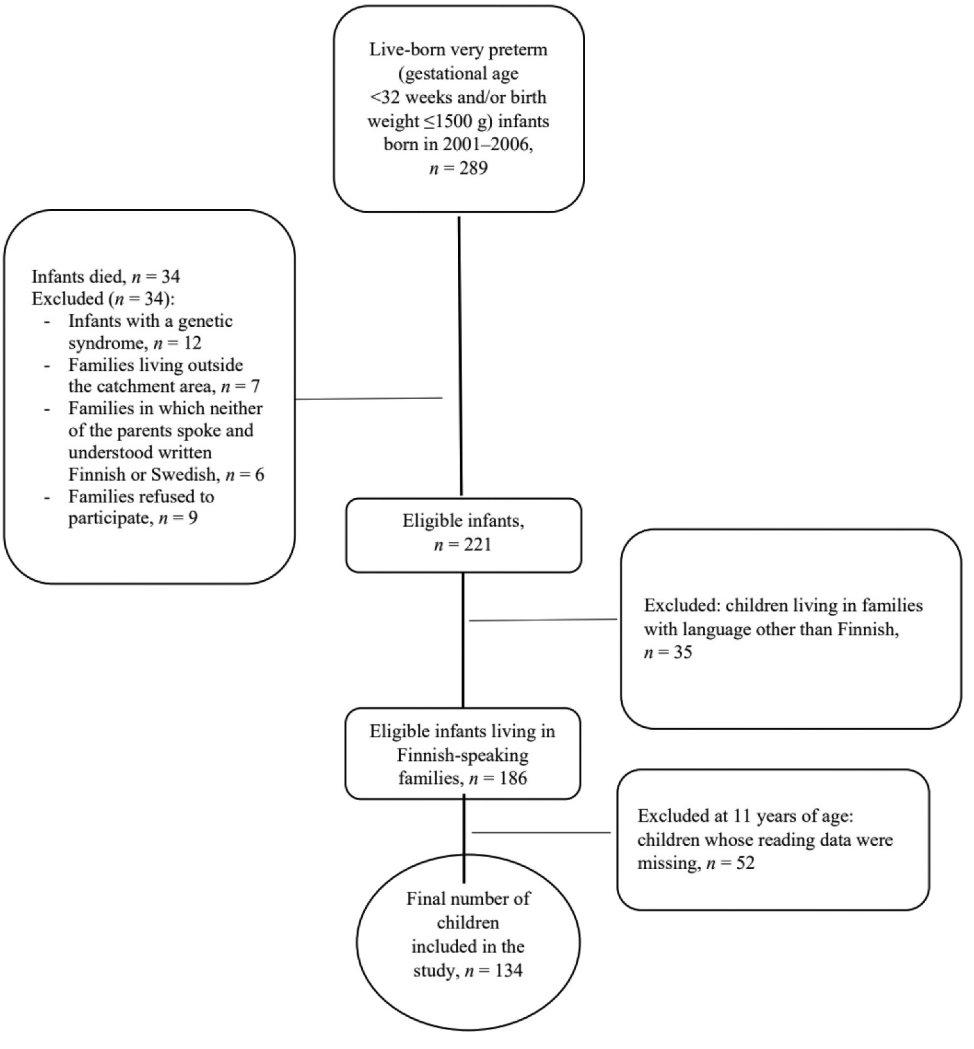

Figure 1. Flowchart of the participants of the present study.

Measures

Assessment at 11 years of age

Reading fluency and reading comprehension were evaluated using the subtests of the Primary School Reading Test (Lindeman, 1998), a standardized Finnish test for reading. The subtest for reading fluency included 78 chains of words, with two to four words in each chain typed together. The children were instructed to separate the non-spaced words from each other and mark the word boundaries with a line using a pencil; for example, järvilaulaaulospuu → järvi/laulaa/ulos/puu [lakesingouttree → lake/sing/out/tree]. The fluency test score (max 214) was the number of correctly recognized words during the time limit of 3.5 min. In the subtest for reading comprehension, the children were instructed to read two texts silently and answer 24 multiple-choice questions regarding them. The first text was an informational text

Table 1. The neonatal and background characteristics of children born very preterm (VP, birth weight ≤1500 g and/or <32 gestational weeks) and children born VP without neurodevelopmental impairment (NDI) participating in the study. Numbers (percentages) are shown. When means (standard deviation) [minimum, maximum] are presented, they are indicated separately.

Characteristic	Children born very preterm ($n = 134$)[d]	Children born very preterm without NDI ($n = 110$)
Gestational age (weeks), *M* (SD) [min, max]	29.2 (2.5) [23.0, 35.3]	29.2 (2.5) [24.3, 29.2]
Birth weight (grams), *M* (SD) [min; max]	1,145 (315) [525; 2120]	1127 (295) [565; 2120]
Small for gestational age[a]	44 (33)	38 (35)
Prenatal corticosteroids	128 (96)	105 (96)
Multiple birth	52 (39)	39 (36)
Male	78 (58)	58 (53)
Bronchopulmonary dysplasia	18 (13)	15 (14)
Sepsis	23 (17)	16 (15)
Operated necrotizing enterocolitis	5 (4)	3 (3)
Laser-treated retinopathy of prematurity	4 (3)	4 (4)
Neurodevelopmental impairment	19 (14)	–
Full Scale Intelligence Quotient < 70	12 (9)	–
Cerebral palsy	7 (5)	–
Hearing impairment	3 (2)	–
Visual impairment	0	–
Brain pathology, MRI at term age[b]		
Normal finding or minor abnormality	99 (75)	88 (82)
Major abnormality	33 (25)	20 (19)
Mother's self-reported reading difficulties[e]	11 (12)	11 (12)
Father's self-reported reading difficulties[e]	11 (12)	9 (10)
Maternal education[c]		
High level	87 (66)	73 (68)
Intermediate and low level	45 (34)	35 (32)
Paternal education[c]		
High level	44 (34)	40 (37)
Intermediate and low level	87 (66)	69 (63)

[a]Small for gestational age was defined as a birth weight < −2.0 SD, according to the age- and gender-specific Finnish growth charts. [b]See specific magnetic-resonance imaging (MRI) protocol and details about the classification of the findings in Setänen et al. (2013). [c]High level is defined as a bachelor's degree, master's degree or doctoral degree; Intermediate level is defined as high school or vocational school; Low level is defined as primary or lower secondary school or less. [d]*n* varied between 131 and 134. [e]$n = 100$.

regarding the effect of light on plant growth, and the second text was a cooking recipe. The questions regarding the texts included five different question types, which were (1) detail/fact, (2) cause-and-effect/order, (3) interpretation/conclusion, (4) word/proverb, and (5) idea/purpose. There was no strict time limit in the reading comprehension subtest. The children were able to spend the entire lesson (45 min) and, if needed, the playtime between the lessons (15 min) to complete the subtest. One point was given for each correct answer (max 24). The testing took place in a group setting in schools. The teachers sent the filled and scored test forms to the researcher of our cohort study.

The test scores were categorized into skill levels following the instructions of the Primary School Reading Test manual. In the reading-fluency subtest, scores from 0 to 98 were transformed into skill levels 1–3, referring to weaker-than-average skills. Scores from 99 to 156 were transformed into skill levels 4–6, corresponding with average skills, and scores from 157 to 214 were transformed into skill levels 7–9, meaning above-average skills. Similarly, in the reading-comprehension subtest, scores from 0 to 14 were transformed into skill levels 1–3, scores from 15 to 20 were transformed into skill levels 4–6, and scores from 21 to 24 were transformed into skill levels 7–8. The variables

were also dichotomized into two groups: weak skills (levels 1 to 3) and average skills or better (levels 4 to 8/9).

Assessment at 7 years of age

In Finland, children enter school at the age of 7 years, after spending 1 year in preschool. Pre-reading skills, decoding, and word-writing ability were studied at the beginning of first grade of primary school (a six-week period from August to September). The pre-reading skills assessed were phonological awareness, letter knowledge, rapid automatized naming (RAN), and receptive vocabulary. To evaluate phonological awareness, three- to seven-letter words were presented phoneme by phoneme (Poskiparta, 1995). Children were instructed to mark one picture out of four alternatives which they thought would best match the word (max 9). To evaluate letter knowledge, children were asked to name 29 uppercase letters presented in random order (max 29) (Lerkkanen et al., 2006). To evaluate RAN, an object-naming task (Ahonen et al., 1999; Denckla & Rudel, 1976) was used. The task comprised five familiar, overlearned objects replicated 10 times in a matrix in random order (10 pictures in five rows). Children were instructed to name the objects as rapidly as possible, beginning with the top row, continuing to the bottom. Time (in seconds) to complete the total matrix was used as the RAN score. Receptive vocabulary was assessed using the short version of the Finnish Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981). Children were instructed to point out the correct item said aloud out of four pictures. The vocabulary score was the number of correctly identified words (max 30).

Decoding skills were evaluated using a short version of the Finnish reading test called ARMI – a tool for assessing reading and writing skills in first grade (Lerkkanen et al., 2006). The test consisted of a word list of two-syllable (seven words), three-syllable (two words), and five-syllable (one word) words. Children were asked to read the words aloud without a time limit. The score for decoding skills evaluated with the ARMI test was the number of correctly read words (max 10). To evaluate word writing, children were asked to write five words and eight pseudowords dictated one word at a time (Niemi et al., 2011). The word-writing score was the total number of correctly written items (max 13).

Statistical analysis

The analyses were performed separately for all study children and for children without NDI. The level of significance was set at p-value <0.05 (two-tailed). Pearson's correlation coefficient (r) was used to assess the correlations between the continuous pre-reading, decoding, and word-writing variables measured at 7 years of age, and the continuous-reading-fluency and reading-comprehension variables measured at 11 years of age. All variables were also categorized. For the variables measured at 7 years, the 10th-percentile values were derived from the full-term control group of the PIPARI study and used for cutoff (for detailed description of the PIPARI control group, see Joensuu et al., 2021). For the variables measured at 11 years, the cutoff values (−1 SD and −2 SD) were based on the normative sample (n = 1675; Lindeman, 2000) of the Finnish Primary School Reading Test. Comparisons between categorical variables were done using cross-tabulation with the chi-square test or Fisher's exact test as appropriate.

Linear regression analyses were conducted to analyze how much the 7-year variables explain the variance in the outcome (reading fluency and reading comprehension) at 11 years of age. Normal distribution assumption was checked from studentized residuals. The main outcome variables were reading fluency and reading comprehension at 11 years. The explanatory variables were phonological processing, letter knowledge, RAN, vocabulary, decoding and word-writing ability at 7 years of age. Since the explanatory variables were strongly correlated with each other, they were analyzed separately (six univariate regression models with reading fluency as the outcome variable and six univariate regression models with reading comprehension as the outcome variable). After the univariate analyses, the effect of the specific background factors was explored. Gestational age, mother's self-reported reading difficulties, father's self-reported reading difficulties, paternal education, and gender (male disadvantage) were added to the analysis based on previous study literature. Due to multicollinearity between maternal and paternal education, only paternal education was included in the analyses. Paternal education levels were the following: high level is defined as a bachelor's degree, Master's degree, or Doctoral degree; Intermediate level is defined as high school or vocational school; Low level is defined as primary or lower secondary or less. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA).

Results

Descriptive statistics for reading fluency and reading comprehension at 11 years of age and pre-reading, decoding, and word-writing skills at 7 years of age in children born VP are presented in Table 2.

Table 2. Means (standard deviations) [minimum, maximum] of reading fluency and reading comprehension measured at 11 years of age, and pre-reading skills, decoding, and word-writing ability measured at 7 years. Values for all children born very preterm (VP, birth weight ≤1500 g and/or <32 gestational weeks) and for the subgroup of children born VP without neurodevelopmental impairment (NDI) are presented.

Measure	Children born very preterm Mean (SD) [min, max] n = 134[a]	Children born very preterm without NDI Mean (SD) [min, max] n = 110
At 11 years		
Reading fluency	97 (43) [0, 214]	101 (40) [2, 214]
Reading comprehension	18 (4) [0, 24]	19 (4) [7, 24]
At 7 years		
Pre-reading skills		
Phonological awareness	7 (2) [1, 9]	7 (2) [2, 9]
Letter knowledge	24 (7) [1, 29]	24 (6) [2, 29]
RAN[b]	75 (21) [35, 156]	72 (17) [35, 133]
Vocabulary	20 (4) [10, 28]	20 (4) [11, 28]
Decoding		
10 words	4 (4) [0, 10]	5 (4) [0, 10]
Word-writing		
13 words (5 words, 8 pseudowords)	3 (4) [0, 13]	3 (4) [0, 13]

[a]n varied between 126 and 134. [b]Rapid automatized naming.

Reading skills at 11 years of age in children born very preterm

Regarding reading fluency, there was a statistically significant difference between children born VP and the normative data ($p < 0.001$, $\chi^2 = 63$, df = 2; Figure 2). In children born VP, 53% ($n = 64$) had weak skills, 39% ($n = 48$) had average skills, and 8% had above-average skills. The respective percentages for the normative data were 23%, 54%, and 23%. After the exclusion of children born VP with NDI, the percentages between children born VP and the normative data remained nearly the same (weak skills 51%, average skills 39% and above-average skills 10%; $p < 0.001$, $\chi^2 = 46$, df = 2).

In terms of the reading-comprehension ability, there were no significant differences between children born VP and the normative data ($p = 0.139$, $\chi^2 = 4$, df = 2; Figure 3). In children born VP, 23% ($n = 31$) had weak skills, 47% ($n = 63$) had average skills, and 30% ($n = 40$) had above-average skills. The respective percentages for the normative data were 23%, 54%, and 23%. After the VP children with NDI were excluded from the analyses, the percentages of the VP group were as follows: weak skills 17%, average skills 47%, and above-average skills 36%, and the difference between the VP and normative group was statistically significant ($p < 0.007$, $\chi^2 = 10$, df = 2). Thus, VP children as a group had better skills than children in the norming sample of the method.

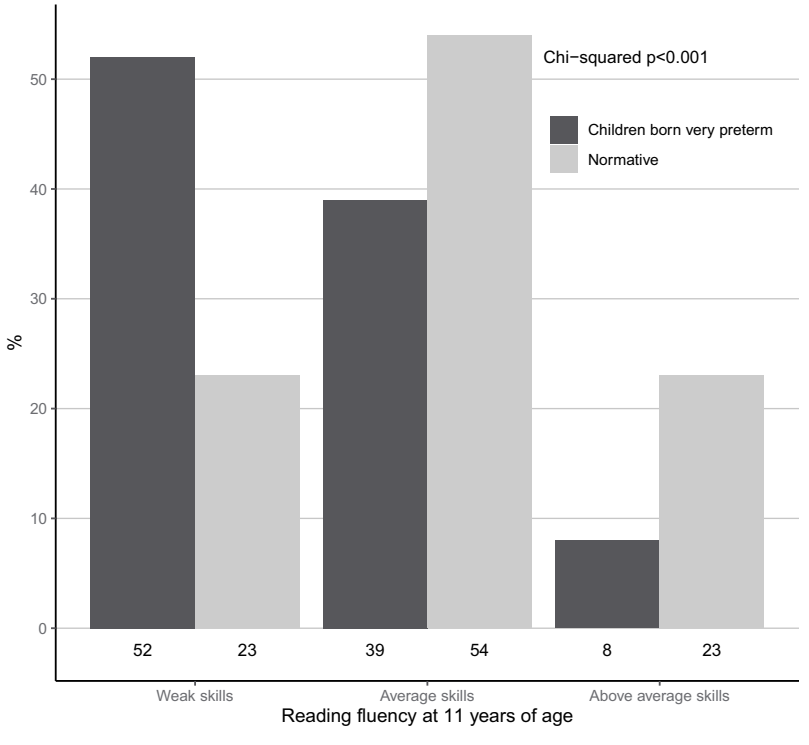

Figure 2. Reading fluency at 11 years of age in children born very preterm, and normative data.

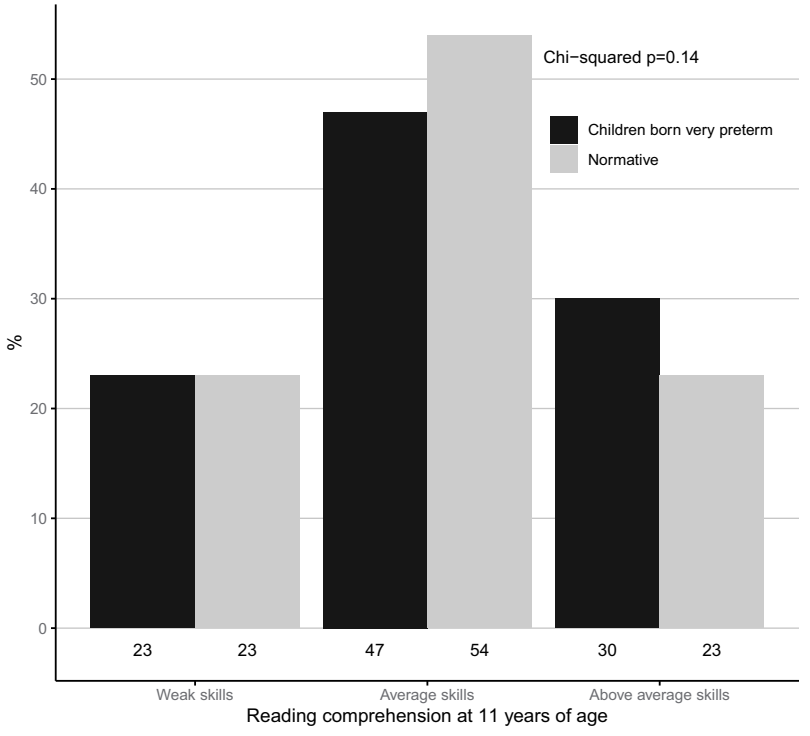

Figure 3. Reading comprehension at 11 years of age in children born very preterm, and normative data.

Associations between pre-reading skills, decoding, and word-writing skills at 7 years and reading fluency and reading comprehension at 11 years

Statistically significant correlations were found between all variables measured at 7 and 11 years (r-values varied between 0.25 and 0.51, $p < 0.01$–0.05; Table 3). After excluding children born VP with NDI, the correlations remained statistically significant between every variable except for the correlation between vocabulary at 7 years and reading fluency at 11 years, and for letter knowledge at 7 years and reading fluency at 11 years.

The cross-tabulation analysis indicated that 63% of the children born VP who had weak skills in decoding and 68% of the children born VP who had weak skills in word writing, at 7 years of age, had also weak skills in reading fluency 4 years later (Table 4). After excluding children born VP with NDI, the percentages were 58% and 66%, respectively. However, only the association between weak word-writing ability at 7 years and weak reading fluency at 11 years of age remained statistically significant.

Respectively, 30% of the children born VP with weak decoding at 7 years and 34% of the children with weak word writing at 7 years had weak reading comprehension at 11 years of age (Table 4). After exclusion of children born VP with NDI, the corresponding percentages were 22% to 26%. The association between weak decoding at 7 years and weak reading comprehension at 11 years remained statistically significant. Further, 41% to 50% of the children born VP who had

Table 3. Pearson's correlation-coefficient values (*r*-values) between pre-reading skills, decoding, and word-writing skills at 7 years and reading fluency and reading comprehension at 11 years. Values for all children born very preterm (VP, birth weight ≤1500 g and/or <32 gestational weeks) and for the subgroup of children born very preterm without neurodevelopmental impairment (NDI) are presented.

	Reading fluency at 11 y	Reading comprehension at 11 y
7-year measures		
Children born VP[a]		
Pre-reading skills		
Phonological awareness	0.37**	0.49**
RAN[b]	−0.34**	−0.44**
Letter knowledge	0.37**	0.47**
Vocabulary	0.25**	0.56**
Decoding (10 words)	0.44**	0.40**
Word writing	0.43**	0.39**
Children born VP without NDI[c]		
Pre-reading skills		
Phonological awareness	0.29**	0.42**
RAN	−0.27**	−0.28**
Letter knowledge	0.19	0.34**
Vocabulary	0.12	0.52**
Decoding (10 words)	0.38**	0.38**
Word writing	0.41**	0.31**

**$p < 0.01$ (2-tailed). [a]*n* varied between 111 and 126. [b]Rapid automatized naming. [c]*n* varied between 94 and 107.

weak pre-reading skills at 7 years of age had also weak skills in reading comprehension 4 years later. After the exclusion of children born VP with NDI, the association between weak vocabulary at 7 years and weak reading comprehension at 11 years remained statistically significant.

The explanatory value of pre-reading skills, decoding, and word-writing ability at 7 years of age on the variance in reading fluency and reading comprehension at 11 years of age

The results of the univariate regression models are presented in Table 5. Twelve univariate models were run to explore how much pre-reading skills, decoding, and word-writing ability at 7 years of age explain the variance in reading fluency (six models) and reading comprehension (six models) 4 years later. The six models with reading fluency as the outcome variable were statistically significant (*p*-values varied between <0.001 and 0.028), and the explanatory variables (pre-reading skills, decoding, and word writing at 7 years) explained 7% to 19% of the variance in reading fluency at 11 years of age. After the exclusion of children born VP with NDI, the models remained statistically significant and explained 2% to 17% of the variance in reading fluency at 11 years of age. Further, the six models with reading comprehension as the outcome variable were statistically significant ($p < 0.001$), and the explanatory variables explained 11% to 31% of the variance in reading comprehension at 11 years of age. After children born VP with NDI were excluded from the analysis, the models remained statistically significant and explained 8% to 27% of the variance in reading comprehension 4 years later.

After the background factors (gestational age, mother's and father's self-reported reading difficulties, paternal education, maternal education, and gender) were added to

Table 4. Results of the cross-tabulation with chi-square or Fisher's exact tests of the associations between weak skills in pre-reading skills including phonological awareness, rapid automatized naming (RAN), letter knowledge, vocabulary and decoding (10th percentile, 0 words), and word-writing (10th percentile, 0 words) measured at 7 years and weak skills in reading fluency and reading comprehension measured at 11 years. Results for all children born very preterm (VP) and for the subgroup of children born VP without neurodevelopmental impairment (NDI) are presented.

	11-y measures							
	Children born VP[a]				Children born VP without NDI[b]			
	Reading fluency							
	Weak *n* (%)	Normal *n* (%)	Total *n* (%)	*p*	Weak *n* (%)	Normal *n* (%)	Total *n* (%)	*p*
7-y measures								
Phonological awareness				0.174				0.855
Weak	19 (61)	12 (39)	31 (100)		12 (52)	11 (48)	23 (100)	
Normal	39 (47)	44 (53)	83 (100)		37 (50)	37 (50)	74 (100)	
RAN				0.681				1.000
Weak	13 (54)	11 (46)	24 (100)		7 (50)	7 (50)	14 (100)	
Normal	44 (49)	45 (51)	89 (100)		41 (50)	41 (50)	82 (100)	
Letter knowledge				0.216				0.721
Weak	11 (65)	6 (35)	17 (100)		5 (46)	6 (54)	11 (100)	
Normal	47 (49)	50 (52)	97 (100)		44 (51)	42 (49)	86 (100)	
Vocabulary				0.889				0.568
Weak	12 (52)	11 (48)	23 (100)		8 (44)	19 (56)	18 (100)	
Normal	46 (51)	45 (50)	91 (100)		41 (52)	38 (48)	79 (100)	
Decoding				0.026				0.300
Weak	29 (63)	17 (37)	46 (100)		22 (58)	16 (42)	38 (100)	
Normal	29 (43)	39 (57)	68 (100)		27 (46)	32 (54)	59 (100)	
Writing words				0.001				0.004
Weak	40 (68)	19 (32)	59 (100)		31 (66)	16 (34)	47 (100)	
Normal	18 (33)	37 (67)	55 (100)		18 (36)	32 (64)	50 (100)	
	11-y measures							
	Children born VP[c]				Children born VP without NDI[d]			
	Reading comprehension							
	Weak *n* (%)	Normal *n* (%)	Total *n* (%)	*p*	Weak *n* (%)	Normal *n* (%)	Total *n* (%)	*p*
7-y measures								
Phonological awareness				0.001				0.058
Weak	13 (41)	19 (59)	31 (100)		7 (29)	17 (71)	24 (100)	

(*Continued*)

Table 4. (Continued).

	11-y measures							
	Children born VP[c]				Children born VP without NDI[d]			
Reading comprehension	Weak *n* (%)	Normal *n* (%)	Total *n* (%)	*p*	Weak *n* (%)	Normal *n* (%)	Total *n* (%)	*p*
Normal	13 (13)	81 (86)	94 (100)		19 (12)	73 (88)	83 (100)	
RAN				<0.001				0.130
Weak	13 (50)	13 (50)	26 (100)		5 (31)	11 (69)	16 (100)	
Normal	13 (13)	86 (87)	99 (100)		12 (13)	78 (87)	90 (100)	
Letter knowledge				0.004				0.376
Weak	8 (47)	9 (53)	17 (100)		3 (27)	8 (73)	11 (100)	
Normal	18 (17)	91 (84)	109 (100)		14 (15)	82 (85)	96 (100)	
Vocabulary				0.001				0.017
Weak	11 (44)	14 (56)	25 (100)		7 (35)	13 (65)	20 (100)	
Normal	15 (15)	86 (85)	101 (100)		10 (12)	77 (86)	87 (100)	
Decoding				0.005				0.037
Weak	16 (34)	31 (66)	47 (100)		10 (26)	29 (75)	39 (100)	
Normal	10 (13)	69 (87)	79 (100)		7 (10)	61 (90)	68 (100)	
Writing words				0.005				0.088
Weak	19 (31)	42 (69)	61 (100)		11 (22)	38 (78)	49 (100)	
Normal	7 (11)	58 (89)	65 (100)		6 (10)	52 (90)	58 (100)	

[a]*n* varied between 112 and 114. [b]*n* varied between 97 and 107. [c]*n* varied between 124 and 126. [d]*n* = 107.

Table 5. Results of the 12 univariate regression-analysis models with reading fluency and reading comprehension measured at 11 years of age as outcome variables, and with literacy skills (pre-reading skills, decoding, and word writing) as explanatory variables. Results for all children born very preterm (VP) are presented.

	Reading fluency at 11 y			
Literacy skills measured at 7 y	*b* (95% CI)	*p*	*F* (*p* for *F*)	R^2 (ΔR^2)
Pre-reading skills:				
Model 1 Phonological awareness	7.15 (3.76 to 10.51)	<0.001	17.6 (<0.001)	0.14 (0.13)
Model 2 RAN	−0.68 (−1.03 to − 0.32)	<0.001	14.6 (<0.001)	0.12 (0.11)
Model 3 Vocabulary	2.78 (0.78 to 4.77)	0.007	7.6 (0.007)	0.07 (0.06)
Model 4 Letter knowledge	2.11 (1.10 to 3.11)	<0.001	17.2 (<0.001)	0.14 (0.13)
Decoding				
Model 5 Decoding	5.11 (2.51 to 5.72)	<0.001	25.8 (<0.001)	0.19 (0.18)
Writing				
Model 6 Writing words	4.61 (2.78 to 6.43)	<0.001	25.1 (<0.001)	0.19 (0.18)
	Reading comprehension at 11 y			
Literacy skills measured at 7 y	*b* (95% CI)	*p*	*F* (*p* for *F*)	R^2 (ΔR^2)
Pre-reading skills				
Model 7 Phonological awareness	0.99 (0.68 to 1.31)	<0.001	38.8 (<0.001)	0.24 (0.23)
Model 8 RAN	−0.09 (−0.12 to − 0.06)	<0.001	29.8 (<0.001)	0.20 (0.19)
Model 9 Vocabulary	0.64 (0.48 to 0.82)	<0.001	56.8 (<0.001)	0.31 (0.31)
Model 10 Letter knowledge	0.29 (0.19 to 0.38)	<0.001	34.1 (<0.001)	0.22 (0.21)
Decoding				
Model 11 Decoding	0.39 (0.23 to 0.54)	<0.001	23.4 (<0.001)	0.16 (0.15)
Writing				
Model 12 Word writing	0.38 (0.19 to 0.57)	<0.001	15.9 (<0.001)	0.11 (0.11)

F = value of *F*-statistic; *p* = significance value; *b* = unstandardized coefficients *b*; 95% CI = 95% confidence interval for *b*; R^2 = coefficient of determination; ΔR^2 = adjusted coefficient of determination.

the models (see Appendix), the literacy skills measured at 7 years of age remained statistically significant in every model except for phonological awareness at 7 years and RAN at 7 years in the models with reading fluency at 11 as the outcome variable. Gender (male disadvantage) was a statistically significant background variable in every model. Mother's self-reported reading difficulties were a statistically significant variable in six models, and father's self-reported reading difficulties in four models. After the exclusion of children born VP with NDI, the models remained statistically significant.

Discussion

This prospective follow-up study provides novel longitudinal information regarding reading skills of school-aged children born VP speaking and reading a transparent language. In reading fluency, at 11 years of age, children born VP had more difficulties compared to the normative data of a standardized reading test. Interestingly, in the present cohort, the reading comprehension ability at 11 years did not differ from the normative data. After the exclusion of children born VP with NDI, the preterm group performed even better compared to the test norms. Further, statistically significant correlations between every pre-reading, decoding, and writing measure at 7 years of age and reading fluency and reading comprehension at 11 years of age was found. In addition, most of the children born VP with weak decoding and word-writing skills had also weak reading fluency 4 years later. Pre-reading, decoding, and word-writing ability

at 7 years of age explained 7% to 19% of the variance in reading fluency, and 11% to 31% of the variance in reading comprehension 4 years later.

Children born VP had weak reading fluency at 11 years of age. Nevertheless, in reading comprehension, VP children had even better skills compared to the norming sample of the method. Some of the previous studies assessing the core components of reading in school-aged children born VP acquiring English have reported that these children continue to have difficulties in every domain of reading during their school years (Kovachy et al., 2015). Also, in the previous study by Guarini et al. (2019, p. 37) children born VP exposed to Italian, an orthographically regular and transparent language, were found to have delays in both reading fluency and reading comprehension at 10 years of age. In our study, with a cohort of 134 VP-born subjects, more than half of the children had weak reading-fluency ability at the age of 11 years. However, the reading comprehension of these children was age appropriate, and furthermore, after the exclusion of children born VP with NDI, the VP group had even better reading comprehension compared to the normative data. The differences between our results and the findings of Guarini et al. (2019) might stem from differences in sample size, study design or, on the other hand, the differences between the support these children received in schools or health care before age 11 (see, e.g., Messina, 2023). Our results are in line with the previous findings of Aarnoudse-Moens et al. (2011) showing that in primary school, children born VP performed comparably with peers in reading comprehension but had more difficulties in reading fluency. A trend for a catch-up in reading comprehension in school-aged children born VP has also been reported previously by Leijon et al. (2018). In their study, 49 children born VP speaking and reading Swedish, a semi-transparent orthography, scored significantly lower in every domain of reading ability compared to 44 term controls at the age of 8 and 10 years. However, the gap with controls had largely narrowed by the second assessment at 10 years of age, especially in reading comprehension. It is interesting to reflect on those results in light of the present study, in which we had a bigger sample size and reading comprehension was assessed 1 year later, at age 11 years. Our findings highlight the importance of evaluating the specific domains of reading separately, since the difficulties may appear in one or several components of reading. Additionally, these findings raise the possibility that difficulties in reading in children born VP may be tracked down to more general deficits such as slowness in processing speed. In Finland, in the fourth grade of primary school, at 11 years of age, children are expected to read fluently, and reading ability is utilized as a tool for learning other subjects. Thus, the evaluation and training of reading comprehension is often emphasized. In view of our results, it is important to pay attention to the possible additional workload and compensational effort that these children born VP with weak reading fluency might have to face – especially, if their difficulties in reading fluency have remained undetected in school.

We found significant correlations between every literacy variable at 7 years and reading fluency and reading comprehension at 11 years of age in children born VP. Previously, longitudinal associations between early school-readiness domains including language and pre-reading skills at age 4 (Pritchard et al., 2014) and at age 6 (Borchers et al., 2019; Guarini & Sansavini, 2012) and later reading ability at up to 8 or 9 years of age have been reported among children born VP. In addition, in typically developing populations, reading and writing skills have been found to correlate significantly with

each other, and they are assumed to be built on the same underlying linguistic and cognitive skills (Ehri & Wilce, 1987). Lerkkanen et al. (2004b) have reported prospective relationships between reading and writing skills in general Finnish school population in the first grade of primary school. To date, it has been unclear whether an association between early writing skills and later reading outcomes can be detected in children born VP. Our results add to existing knowledge by suggesting that the association between early word-writing skills and later reading fluency and comprehension ability at 11 years of age is evident already at 7 years of age in children born VP.

In the present study, a majority (63% to 68%) of the children born VP with weak decoding and word-writing skills at 7 years of age had also weak reading fluency 4 years later compared to those with more advanced skills in decoding and writing at 7 years. In reading comprehension, the corresponding percentages were smaller (31% to 34%) but statistically significant. Also, a significant amount (44% to 50%) of the children born VP with weak pre-reading skills at 7 years had weak reading comprehension at 11 years of age. Surprisingly, the associations between weak pre-reading skills at 7 years and weak reading fluency at 11 years of age were nonsignificant. It is interesting to compare these results with the previous findings of Leppänen et al. (2008) who showed using path-model analysis that in the general Finnish school population, the pre-reading skills (phonological awareness and letter knowledge) in the first grade of primary school, at 7 years of age, predicted later reading fluency at 11 years of age, mainly via early word-decoding ability at 7 years of age, even though in kindergarten at 5–6 years of age, pre-reading skills had been directly associated with reading fluency at 11 years of age. Especially, the effect of phonological awareness on reading fluency at 11 years of age was strongly mediated via early reading ability in first grade (Leppänen et al., 2008). The findings of the present study highlight the need for screening widely both weak pre-reading skills and early weak decoding and writing acquisition in the beginning of schooling in this high-risk population of children born VP.

Another novel finding of the present study was that literacy skills in the beginning of formal reading instruction at 7 years of age explained a significant amount of the variance in reading fluency and reading comprehension 4 years later in children born VP. In the univariate regression models with reading fluency at 11 years of age as the outcome variable, both early decoding and early writing skills at 7 years of age explained the greatest amount (19%) of the unique variance in reading fluency 4 years later. Further, in the univariate models including reading comprehension at 11 years as the outcome variable, the best explanatory variables were pre-reading skills at 7 years of age, of which vocabulary explained the greatest amount (31%) of the variance in reading comprehension at 11 years of age. These results support the view that evaluation of early literacy skills in the beginning of schooling provides valuable information on later reading skills in children born VP.

Gender (male disadvantage) was a significant background variable in every regression model. Male gender is a well-known risk factor for cognitive and educational difficulties in children born preterm (Linsell et al., 2015). In a previous study regarding the same PIPARI cohort (Nyman et al., 2017), male gender was found to be a significant risk factor for working-memory and processing-speed functioning up to 11 years of age. The present finding is in line with these previous results.

The present study also indicated that mother's and father's self-reported reading difficulties affected reading fluency but not reading comprehension at 11 years of age.

It is well known that reading difficulties run in families (Snowling & Melby-Lervåg, 2016). Furthermore, some studies support the view that even family-risk children who do not develop dyslexia perform slightly poorer in reading and literacy at preschool and school age compared to their peers without family risk (Snowling et al., 2003; van Bergen et al., 2012). In light of our results, when evaluating the reading and literacy abilities of children born VP in the beginning of schooling, it is beneficial to pay attention to parents' self-reported reading difficulties.

Surprisingly, paternal and maternal education did not have an effect on 11-year-olds' reading fluency or reading comprehension. We have previously shown in the same PIPARI cohort that paternal education independently associated with early language skills at 2 years and literacy skills at 7 years in children born VP (Joensuu et al., 2021). Similarly, paternal education has been shown to be associated with precursors of reading at 5 years (Munck et al., 2012) and with verbal comprehension at 11 years of age (Nyman et al., 2017) in children born VP in the PIPARI cohort. Based on this, one could assume that especially paternal education would have an effect on reading at 11 years in this group of children. However, the results of the current study suggest that the effect of parental education level on reading ability may diminish with age, while other factors such as gender and parents' reading difficulties may continue to have a significant impact on reading up to later school age in children born VP. These results emphasize the importance of continued evaluation of and support for reading skills in these children throughout their school years.

This study has several implications. It presents new knowledge of the reading ability of children born VP acquiring a transparent language, revealing that most of these children had weak skills in reading fluency even though their reading comprehension was age appropriate at 11 years of age. These results provide valuable information for health care and educational professionals working with school-aged children born VP, highlighting the importance of evaluating not only reading comprehension but also reading fluency in later school age, since the difficulties may appear in one or several components of reading. These findings also raise a concern that children born VP with weak reading fluency may struggle to achieve the learning objectives and may thus encounter a greater risk for stress and exhaustion during the school years compared to their peers, especially if the reading difficulties have remained hidden. In addition, our findings reveal longitudinal associations between early literacy skills at 7 years and later reading fluency and reading comprehension at 11 years in children born VP. The current results emphasize the usefulness of assessing pre-reading skills and early decoding and writing skills in the beginning of schooling for identifying children at risk for later difficulties in reading and for providing timely support.

In Finland, special support services for students with learning difficulties are provided without diagnosis through the legislative support systems available in every Finnish school (see, e.g., Judith Solheim et al., 2021). The support consists of three levels: general support all pupils, and for minor learning problems, intensified support for special problems, and special support for special education (Finnish National Agency for Education, 2014). Additionally, in Finnish schools, a web-based learning game called the GraphoGame (Saine et al., 2011; Lovio et al., 2012) is used extensively as a supplementary tool for strengthening reading acquisition. In a previous study of the same PIPARI cohort, Nyman et al. (2019) report the results of the teacher-rated questionnaire which includes information about the support services received by the children in school. In addition to the extensive support provided for children with difficulties in

learning regardless the gestational age in Finland, specific learning resources developed to improve knowledge in supporting prematurely born children in classrooms might still be useful (see, e.g., Johnson et al., 2019)

The strength of the present study is that it provides prospective longitudinal information on reading acquisition in a well-defined, population-based cohort of children born VP acquiring a transparent language. Methods used to assess reading development in the study are cost-effective, broadly available in Finland and provide clinically valuable information to educational and healthcare professionals working with school-aged children born VP. As a limitation, it was not possible to compare the reading performance at 11 years of age with the large control group of children born at term of the PIPARI study since the reading assessment at 11 years included only children born VP. However, the normative data of the method was used for comparison. In addition, there were relatively more children with NDI in the drop-out group compared to the children participating the study. This should be taken into consideration while interpreting the results of the present study. The method for reading fluency used in the present study was a word-chain test in which the child was asked to separate non-spaced words from each other and mark the word boundaries with a line using a pencil. Even though this is a widely used test for assessing reading fluency (Leppänen et al., 2008; Nurmi & Aunola, 1999; Torppa et al., 2020), a broader evaluation of reading fluency using several test types is recommended in the future studies. It is important to consider that this type of task used in the present study may also relate to visuomotor skills. Children born VP have been reported to have an increased risk for specific functional difficulties and delays in visuomotor skills (such as visual crowding) (Geldof et al., 2012; Perez-Roche et al., 2016). The analyses were run also for those children without neurodevelopmental impairment (NDI). The exclusion of the children with NDI did not significantly affect the results regarding the performance in reading fluency task at 11 years of age. Still, the possible effect of visuomotor difficulties should be considered even more precisely in the future research evaluating reading fluency of children born VP. For future studies, we also propose a closer assessment of children's grammar skills which might play a significant role in reading comprehension especially in Finnish language which has a very rich inflectional system (see, e.g., Lehtonen et al., 2007; Marjokorpi & van Rijt, 2024).

Conclusions

Adequate reading skills are necessary for active participation and success in modern societies. It is essential to identify potential difficulties in reading acquisition emerging in school age. Our study shows that children born very preterm have weak reading fluency at later school age even though their reading comprehension is age appropriate. Evaluating the specific domains of reading separately also at later school age may offer a more precise perception regarding the reading ability of these children. Identifying weak pre-reading skills and early weak decoding and writing ability in the beginning of schooling is valuable for providing timely support.

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Appendix.1. Table A

Table A1. Results of multivariate linear regression analysis with reading fluency and reading comprehension at 11 years of age as outcome variables, and with **phonological awareness** at 7 years of age and background factors (gestational age, mother's and father's self-reported reading difficulties, paternal education, and gender) as explanatory variables. Results for all children born very preterm (VP) and for the subgroup of children born VP without neurodevelopmental impairment (NDI) are presented.

	Reading fluency		Reading comprehension	
	b (95% CI)	*p*	*b* (95% CI)	*p*
Children born VP				
Gestational age	−0.96 (−3.69 to 1.77)	0.36	0.07 (−0.27 to 0.36)	0.642
Self-reported reading difficulties				
Mothers	32.90 (9.47 to 56.34)	0.007	0.76 (−1.84 to 3.37)	0.562
Fathers	24.03 (1.22 to 46.83)	0.039	1.29 (−1.23 to 3.81)	0.312
Paternal education	3.73 (−12.37 to 19.84)	0.646	0.65 (−1.06 to 2.35)	0.452
Maternal education	−5.76 (−22.90 to 11.38)	0.505	0.64 (−1.20 to 2.45)	0.490
Gender	28.87 (13.52 to 44.22)	<0.001	2.35 (0.73 to 3.96)	0.005
Phonological awareness	3.29 (−0.29 to 6.87)	0.071	0.92 (0.53 to 1.31)	<0.001
Fit statistics				
F	4.7		7.5	
p for *F*	<.001		<.001	
R^2	0.30		0.38	
ΔR^2	0.24		0.33	
Children born VP without NDI				
Gestational age	−0.86 (−3.87 to 2.15)	0.57	0.054 (−0.25 to 0.36)	0.719
Self-reported reading difficulties				
Mothers	24.62 (−0.48 to 49.71)	0.054	−1.47 (−4.04 to 1.10)	0.259
Fathers	27.43 (0.58 to 54.23)	0.045	−0.33 (−3.08 to 2.43)	0.814
Paternal education	−1.13 (−17.27 to 15.02)	0.890	0.42 (−1.16 to 2.01)	0.596
Gender	33.25 (16.76 to 49.75)	<0.001	1.85 (0.24 to 3.47)	0.025
Phonological awareness	1.74 (−2.10 to 5.58)	0.369	0.91 (0.52 to 1.3)	<0.001
Fit statistics				
F	3.8		6.01	
p for *F*	<.003		<.001	
R^2	0.27		0.34	
ΔR^2	0.20		0.28	

Table A2. Results of multivariate linear regression analysis with reading fluency and reading comprehension at 11 years of age as outcome variables, and with **rapid automatized naming (RAN)** at 7 years of age and background factors (gestational age, mother's and father's self-reported reading difficulties, paternal education, maternal education, and gender) as explanatory variables. Results for all children born very preterm and for the subgroup of children born VP without neurodevelopmental impairment (NDI) are presented.

	Reading fluency		Reading comprehension	
	b (95% CI)	*P*	b (95% CI)	*P*
Children born VP				
Gestational age	−0.57 (−3.73 to 2.60)	0.723	0.01 (−0.29 to 0.32)	0.928
Self-reported reading difficulties				
Mothers	31.62 (4.44 to 58.81)	0.023	1.13 (−1.50 to 3.76)	0.102
Fathers	32.54 (7.04 to 58.03)	0.013	2.01 (−0.41 to 4.52)	0.144
Paternal education	14.26 (−4.026 to 32.56)	0.125	1.66 (−0.11 to 3.43)	0.065
Maternal education	4.58 (−14.24 to 23.41)	0.629	0.53 (−1.30 to 2.35)	0.567
Gender	33.48 (16.78 to 50.19)	<0.001	2.35 (0.73 to 3.97)	0.005
RAN	−0.46 (−0.86 to −0.06)	0.025	−0.76 (−0.12 to – 0.04)	<0.001
Fit statistics				
F	5.9		5.9	
P for F	<.001		<.001	
R^2	0.35		0.32	
ΔR^2	0.29		0.27	
Children born VP without NDI				
Gestational age	−0.53 (−3.51 to 2.44)	0.721	0.07 (−0.27 to 0.40)	0.682
Self-reported reading difficulties				
Mothers	23.10 (−1.20 to 47.31)	0.062	0.30 (−3.09 to 2.48)	0.830
Fathers	24.44 (−2.20 to 51.01)	0.071	0.67 (−2.38 to 3.71)	0.663
Paternal education	1.94 (−14.33 to 18.21)	0.812	1.15 (−0.65 to 2.96)	0.205
Maternal education	−10.96 (−30.0 to 7.70)	0.244	0.30 (−1.74 to 2.34)	0.769
Gender	30.15 (17.39 to 49.56)	<0.001	2.33 (0.57 to 4.10)	0.010
RAN	−0.45 (−0.97 to 0.07)	0.053	−0.05 (−0.09 to – 0.01)	<0.029
Fit statistics				
F	2.7		2.6	
P for F	<.017		<.021	
R^2	0.24		0.20	
ΔR^2	0.15		0.12	

Table A3. Results of multivariate linear regression analysis with reading fluency and reading comprehension at 11 years of age as outcome variables, and with **vocabulary** at 7 years of age and background factors (gestational age, mother's and father's self-reported reading difficulties, paternal education, maternal education, and gender) as explanatory variables. Results for all children born very preterm and for the subgroup of children born VP without neurodevelopmental impairment (NDI) are presented.

	Reading fluency		Reading comprehension	
	b (95% CI)	*P*	b (95% CI)	*P*
Children born VP				
Gestational age	−0.69 (−3.90 to 2.50)	0.668	−0.01 (−0.28 to 0.26)	0.943
Self-reported reading difficulties				
Mothers	36.74 (10.14 to 62.35)	0.007	1.61 (−0.67 to 3.90)	0.163
Fathers	32.31 (6.60 to 58.01)	0.014	1.98 (−0.23 to 4.18)	0.078
Paternal education	11.98 (−6.58 to 30.53)	0.202	1.05 (−0.54 to 2.64)	0.193
Maternal education	5.08 (−13.89 to 24.05)	0.595	0.31 (−1.31 to 1.94)	0.702
Gender	36.97 (20.24 to 53.72)	<0.001	3.04 (1.61 to 4.50)	<0.001
Vocabulary	2.22 (0.34 to 4.02)	0.021	0.63 (0.43 to 0.82)	<0.001
Fit statistics				
F	5.6		10.5	
P for F	<0.001		<0.001	
R^2	0.34		0.46	
ΔR^2	0.28		0.42	
Children born VP without NDI				
Gestational age	0.031 (−3.56 to 3.61)	0.986	0.018 (−0.26 to 0.29)	0.131
Self-reported reading difficulties				
Mothers	27.05 (−2.04 to 56.15)	0.068	0.47 (−1.75 to 2.69)	0.673
Fathers	33.91 (2.34 to 65.47)	0.036	1.92 (−49 to 4.32)	0.117
Paternal education	7.80 (−12.36 to 65.47)	0.443	0.62 (−0.92 to 2.15)	0.424
Maternal education	2.45 (−18.63 to 23.53)	0.817	0.09 (−1.52 to 1.69)	0.916
Gender	33.80 (14.64 to 52.93)	<0.001	2.66 (1.20 to 4.12)	<0.001
Vocabulary	1.80 (−0.80 to 4.40)	0.172	0.57 (0.38 to 0.77)	<0.001
Fit statistics				
F	2.5		6.5	
P for F	0.025		<0.001	
R^2	0.22		0.39	
ΔR^2	0.13		0.33	

Table A4. Results of multivariate linear regression analysis with reading fluency and reading comprehension at 11 years of age as outcome variables, and with **letter knowledge** at 7 years of age and background factors (gestational age, mother's and father's self-reported reading difficulties, paternal education, maternal education, and gender) as explanatory variables. Results for all children born very preterm and for the subgroup of children born VP without neurodevelopmental impairment (NDI) are presented.

	Reading fluency		Reading comprehension	
	b (95% CI)	*P*	b (95% CI)	*P*
Children born VP				
Gestational age	−0.66 (−3.84 to 2.53)	0.682	−0.001 (−.031 to 0.31)	0.994
Self-reported reading difficulties				
Mothers	34.70 (7.94 to 61.44)	0.012	1.61 (−0.98 to 4.20)	0.220
Fathers	27.63 (1.62 to 53.64)	0.038	1.21 (−1.32 to 3.73)	0.344
Paternal education	12.26 (−6.17 to 30.70)	0.190	1.32 (−0.47 to 3.11)	0.145
Maternal education	1.13 (−18.55 to 20.80)	0.910	−0.84 (−1.99 to 1.82)	0.931
Gender	34.33 (17.63 to 51.03)	<0.001	2.50 (0.87 to 4.10)	0.003
Letter knowledge	1.40 (0.10 to 2.68)	0.036	0.24 (0.11 to 0.36)	<0.001
Fit statistics				
F	5.7		5.7	
P for F	<0.001		<0.001	
R^2	0.35		0.31	
ΔR^2	029		0.26	
Children born VP without NDI				
Gestational age	0.035 (−3.56 to 3.63)	0.984	0.02 (−2.90 to 0.33)	0.901
Self-reported reading difficulties				
Mothers	20.41 (−10.64 to 51.46)	0.194	−1.24 (−3.90 to 1.41)	0.355
Fathers	26.80 (−5.63 to 59.21)	0.104	−0.06 (−2.82 to 2.71)	0.968
Paternal education	7.90 (−12.34 to 28.15)	0.438	0.76 (−0.97 to 2.50)	0.384
Maternal education	1.94 (−19.48 to 23.36)	0.857	0.10 (−1.73 to 1.93)	0.912
Gender	29.30 (9.97 to 48.58)	0.004	1.37 (−0.28 to 3.02)	0.102
Letter knowledge	2.91 (−2.07 to 7.89)	0.247	0.73 (0.31 to 1.16)	<0.001
Fit statistics				
F	2.4		3.04	
P for F	0.030		0.007	
R^2	0.22		0.23	
ΔR^2	0.13		0.16	

Table A5. Results of multivariate linear regression analysis with reading fluency and reading comprehension at 11 years of age as outcome variables, and with **decoding** at 7 years of age and background factors (gestational age, mother's and father's self-reported reading difficulties, paternal education, maternal education, and gender) as explanatory variables. Results for all children born very preterm and for the subgroup of children born VP without neurodevelopmental impairment (NDI) are presented.

	Reading fluency		Reading comprehension	
	b (95% CI)	*P*	b (95% CI)	*P*
Children born VP				
Gestational age	−0.70	0.658	−0.01 (−0.33 to 0.31)	0.972
Self-reported reading difficulties				
Mothers	32.19	0.017	1.76 (−0.95 to 4.46)	0.200
Fathers	27.48	0.034	1.56 (−1.04 to 4.16)	0.236
Paternal education	8.35 (	0.370	1.07 (−0.82 to 2.96)	0.265
Maternal education	4.59 (.13.87 to 23.05)	0.622	0.74 (−1.20 to 2.64)	0.438
Gender	32.36 (15.70 to 48.90)	<0.001	2.41 (0.72 to 4. 11)	0.006
Decoding	2.74 (0.80 to 4.70)	0.006	0.27 (0.07 to 0.47)	0.009
Fit statistics				
F	6.4		4.4	
P for F	<0.001		<0.001	
R^2	0.37		0.26	
ΔR^2	0.31		0.21	
Children born VP without NDI				
Gestational age	−0.24 (−3.71 to 3.23)	0.835	−0.01 (−0.32 to 0.30)	0.945
Self-reported reading difficulties				
Mothers	18.95 (−9.86 to 47.75)	0.193	−0.52 (−3.11 to 2.09)	0.694
Fathers	26.63 (−3.93 to 57.20)	0.086	0.68 (−2.20 to 3.34)	0.677
Paternal education	5.23 (14.41 to 24.87)	0.596	0.45 (−1.10 to 2.45)	0.447
Maternal education	0.52 (−19.93 to 20.96)	0.960	0.32 (−1.5 to 2.20)	0.728
Gender	28.66 (10.30 to 47.04)	0.003	1.62 (−0.04 to 3.28)	0.056
Decoding	2.60 (0.51 to 4.70)	0.016	0.28 (0.09 to 0.47)	0.004
Fit statistics				
F	3.3		2.6	
P for F	0.005		0.020	
R^2	0.27		0.21	
ΔR^2	0.19		0.13	

Table A6. Results of multivariate linear regression analysis with reading fluency and reading comprehension at 11 years of age as outcome variables, and with **word-writing** at 7 years of age and background factors (gestational age, mother's and father's self-reported reading difficulties, paternal education, maternal education, and gender) as explanatory variables. Results for all children born very preterm and for the subgroup of children born VP without neurodevelopmental impairment (NDI) are presented.

	Reading fluency		Reading comprehension	
	b (95% CI)	*P*	b (95% CI)	*P*
Children born VP				
Gestational age	−0.57 (−97.21 to 95.25)	0.715	0.004 (−0.32 to 0.33)	0.978
Self-reported reading difficulties				
Mothers	34.08 (8.23 to 60.00=	0.010	2.07 (−0.63 to 4.80)	0.132
Fathers	25.87 (0.58 to 51.15)	0.045	1.56 (−1.10 to 4.20)	0.247
Paternal education	10.50 (−7.50 to 28.50)	0.250	1.36 (−0.53 to 3.24)	0.156
Maternal education	3.40 (−14.40 to 22.31)	0.700	0.76 (−1.20 to 2.68)	0.432
Gender	32.47 (16.13 to 48.80)	<0.001	2.50 (0.80 to 4.21)	0.005
Word-writing	3.30 (1.13 to 5.50)	0.003	0.25 (0.03 to 0.48)	0.030
Fit statistics				
F	6.7		3.9	
P for F	<0.001		<0.001	
R^2	0.38		0.24	
ΔR^2	0.32		0.18	
Children born VP without NDI				
Gestational age	−0.06 (−3.50 to 3.33)	0.970	0.01 (−0.31 to 0.33)	0.942
Self-reported reading difficulties				
Mothers	19.87 (−8.02 to 47.76)	0.159	−0.17 (−2.80 to 2.50)	0.896
Fathers	23.38 (−6.74 to 53.50)	0.126	0.51 (−2.33 to 3.36)	0.720
Paternal education	6.71 (−12.30 to 25.72))	0.483	0.94 (−0.86 to 2.73)	0.301
Maternal education	−1.35 (−21.50 to 18.78)	0.894	0.34 (−1.56 to 2.23)	0.730
Gender	29.12 (11.21 to 47.03)	0.002	1.75 (0.06 to 3.44)	0.042
Word-writing	3.42 (1.17 to 5.70)	0.004	0.25 (0.03 to 0.46)	0.023
Fit statistics				
F	3.8		2.1	
P for F	0.002		0.065	
R^2	0.30		0.17	
ΔR^2	0.23		0.09	