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Year: 2018

Version: Accepted version (Final draft)

Please cite the original version:

Eklund, K., Torppa, M., Sulkunen, S., Niemi, P., & Ahonen, T. (2018). Early cognitive predictors of PISA reading in children with and without family risk for dyslexia. Learning and Individual Differences, 64(2018), 94-103. https://doi.org/10.1016/j.lindif.2018.04.012

Early Cognitive Predictors of PISA Reading in Children with and without Family-risk for Dyslexia

ABSTRACT

This study examined language skills and pre-literacy skills (phonological awareness, rapid naming, and letter knowledge) before school-age as predictors of PISA reading at age 15 in two groups of children, with (n=88) and without (n=70) family-risk for dyslexia. Moreover, effects of family-risk on these early predictors, reading fluency, and PISA reading were examined while controlling the effect of gender. Children were followed from age 2 to 15. Family-risk had a significant effect on early language and pre-literacy skills, reading fluency and PISA reading. A similar model predicting PISA reading fitted the data well in the Family-risk and the No family-risk group. Language skills explained a good portion and pre-literacy skills to a lesser extent the variance in PISA reading. Altogether 68% of the variance in PISA reading was explained in the Family-risk group and 44% in the No family-risk group. Findings suggest that family risk sets children at elevated risk to develop long-standing difficulties in language and literacy and that the early language and pre-literacy skills are strong predictors of reading as far as PISA reading at age 15.

Keywords: PISA reading literacy, family-risk for dyslexia, cognitive predictor, development, longitudinal study

1. INTRODUCTION

It is well documented that a substantial proportion, 34%–66%, of children with a family history of dyslexia have severe difficulties in reading and spelling acquisition during their first grades at school (Pennington & Lefly, 2001; Puolakanaho et al., 2007; Scarborough, 1990; Snowling, Callagher, & Frith, 2003). For most individuals these difficulties sustain into adolescence even in transparent orthographies (Eklund, Torppa, Aro, Leppänen, & Lyytinen, 2015; Landerl & Wimmer, 2008; Torppa, Eklund, van Bergen, & Lyytinen, 2015). Not only have children with dyslexia compromised pre-literacy skills, i.e., phonological awareness, rapid automatized naming, and letter knowledge (e.g. Boets et al., 2010; Snowling et al., 2003; Snowling, Muter, & Carroll, 2007; Torppa, Lyytinen, Erskine, Eklund, & Lyytinen, 2010; van Bergen et al., 2010; van Bergen, de Jong, Plakas, Maassen, & van der Leij, 2012), but also difficulties in early receptive and expressive vocabulary (see Snowling & Melby-Lervåg, 2016, for review and meta-analysis), another cornerstone of reading comprehension besides word identification (Perfetti & Hart, 2001). In our prior report from the Jyväskylä Longitudinal Study of Dyslexia (JLD), we found not only that children with a family history of dyslexia were overrepresented in the subgroup of slow decoders, but also that twice as many children with family-risk for dyslexia compared to control children were in the group of poor readers, with poor performance in both word recognition and reading comprehension in Grade 2 (Torppa et al., 2007). In the present study, we extend our investigation until Grade 9 (age 15-16) and broaden our reading outcome from reading fluency and reading comprehension to PISA reading literacy. We examine to what extent children's performance in PISA reading can be predicted by early language skills, on one hand, and pre-literacy skills, i.e., phonological awareness, rapid naming, and letter knowledge through reading fluency at school age, on the other hand. Moreover, the effect of family-risk on these early predictors and reading measures, as well as on their associations is examined while controlling for the effect of children's gender.

1.1. PISA Reading Literacy

The OECD Program for International Student Assessment (PISA), conducted once every three years from the year 2000, was to "set up to measure how well young adults near the end of compulsory schooling are prepared to meet the challenges of today's knowledge societies" (OECD, 2002, p. 3). Reading is one of the three target areas assessed in PISA, the other two being mathematics and science. In reading, PISA intends to assess skills which go beyond decoding and reading comprehension, i.e. reading literacy, that involve "an individual's capacity to: understand, use, reflect on and engage with written texts, in order to achieve one's goals, to develop one's knowledge and potential, and to participate in society" (OECD, 2009, p. 14). In other words, decoding and reading comprehension are seen as basic skills that enable readers to employ reading as a tool for the acquisition of new information, although, to make full use of printed material, other skills are needed as well. The skills claimed to be required for success in PISA reading literacy tasks include decoding, knowledge of words, grammar and other linguistic skills, textual structures and features, and metacognitive knowledge (OECD, 2009). To assess these skills, several texts which challenge students' ability to find, select, interpret and evaluate information are included in the PISA reading tasks (OECD, 2009).

Research on cognitive prerequisites, not to mention predictors, related to PISA reading literacy is limited. This is understandable as "improving the quality of education" (OECD, 2002, p.12) has been the major policy initiative in the Organization for Economic Co-operation and Development (OECD), not the origin of students' literacy skills per se. According to a study of Arnbak (2012), concurrently measured word recognition and vocabulary together explained about 40% of the variance in PISA reading scores. Artelt, Schiefele, and Schneider (2001) showed that concurrently measured decoding speed explained about 13% of the variance in PISA reading literacy. Finally, in a recent study with Finnish students focusing on gender differences in PISA reading, concurrently assessed reading fluency was found to be the main predictor of PISA reading explaining approximately 15% of its variance (Torppa, Eklund, Sulkunen, Niemi, & Ahonen, 2018). However, no cognitive measures were included in that study.

1.2. Cognitive Predictors of Reading Comprehension

According to the lexical quality hypothesis (Perfetti & Hart, 2001) and the Simple View of Reading (Gough & Tunmer, 1986), word recognition and vocabulary are the basic building blocks for reading comprehension. Efficient decoding has generally been seen as necessary for reading comprehension – one has to decipher letter strings, first in words and ultimately in sentences and texts, to be able to understand their meaning. Well automatized word reading skills free up resources for higher-level processing (Perfetti, 1985), supporting reading comprehension. Empirical findings have revealed a strong link between fluent word reading skills and reading comprehension (for a recent meta-analysis of factors affecting the strength of this relationship, see García & Cain, 2014). The link is very strong in the early grades, after which its role is diminished, particularly in transparent orthographies (for a meta-analysis in different orthographies, see Florit & Cain, 2011), although not ceasing to exist (Artelt et al., 2001; Verhoeven & van Leeuwe, 2008). On the other hand, according to the Simple View of Reading (Gough & Tunmer, 1986), a subgroup of poor comprehenders without difficulties in decoding also exists. Accordingly, several studies have shown that at least average text comprehension is possible also for inaccurate or slow decoders (Catts, Adlof, & Weismer, 2006; Nation, Clarke, Marshall, & Durand, 2004; Torppa et al., 2007).

Moreover, a strong link has also been found between vocabulary and reading comprehension (e.g. Muter, Hulme, Snowling, & Stevenson, 2004; Nation & Snowling, 2004; Torppa et al., 2007; Verhoeven & van Leeuwe, 2008). Vocabulary has been reported to account for the variability of subsequent reading comprehension even after taking into account the effect of word reading (e.g. Olson et al., 2011). Besides vocabulary, linguistic processes involved in the comprehension of oral language, such as parsing sentences, drawing interferences, and integration of information (Hoover & Gough, 1990; Verhoeven & van Leeuwe, 2008), as well as semantic knowledge, syntactic knowledge, and background knowledge have been shown to be tightly connected to reading comprehension (for a review on low-progress readers, see Tan, Wheldall, Madelaine, & Lee, 2007).

1.3. Effects of Family-risk for Dyslexia on Reading Development

Children with family-risk for dyslexia are in high risk for performing poorly in PISA reading. This is due to, first, their elevated risk for compromised word reading skills: their risk for reading disability is four to tenfold when compared to children without family-risk (Pennington & Lefly, 2001; Puolakanaho et al., 2007; Scarborough, 1990; Snowling et al., 2003). Second, as the same genes which are largely behind learning disabilities are expected to be behind cognitive abilities as well (the generalist genes hypothesis, see Kovacs & Plomin, 2007; Plomin & Kovacs, 2005), compromised skills of family-risk children are not expected to be restricted to word reading and its pre-requisites, but broader language skills are probably affected, too. According to the ideas of the Multiple deficit model of dyslexia (Pennington, 2006; van Bergen, van der Leij, & de Jong, 2014), the offspring of parents with dyslexia are expected to inherit various amounts of risk factors in several domains from their parents (e.g. Bishop, 2009; Pennington, 2006; Snowling et al., 2003). As a consequence, the inherited risk factors are, at the individual level, expressed in various amounts of word reading difficulties, compromised language skills, and their combinations.

Empirical findings have confirmed that children with dyslexia have compromised pre-literacy skills, i.e., phonological awareness, rapid automatized naming, and letter knowledge (e.g. Boets et al., 2010; Snowling et al., 2003, 2007; Torppa et al., 2010; van Bergen et al., 2010, 2012). They have also been shown to be capable of sight word reading or processing large chunks of graphemes later in their development than their age-mates (Eklund et al., 2015; Zoccolotti et al., 2005). Moreover, family-risk children with dyslexia have been shown to have deficient skills in early receptive and expressive vocabulary (e.g. Snowling et al., 2007; Torppa et al., 2010) already before school age. Even the children with family-risk who do not fulfill the criteria of dyslexia have usually been shown to perform between the level of controls and children with dyslexia in several pre-literacy, language and literacy skills both prior to and after school entry (e.g. Pennington & Lefly, 2001; Snowling et al., 2003; van Bergen et al., 2010, 2012), although these differences have not always been statistically significant (Boets et al., 2010; Eklund et al., 2015; Torppa et al., 2010).

In spite of the compromised pre-literacy skills of family-risk children before school-age the reading comprehension outcome of these children is not clear. On one hand, English-speaking family-risk children with reading disability have been shown to have poor reading comprehension skills at 12-13 years of age (Snowling et al., 2007). On the other hand, family-risk children who do not develop reading problems have been shown to overcome their shortcomings in language skills by the time of formal schooling, and not differing from children without family-risk in their reading comprehension skills at 12-13 years of age (Snowling & Melby-Lervåg, 2016; Snowling et al., 2007). In the present sample family-risk has been shown to be linked to reading comprehension difficulties in grades 1-2 but only when accompanied by reading fluency difficulties: approximately twice as many children were classified as poor readers, i.e. having difficulties both in reading fluency and reading comprehension, in the family-risk group compared to children without family-risk, (17% vs. 9% respectively), (Torppa et al., 2007). The finding is, however, based on very early phase of reading acquisition when reading comprehension is still strongly dependent of reading fluency and it is possible that by the age of PISA assessment in grade 9 the situation has changed.

1.4. Effects of Gender on Reading Skills

Gender differences have been clear in PISA reading performance, where girls have outperformed boys in every OECD country in recent assessments 2009, 2012, and 2015 (OECD, 2011, 2013, 2016; see also Chiu & McBride-Chang, 2006). Moreover, more male than female students have been found among those on the lowest reading proficiency level (OECD, 2011). In addition, a meta-analysis of reading achievement in large-scale studies between 1970 and 2002 concluded that female secondary school students outperformed their male peers by, on average, 0.19 standard deviation units in reading achievement, with the largest gender gap (effect size = 0.32) in PISA reading literacy (Lietz, 2006), the outcome measure of the present study.

Poorer performance of males in PISA reading could be due to higher prevalence of dyslexia in this group: a greater number of males with reading problems has usually been reported both in clinical and research samples (Hawke, Olson, Willcutt, Wadsworth, & DeFries, 2009; Quinn & Wagner, 2015; Rutter et al., 2004), while the ratio between males and females has been shown to increase along with the severity of reading impairment (Quinn & Wagner, 2015). However, no obvious reason for such gender differences has been found in genetic etiology studies of reading difficulties (Hawke, Wadsworth, & DeFries, 2006; Hawke, Wadsworth, Olson, & DeFries, 2007). Slightly larger variability in reading performance among males has been suggested as an explanation for the higher prevalence of reading difficulties (Hawke et al., 2009), leaving, however, the origin of this larger variance unspecified. Prospective family-risk studies have not reported gender differences in the pre-literacy skills, and no sustainable differences between males and females have been found in language development, either (for a review of gender differences in language, see Hyde & Linn, 1988, and Wallentin, 2009). However, a slight advantage for girls has been found especially in the early phase of language development (e.g. Berglund, Eriksson, & Westerlund, 2008; Fenson et al., 1994).

1.5. The Present Study

Although various cognitive skills have been shown to predict reading accuracy, fluency, and comprehension, long-term predictions of these skills for adolescent reading are unknown. PISA reading is an interesting outcome because, on the one hand, a wide range of skills besides decoding and reading comprehension are assumed to be needed to perform well in it, and, on the other hand, it is set up to measure the skills that are needed to meet the challenges of today’s knowledge societies (OECD, 2002).

This study addresses three questions. First, what is the effect of family-risk for dyslexia on PISA reading and its predictors when taking into account the effect of gender? Family-risk for dyslexia is expected to affect reading fluency and its cognitive prerequisites, family-risk children showing deficient skills throughout the development (e.g. Snowling & Melby-Lervåg, 2016; Torppa et al., 2010; van Bergen et al., 2010, 2012). Moreover, gender is expected to have a significant effect especially on early language (e.g. Berglund et al., 2008; Fenson et al., 1994) and school-age reading measures (e.g. Lietz, 2006, Torppa et al., 2018). Second, how well is PISA reading predicted by the two paths leading to reading comprehension: language skills on one hand, and pre-literacy skills through reading fluency at school-age, on the other hand? Based on earlier research on PISA reading (Arnbak, 2012) and reading comprehension (e.g. García & Cain, 2014; Olson et al., 2011), we expect that both paths are significant. Third, does the same predictive model for PISA reading fit to both Family-risk and No family-risk group, and furthermore, are the predictive paths similar in both groups? Similar model is expected to fit to both groups. However, as more children with deficient pre-literacy skills due to stronger genetic liability are expected to exist in the Family-risk group (e.g. Pennington & Lefly, 2001; Puolakanaho et al., 2007; Scarborough, 1990; Snowling et al., 2003; van Bergen et al., 2012), we expect both predictive paths to PISA reading to be stronger in this group.

2. MATERIAL AND METHODS

2.1. Participants

All participants (n=158) were Finnish-speaking and recruited as part of Jyväskylä Longitudinal Study of Dyslexia (JLD) (Lyytinen, et al., 2008). All parents have given their written consent to participation when they were recruited into the study. Moreover, a written consent was given by the children themselves as well in Grade 7 (age 12), when they entered the lower-secondary level. The study has been evaluated and approved by the ethics committee of the Central Finland Health Care District. Children were originally selected for one of two groups: with family-risk for dyslexia or without it. Altogether, 159 students participated in the PISA reading assessment at Grade 9, but one participant was removed owing to a serious inflammation in his central nervous system at age three, which severely affected his language skills for two years. Thus, the final group sizes in this study are: the Family-risk group (n=88, 48% boys) and the No family-risk group (n=70, 57% boys). Characteristics of the groups are presented in Table 1. There were no differences between the groups in parents' age or education, or in children's Grade 2 verbal and performance IQ or gender distribution. Moreover, no differences between the groups were found in children's age in any of the assessment time points (t = 0.145–1.52, ps > .05).

2.1.1. Family-risk: Screening of Families

The children were originally selected as participants for the JLD from among 9 368 newborns. For a child to be included in the family-risk group (n = 108), one or the other of the parents had to show deficient performance in oral text reading or spelling, and in phonological and orthographic processing. In addition, a reported onset of literacy problems during the early school years and a first-degree relative with corresponding difficulties was required for inclusion in the family-risk group. In the group without family-risk, neither parent (n = 92) had a reported family history of dyslexia and both had a z-score above -1.0 in all the reading and spelling tasks described above. The IQ of all parents had to be 80 or above (for full details of the recruitment process, see Leinonen et al., 2001).

2.1.2. Attrition

Altogether, 159 students from the original sample of 200 participants took part in the PISA reading assessment in Grade 9. Attrition in the High- and No family-risk groups, 18.5% and 22.8%, respectively, was similar. No significant differences either in early cognitive predictors before school age or in literacy skills at school age were observed between students who attended or did not attend the PISA reading assessment.

2.2. Measures

Trained testers assessed children's skills individually in a laboratory setting at age 2.0, 3.5, 5.0, 5.5, and 6.5 years, as well as in school-classes after school entry in the year the children turned 7 in Grades 1 (Spring term), 2 (Spring), 3 (Spring), 8 (Fall), and Grade 9 (Spring). In addition, children were tested at home at age 2.5 years and parents reported on their child's language skills at ages 2.0 and 2.5. To obtain comprehensive and reliable measures, we calculated composite scores (arithmetical means) for each skill domain using z-scores (with respect to the mean and standard deviation of the No family-risk group) for all the tasks in each skill domain and at each assessment. The measures used in the calculation of the composite scores are described below (for full details of measures, see Pennala et al., 2013).

Language skills. *At 2.0–2.5 years.* A composite mean (Cronbach α=0.91) was calculated from eight different measures: Mastery of Inflections, Vocabulary Production, and Mean Length of Longest Utterances from the Finnish (Lyytinen, 1999) toddler version of the MacArthur Communicative Development Inventories (MCDI) (Fenson et al., 1994) at 2.0 and 2.5 years (3 + 3 measures), and the expressive and comprehension language scale scores from the Reynell Developmental Language Scales (RDLS) (Reynell & Huntley, 1987) at 2.5 years.

At 3.5 years. A composite mean (Cronbach α=0.80) was calculated from four different measures: Peabody Picture Vocabulary Test – Revised (PPVT) (Dunn & Dunn, 1981), the subtest of Comprehension of Instructions of the Developmental Neuropsychological Assessment (NEPSY) (Korkman, Kirk, & Kemp, 1998), the Boston Naming Test (BNT) (Kaplan, Goodglass, & Weintraub, 1983), and the Mastery of Finnish Inflectional Morphology (Lyytinen et al., 2001).

At 5.0–5.5 years. A composite mean (Cronbach α=0.83) was calculated from five different measures: the four tests administered at 3.5 years were repeated, and the vocabulary scale of the WPPSI-R (Wechsler Preschool and Primary Scale of Intelligence-R; Wechsler, 1991) was added as the fifth measure.

Phonological awareness. *At 3.5 years.* The composite mean was derived from performance in three tasks (Cronbach α=0.66): from two computer-based tasks, i.e. Syllable-level Segment Identification, and Word-level Segment Identification (Puolakanaho, Poikkeus, Ahonen, Tolvanen, & Lyytinen, 2003), and from the Phonological Processing: Word Segment

Identification task of the Developmental Neuropsychological Assessment battery (NEPSY, Korkman et al., 1998). *At 5.5 years.* The composite mean of phonological awareness comprised five tasks (Cronbach α=.80): computer-based Initial Phoneme Identification and Production, and Syllable-level Segment Identification (Puolakanaho et al., 2003), Word/Pseudoword Segmentation (Pennala et al., 2013), Phonological Processing: Word Segment Identification, and Word Segment Deletion (NEPSY, Korkman et al., 1998). *At 6.5 years.* The composite mean of phonological awareness comprised five tasks (Cronbach α=.84): computer-based Initial Phoneme Identification and Production, and Phoneme and Syllable-level Segment Identification (Puolakanaho et al., 2003), Word/Pseudoword Segmentation (Pennala et al., 2013), and Initial Phoneme Naming and Initial Phoneme Deletion (Poskiparta, Niemi, & Lepola, 1994).

Rapid naming. *At 3.5, 5.5 and 6.5 years.* RAN objects was presented using the standard procedure (Denckla & Rudel, 1976). The test was scored as the time taken to name 30 items at ages 3.5 and 5.5 years and 50 items at age 6.5 years. Altogether 28 children (11 Family-risk and 17 No family-risk) were unable to finish the RAN task at 3.5 years. The measure was, however, retained in the analyses for constructing the latent factor from three measures similarly to other skills.

Letter knowledge. *At 3.5 and 5.0–5.5 years.* Four sets of uppercase letters from a total of 23 different letters were presented to the child, whose task was to name each of the letters. Testing was discontinued if the child was unable to name any of the items in a given set of 6 letters. The total number of correctly named letters was used as the measure. *At 6.5 years.* We presented all 29 letters used in Finnish and asked the children to name them. (For full details of measures, see Torppa, Poikkeus, Laakso, Eklund, &Lyytinen, 2006).

IQ. *At 8.0 years.* The Wechsler Intelligence Scale for Children – Third Edition (WISC-III, Wechsler, 1991) was administered at the age of 8 years. The scale scores of four performance quotient subtests (Picture Completion, Block Design, Object Assembly, and Coding) were used to form the performance IQ measure. Similarly, verbal IQ was calculated according to the standard guidelines given in the manual from the scale scores of five subtests: Similarities, Vocabulary, Comprehension, Series of numbers, and Arithmetic.

Reading fluency. Arithmetic means of z-scored values (with respect to the mean and standard deviation of the No family-risk group) were calculated for the composite measure of reading fluency separately for each grade (Cronbach's α was .93, .88, .91, and .88, for Grades 1, 2, 3, and 8, respectively). *Grade 1.* At the end of the spring term, two lists of individually presented words and two lists of pseudowords (altogether 36 items), and an age-appropriate text were used to assess oral reading fluency. *Grades 2, 3, and 8.* We used three oral reading tasks: A word list reading (standardized reading test (Lukilasse; Häyrinen, Serenius-Sirve, & Korkman, 1999), text reading, and pseudoword text reading. (For full details of the reading measures in Grade 1, see Pennala et al., 2010, and for those in Grades 2, 3 and 8, see Eklund et al., 2015).

PISA reading. *Grade 9.* The tasks were adopted from PISA reading link items which are used repeatedly in each cycle of the survey to ensure measurement comparability (OECD, 2010a, p. 26). The test booklet contains 8 different sections, including texts, tables, graphs, and figures. Students were given 60 minutes to read and answer several questions per section. Of the questions, 15 were multiple choice and 16 required a written response. Moreover, 12 of the questions required students to access and retrieve information, 12 to integrate and interpret information, and seven to reflect on and evaluate information. A total mean score for all the PISA reading items was calculated. Cronbach's alpha for the total score in this sample was .85.

2.3. Distributions and Analyses

The normality of distributions was inspected across all participants and separately within the two groups. Most of the distributions of the composite scores used in the analyses approximated the normal distribution. However, slightly skewed distributions were found for Rapid naming (age 3.5, 5.5 and 6.5 years), Letter knowledge (3.5 and 6.5 years), Reading fluency (Grades 1, 2, and 8), and PISA reading in Grade 9. In addition, a slightly skewed distribution was found for Phonological awareness (3.5 years) when the distributions were inspected separately within the Family-risk and the No family-risk group. Logarithmic transformations normalized the distributions in all measures except Letter knowledge at 3.5 years, which was subsequently recoded into three categories. In addition, one outlier in four measures, two outliers in four measures, and five outliers in two measures were moved to the tails of the distributions before the analyses to avoid overemphasizing their effects on the results. The rank order of the participants was retained and no participants were dropped from the sample.

Levene's homogeneity test of variances showed differences in the variances between the Family-risk and No family-risk group in Language skills (age 5–5.5 years, $F(1,156) = 7.84$, $p < .01$), Phonological awareness (5.5 years, $F(1,156) = 10.46$, $p < .001$), Letter knowledge (5–5.5 years, $F(1,156) = 8.56$, $p < .01$), and Reading fluency in Grade 1 ($F(1,155) = 16.20$, $p < .001$). In all these measures, the variance was larger in the Family-risk group.

The significance of the effects of family-risk on cognitive skills, reading fluency, and PISA reading were examined first with multivariate analysis of variance (MANCOVA) using children's gender as a covariate. Differences in these skills were further inspected with ANCOVAs, to examine at which ages the two groups differed from each other. In addition, pairwise group comparisons were conducted by calculating effect sizes (Cohen's d) using the pooled standard deviation of the two groups as the denominator.

Next, structural equation modelling (SEM) was used to examine the significance of the two predictive paths on PISA reading literacy: the direct path from early language skills and the indirect path from pre-literacy skills through reading fluency on PISA reading (see Figure 1). The Mplus 8.0 program (Muthén & Muthén, 1988–2017) was used for modelling. Factor-scores for each of the following skills were created first and imported to the Mplus program: Language 2–2.5 years, Phonological awareness 3.5–6.5 years, Letter knowledge 3.5–6.5 years, Rapid naming 3.5–6.5 years, Reading fluency Grade 1-3, Reading fluency Grade 8, and PISA reading Grade 9. Children's gender was added as a dichotomous measure, but due to non-significant association to all other measures it was dropped out from the final model. The final model (Figure 1) was constructed as follows: First, a latent factor named Pre-literacy skills was constructed from Phonological awareness, Letter knowledge, and Rapid naming. Next, the hypothesized paths were added and significance of each hypothesized predictive path was examined. Finally, the model was further developed by adding a predictive path between Rapid naming and Grade 8 Reading fluency, based on the modification indices suggested by the Mplus program. All error variances were estimated freely. Finally, the model estimates for the two groups (the Family-risk and the No family-risk group) were compared with the GROUPING option of Mplus to test whether the same predictive model was valid in both groups. The MODEL CONSTRAINT option of the Mplus was carried out to test if there was a group difference in the unstandardized estimates of the predictive paths or in the size of the PISA residual variance. Moreover, similarity of the variances of the predictors (Language skills, Phonological awareness, Letter knowledge, Rapid naming, Reading fluency) and PISA reading was tested to reveal factors that could explain possible differences in predicted variances of PISA reading in the two groups.

The parameters of the models were estimated using the maximum likelihood robust (MLR) procedure. The goodness of fit of the estimated model was evaluated using five indicators: the χ^2 test, Comparative Fit Index (CFI), Tucker-Lewis Fit Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR).

3. RESULTS

3.1. The Effect of Family-risk Group and Gender

We first compared the family risk groups in PISA reading using ANCOVA with children's gender as a covariate (see Table 2*)*. The No family-risk group outperformed the Family-risk group in PISA reading, although the effect-size between the two groups was small. Also the effect of children's gender on PISA-reading was significant with girls performing better than boys ($F(1, 157) = 11.03$, $p < .01$).

Comparisons of group means in early cognitive skills with MANCOVA using children's gender as covariate showed that the No family-risk group outperformed the Family-risk children in Language skills, Phonological awareness, Rapid naming, and Letter knowledge. The effect-sizes were small in the earliest assessment points (2.0–3.5 years), but increased to being moderate in the two latter assessment points before school-age, i.e. 5.0–5.5 and 6.5 years. Gender had a significant effect on Language skills ($F(3, 150) = 4.90$, $p < .01$) with girls outperforming boys. In addition, close to significant effects of gender in favor of girls were found in before school-age Phonological awareness ($F(1, 149) = 2.50$, $p < .07$) and Rapid naming skills ($F(1, 123) = 2.48$, $p < .07$). No effect of gender was found in Letter knowledge before school-age.

Comparisons of group means in reading fluency with MANCOVA using children's gender as covariate showed that children in the No family-risk group read more fluently than children with family-risk throughout grades 1 to 8. Effect-sizes varied between moderate to high, being largest soon after the beginning of children's school-career, i.e. at the end of Grade 1. In addition, the main effect of gender was also significant ($F(4, 141) = 2.54$, $p < .05$). However, further inspection of the effect of gender with ANOVAs failed to reach statistical significance at any of the grades.

3.2. Prediction of PISA Reading

The correlations between the cognitive predictors, reading fluency and PISA reading are presented separately for the two groups (Family-risk and No family-risk) in Table 3. Concerning the prediction of PISA reading, the associations between the predictors and PISA reading are of special interest. Among family-risk children, all cognitive measures from all assessment ages before school-age as well as all reading fluency measures at school-age were significantly associated with PISA reading: better cognitive skills predicted better performance in PISA reading. Also in the No family-risk group significant positive associations were found from all assessed cognitive skills and reading fluency to PISA reading. However, within each skill the earliest assessed measure was not significantly associated to PISA reading in the No family-risk group. According to Fisher's z-transformed difference test, the correlations between PISA reading and Language skills 2–2.5 and 3.5 years, Phonological awareness 3.5 years, and Letter knowledge 3.5 years were significantly lower in the No family-risk group than in the Family risk group.

Next, a structural equation model was constructed to test the significance of the predictive paths to PISA reading. All participants were included in the first model, which fitted well the data according to the fit-indices (see Figure 1). The model explained altogether 60% of the variance in PISA reading. Language skills before school-age explained directly 46% of the variance in PISA reading. In addition, it explained indirectly through Pre-literary skills and Reading fluency in Grade 1-3 and Grade 8 an additional 6%. The rest of the explained variance in PISA reading (8%) was explained by Pre-literacy skills (Phonological awareness, Letter knowledge, and Rapid naming) through Reading fluency in Grade 1-3 and

Grade 8. Rapid naming had a significant effect on PISA reading through two separate paths: first, as part of the pre-literacy skills, and, second, through a specific path via Grade 8 reading fluency.

Next, the model estimates were calculated for the Family-risk and No family-risk group (see Table 4). The model explained 68% and 44%, of PISA reading in the Family-risk and No family-risk group, respectively. Language skills was the most potent predictor of PISA reading in both groups explaining 53% and 31% of PISA reading in the Family-risk and No family-risk group, respectively. Pre-literacy skills via reading fluency explained additional 15% and 13% of the PISA reading variance. Next, we tested whether the estimates of the predictive paths differed significantly from each other in the two groups. The results showed that none of the path estimates was statistically different between the two groups. Moreover, the size of the residual variance of PISA reading did not differ in the two groups, either. Comparisons of the variances of the predictors showed that the only significant difference was found in Language skills, in which the variance was larger in the Family-risk group ($p < .05$).

4. DISCUSSION

This study examined early predictors (from age 2 onwards) of PISA reading measured at 15 years of age. Based on previous studies we expected to identify two predictive paths: a direct path from language skills and an indirect path from the pre-literacy skills (phonological awareness, rapid naming, and letter knowledge) through school-age reading fluency to PISA reading. We included two samples of children, one with and the other without family-risk for reading difficulties to investigate the effect of family risk on reading development. The effect of gender was examined in all analyses. Children with family-risk scored significantly poorer than children with no family-risk in all measures of language and pre-literacy skills before school age, as well as in all measures of reading fluency in grades 1-8, and PISA reading in Grade 9. However, a similar model predicting PISA reading fitted the data well in the Family-risk and the No family-risk group. Language skills explained a good portion of the variance in PISA reading in both groups. Moreover, pre-literacy skills explained a significant portion of the variance in PISA reading through reading fluency in both groups, but to a lesser extent than language skills. Altogether 68% of the variance in PISA reading was explained in the Family-risk group in contrast to the 44% in the No family-risk group. Although girls slightly outperformed boys in language skills, reading fluency and PISA-reading, gender effect was not significant in the predictive models.

4.1. Family-risk Group Differences in Cognitive Skills, Reading Fluency and PISA Reading

In line with our hypothesis, we found salient differences between the Family-risk and the No family-risk group in favor of the latter in all cognitive skills assessed before school age. Children with family-risk for dyslexia have been shown to have delayed development in pre-literacy skills (phonological awareness, rapid naming, and letter knowledge), as well as in language skills (articulation, vocabulary knowledge, and grammar) (for a review, see Snowling & Melby-Lervåg, 2016, see also Torppa et al., 2010 for group differences in Finnish). Our results thus support earlier findings suggesting high vulnerability for family-risk children. Not surprisingly, Family-risk group children showed also poorer reading fluency than the No family-risk group children did, especially during the first grade, but also later on in grades 2, 3 and 8. Slower acquisition of reading fluency was expected, as a large proportion (36%) of the participants with family-risk for dyslexia had encountered reading difficulties by the end of Grade 2 (Puolakanaho et al., 2007). For family-risk children, the risk for dyslexia has been reported to range from four to tenfold depending on the criteria applied (e.g., Puolakanaho et al., 2007; van Bergen et al., 2012). In addition, their compromised reading skills tend to be persistent (Eklund et al., 2015; Landerl & Wimmer, 2008), although a subgroup of the present sample has been shown to be able to resolve from early difficulties (Torppa et al., 2015).

While the family-risk children were expected to show poorer skills in language and pre-literacy skills as well as reading fluency, expectations for PISA reading performance were less self-evident. Children with family-risk for dyslexia can be expected to show deficient performance in word reading, which will not, however, necessarily lead to poor reading comprehension (Catts et al., 2006; Nation et al., 2004; Torppa et al., 2007). In line with this, also in the present sample family-risk has been previously shown to be linked to grade 1 and 2 reading comprehension difficulties, but only when accompanied by reading fluency difficulties (Torppa et al., 2007). In the current study, the Family-risk group scored lower in PISA reading compared to the No family-risk, but the effect size was smaller than for reading fluency. Previously, English-speaking family-risk children with reading disability have been shown to have somewhat poorer reading comprehension skills at adolescence, 12-13 years of age, whereas reading comprehension skills of the unimpaired family-risk children were at the level of children without family-risk (Snowling et al., 2007). In our study, pooling these two family-risk groups together resulted in a small difference between the Family-risk and No family risk group, which fits well to the previous findings. The small difference could also suggest that a portion of slow readers can develop good reading comprehension skills (Torppa et al., 2007). The difference in PISA reading between the two groups also reflects the impaired language skills of family-risk children. This is in line with the generalist genes hypothesis (Kovacs & Plomin, 2007; Plomin & Kovacs, 2005) and the Multiple deficit model of dyslexia (Pennington, 2006; van Bergen et al., 2014) which state that family-risk children would show broad signs of deficiencies, including language skills.

4.2. Prediction of PISA Reading

The two separate skills related to the two cornerstones of reading comprehension stated by both the lexical quality hypothesis (Perfetti & Hart, 2001) and the Simple View of Reading (Gough & Tunmer, 1986), namely language skills and reading fluency (decoding efficiency), turned out to explain a large proportion of variability in PISA reading, too. Language skills before school-age explained both directly and indirectly a large portion of PISA reading, whereas the effect of pre-literacy skills was indirect through reading fluency at school-age and small in magnitude. This is in line with the earlier finding of Arnbak (2012), showing that concurrently measured vocabulary and word recognition together explained approximately 40% of the variance in PISA reading. Moreover, in spite of the long time gap in our study between the predictors and outcome, approximately 10 years, the portions of explained variances were similar to those found by Arnbak (2012). When groups were pooled together, 46% and 8% of PISA reading variance was predicted by language skills and reading fluency, respectively, in our study compared to 36% and 4%, by vocabulary and word recognition skills, respectively, in the Arnbak (2012) study. However, our study extends Arnbak's finding by predicting PISA reading with language skills assessed already before school age, and including the various precursors of reading fluency.

Despite the similar predictive model in the two groups, the amount of explained variance in PISA reading varied according to the presence of family-risk of dyslexia, 68% in contrast to 44% in the Family-risk and the No family-risk group, respectively. Although not a statistically significant difference, it is noteworthy that this difference was comparable in magnitude to the difference between the groups in explained variance by language skills

(53% vs. 31%, the Family-risk and the No family-risk group, respectively). In the Family-risk group, there was also a larger variance in the latent factor of language skills than in the No-family-risk group. Increased variability has previously been observed in family-risk children in reading accuracy and fluency (e.g. Eklund et al., 2015, Snowling et al., 2003) as well as language skills (see Snowling & Melby-Lervåg, 2016, for review). Large variability is in line with the ideas of the Multiple deficit model of dyslexia (Pennington, 2006; van Bergen et al., 2014), in which various inherited risk factors are, at the individual level, expected to be expressed in various amounts of compromised language skills, pre-literacy skills, or their combinations. Some children with family-risk of dyslexia thus express broad language-difficulties as infants and toddlers in this sample as well as in other Family risk samples (see Snowling & Melby-Lervåg, 2016, for review). Our findings show that these difficulties can have long-term effects on reading skills of these children. The lower skill level and strong associations between the earliest (2–3.5 years) measures of language skills, phonological awareness, and letter knowledge to PISA reading in the Family-risk group suggests that genetic vulnerability among these children is identifiable already early in development. This is promising in terms of early identification of children in need of support for their language and literacy development.

No difference was found between the groups in the amount of explained variance in PISA reading by pre-literacy skills, 15% and 13% in the Family-risk and No family-risk group, respectively. However, rapid naming had an additional indirect effect on PISA reading through Grade 8 reading fluency, but only in the Family-risk group. The effect of rapid naming on grade 8 reading fluency was not surprising as the impact of rapid naming on reading fluency increases along with reading skill development (Kirby, Parrila, & Pfeiffer, 2003; Vaessen et al., 2010). In the present sample, the effect was significant only for the family risk group which fits to our previous findings on late-emerging dyslexia. Rapid naming was the key characteristic of children with late-emerging dyslexia, i.e., children whose reading fluency falls behind classmates between grades 2 and 8, 83% of whom were from the Family-risk group (Torppa et al., 2015). These children also had parents with very slow rapid naming which suggests intergenerational transmission of slow rapid naming and hence slow reading among these families.

4.3. The Effect of Gender

Gender comparison before school age yielded a statistically significant difference in language skills in favor of girls whereas differences in pre-reading skills fell short of significance. This is in line with earlier findings of a slight advantage for girls especially in the early phase of language development (e.g. Berglund et al., 2008; Fenson et al., 1994). In contrast to our expectations, the effect of gender on reading fluency was vague: although the main effect of gender reached statistical significance, none of single comparisons in different grades did so. More males than females with reading problems have usually been reported both in clinical and in research samples (Hawke et al., 2009; Quinn & Wagner, 2015; Rutter et al., 2004). Moreover, in a recent study of Finnish-speaking mainstream ninth graders, Torppa and colleagues (2018) found that girls outperformed boys in reading fluency. On the other hand, also some other previous studies have shown no or small gender differences in reading (e.g. Below, Skinner, Fearrington, & Sorrel, 2010) or found differences only in reading comprehension, not in reading fluency (Leppänen, Aunola, Niemi, & Nurmi, 2008).

A significant gender effect in favor of girls was found also in PISA reading, although the effect size was small. The poor performance of boys is in line with earlier findings of gender differences in PISA reading performance, where girls outperformed boys in every OECD country in the recent 2009, 2012, and 2015 assessments, and more boys scored at the lowest reading proficiency level (OECD, 2011, 2013, 2016). Poor performance of boys in PISA reading in the present study can be due to their compromised language skills. Language skills have generally been seen as one of the cornerstones of reading comprehension (Perfetti & Hart, 2001), and they have also been shown to explain a large portion of PISA reading literacy (Arnbak, 2012). Slightly compromised reading fluency, another important factor explaining success in PISA reading tasks (Arnbak, 2012; Artelt et al., 2001), could stand as an additional explanation for the poor performance of boys (Torppa et al., 2018).

As no measures other than cognitive skills and reading fluency were available in the present study, the possible effects of other factors such as school engagement and reading activity on PISA reading literacy, remain unclear. Girls have reported to be more engaged in school and to receive more support from teachers, and this engagement has been found to partially mediate the effects of gender and teacher support on girls' academic performance (Lam et al., 2012). In addition, according to the PISA 2009 results, reading engagement and reading for enjoyment was higher for girls than boys in all the European countries (OECD, 2010b; Sulkunen, 2013), suggesting self-generated opportunities to practice reading skills, as proposed by Guthrie and Wigfield (2000). However, a recent study by Torppa and colleagues (2018) showed that although mastery orientation, leisure book reading and homework activity are concurrent predictors of PISA reading over and above reading fluency, they do not explain gender difference.

4.4. Strengths and Limitations

The strengths of the present study are the exceptionally long follow-up period and the uniqueness of participant sample. Covering an important formative period during the pre-school age, the former makes it possible to delineate how important the early language and reading-related skills are as predictors before formal teaching of literacy has begun to exert an effect. Together with the second strength, the pre-selected group of children with family-risk for dyslexia participating, the study is the first to shed light on the question of how deterministic the literacy development is when the assets are constrained from the very start. The major limitation is dictated by the strengths. Recruiting about 100 families that are enough burdened by reading disability required initial contact with about 10,000 unselected families. This and the fact that follow-up sessions must be conducted individually led to rather small participant samples, thus precluding more detailed and powerful multivariate analyses which are common practice in longitudinal studies of larger unselected samples. A further limitation is the absence of measures tapping the early development of listening comprehension skills which have a well-known impact on reading comprehension skills later in school (e.g. Lepola, Kiuru, Lynch, Laakkonen, & Niemi, 2016; Verhoeven & van Leeuwe, 2008).

4.5. Conclusions

To conclude, we stress the importance of taking family-risk for dyslexia seriously as a strong risk marker of problematic reading development, particularly when it is combined with difficulties in early language and cognitive development. A rather deterministic picture of development for children with family-risk for dyslexia emerged, as no less than 68% of the variance in PISA reading literacy was explained by language and pre-literacy skills measured before school age. This does not mean, however, that all family-risk children will fall behind the typical development of cognition starting from the early years of life. Instead, our results suggest that family-risk children who show poor cognitive skills in their early development and are thus likely to show poor literacy skills in adolescence, are relatively easy to identify. Special emphasis should be placed on enhancing their language and pre-literacy skills, as these play a crucial role in their later literacy development. We have previously shown that when family-risk status, phonological awareness, rapid naming, and letter knowledge are known, we can reliably estimate individual risk for reading disability (accuracy and fluency) in Grade 2 (Puolakanaho et al.,2007). Based on the present results, we suggest that language skills also need to be considered if we want to predict reading ability in adolescence.

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Table 1. Characteristics of Parents and Their Children in the Family-risk and No family-risk Group.

	Group				
	Family-risk (*n* = 88)		No family-risk (*n* = 70)		
	M	*SD*	*M*	*SD*	*t(154-156)*
Parents					
Mother's Age	29.41	4.45	30.06	4.18	-0.93
Mother's Education[a]	4.23	1.48	4.61	1.32	-1.71
Father's Age	31.85	5.40	33.19	5.19	-1.57
Father's Education[a]	3.66	1.28	3.70	1.39	-0.21
Children					
Verbal IQ[b]	98.73	12.00	102.04	11.28	-1.76
Performance IQ[b]	99.31	13.07	102.37	14.64	-1.38

[a)] Parental education was classified using a 7-point scale: 1 = only comprehensive school (CS); 2 = CS and short-term vocational courses; 3 = CS and a vocational school degree; 4 = CS and a vocational college degree; 5 = CS and a lower university degree / a polytechnic degree; 6 = upper secondary general school and a lower university degree / a polytechnic degree; 7 = CS or upper secondary general school and a higher university degree (Master's or Doctorate-level degree).

[b)] Children's verbal and performance IQ was estimated using the Wechsler Intelligence Scale for Children—Third Edition (WISC—III; Wechsler, 1991).

Table 2. Means, Standard Deviations and Group Comparisons in Early Cognitive Skills, Reading Fluency and PISA Reading Using Children's Gender as Covariate

	Group					
	Family-risk (n = 76-88)		No family-risk (n = 52-70)			
	M	*SD*	*M*	*SD*	F(3,123-155)[a]	Effect size[b]
Language skills					3.61 *	
2.0 – 2.5 years	-0.17	0.79	0.06	0.82	2.56 *	.29
3.5 years	-0.29	0.82	0.04	0.76	4.83 **	.42
5.0 – 5.5 years	-0.34	0.96	0.07	0.67	7.14 **	.50
Phonological awareness					4.56 **	
3.5 years	-0.30	0.81	-0.00	0.78	5.40 *	.38
5.5 years	-0.40	0.97	0.04	0.65	11.18 **	.53
6.5 years	-0.33	0.93	0.08	0.74	10.06 **	.49
Rapid naming					3.00 *	
3.5 years	0.05	0.85	-0.06	0.97	0.37	.12
5.0 – 5.5 years	-0.61	1.65	0.09	0.87	5.98 *	.53
6.5 years	-0.47	1.64	0.20	0.76	7.24 **	.52
Letter knowledge					5.15 **	
3.5 years	-0.15	0.84	0.06	1.00	4.51 **	.23
5.0 – 5.5 years	-0.39	1.07	0.24	0.82	12.81 ***	.66
6.5 years	-0.48	1.14	0.27	0.72	15.34 ***	.79
Reading fluency					6.35 ***	

Grade 1, spring	-0.93	1.58	0.17	0.79	25.38 ***	.88
Grade 2, spring	-0.48	1.41	0.11	0.91	15.68 ***	.50
Grade 3, spring	-0.41	0.92	0.13	0.93	11.74 ***	.58
Grade 8, fall	-0.51	1.01	-0.02	0.83	9.82 **	.53
PISA reading						
Grade 9	-0.05	0.91	0.18	0.92	5.13 *	.25

* $p < .05$, ** $p < .01$, *** $p < .001$

Note. All means reported in z-scores calculated using the mean and standard deviation of the No family-risk group.

[a] Degrees of freedom varied due to different amount of missing data in different measures.

[b] Effect sizes were estimated with Cohen's *d* computed using pooled standard deviation.

Table 3. Correlations of Early Cognitive Skills, Reading Fluency and PISA Reading in the Family-risk (above diagonal) and the No family-risk Group (below diagonal).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
1. Language skills, 2–2.5 years		.70***	.64***	.26*	.42***	.39***	-.27*	-.18	-.29**	.19	.33**	.30**	.14	.06	.11	.07	.58***
2. Language skills, 3.5 years	.35**		.78***	.41***	.45***	.52***	-.32**	-.19	-.33**	.23*	.44***	.44***	.15	.07	.14	.08	.62***
3. Language skills, 5.0–5.5 years	.36**	.72***		.42***	.59***	.56***	-.34**	-.33**	-.44***	.28*	.47***	.45***	.21*	.13	.17	.13	.58***
4. Phonological awareness, 3.5 years	.18	.36**	.36**		.30*	.35**	-.33*	.01	-.15	.15	.34**	.30**	.07	.03	.10	.08	.40***
5. Phonological awareness, 5.5 years	.45***	.43***	.38**	.26*		.78***	-.31**	-.29**	-.39***	.44***	.66***	.68***	.47***	.43***	.37***	.30**	.50***
6. Phonological awareness, 6.5 years	.40***	.31*	.45***	.24	.69***		-.41***	-.25*	-.38***	.40***	.65***	.72***	.47***	.40***	.35**	.30**	.52***
7. Rapid naming, 3.5 years	-.14	-.14	-.26	-.09	-.17	-.06		.46***	.51***	-.36**	-.38***	-.39***	-.11	-.10	-.19	-.22	-.30**
8. Rapid naming, 5.0–5.5 years	-.03	-.14	-.19	-.20	-.32**	-.25*	.32*		.66***	-.39***	-.37***	-.35***	-.27*	-.30**	-.38***	-.49***	-.30**
9. Rapid naming, 6.5 years	-.05	-.12	-.32**	-.30*	-.22	-.23	.32*	.56***		-.40***	-.49***	-.48***	-.30**	-.37***	-.44***	-.45***	-.37***
10. Letter knowledge, 3.5 years	.29*	.20	.16	.31*	.22	.18	-.07	-.18	-.20		.54***	.50***	.44***	.42***	.41***	.41***	.46***
11. Letter knowledge, 5.0–5.5 years	.29*	.24*	.40***	.33**	.55***	.69***	-.32*	-.35**	-.40***	.44***		.86***	.53***	.46***	.43***	.46***	.43***
12. Letter knowledge, 6.5 years	.32**	.23	.39***	.35**	.61***	.78***	-.22	-.32**	-.40***	.37**	.83***		.52***	.54***	.50***	.48***	.47***
13. Reading fluency, Grade 1	.11	.21	.12	.27*	.40***	.52***	-.15	-.17	-.38**	.23	.58***	.58***		.73***	.64***	.53***	.29**
14. Reading fluency, Grade 2	.08	.12	.21	.19	.21	.40***	-.17	-.15	-.37**	.20	.54***	.47***	.84***		.87***	.73***	.23*
15. Reading fluency, Grade 3	.12	.12	.18	.08	.14	.33**	-.15	-.12	-.35**	.18	.41***	.39**	.74***	.89***		.87***	.40***
16. Reading fluency, Grade 8	.16	.09	.14	.10	.12	.25*	-.04	-.11	-.37**	.09	.27*	.26*	.53***	.72***	.76***		.38***
17. Pisa reading, Grade 9	.15	.31**	.47***	.14	.31**	.35**	-.08	-.24*	-.37**	.01	.24*	.34*	.21	.32***	.31**	.30**	

* $p < .05$, ** $p < .01$, *** $p < .001$

Note. Number of participants varies between 77-88 and 53-70, in the Family-risk and No family-risk group, respectively, due to missing values in single measures.

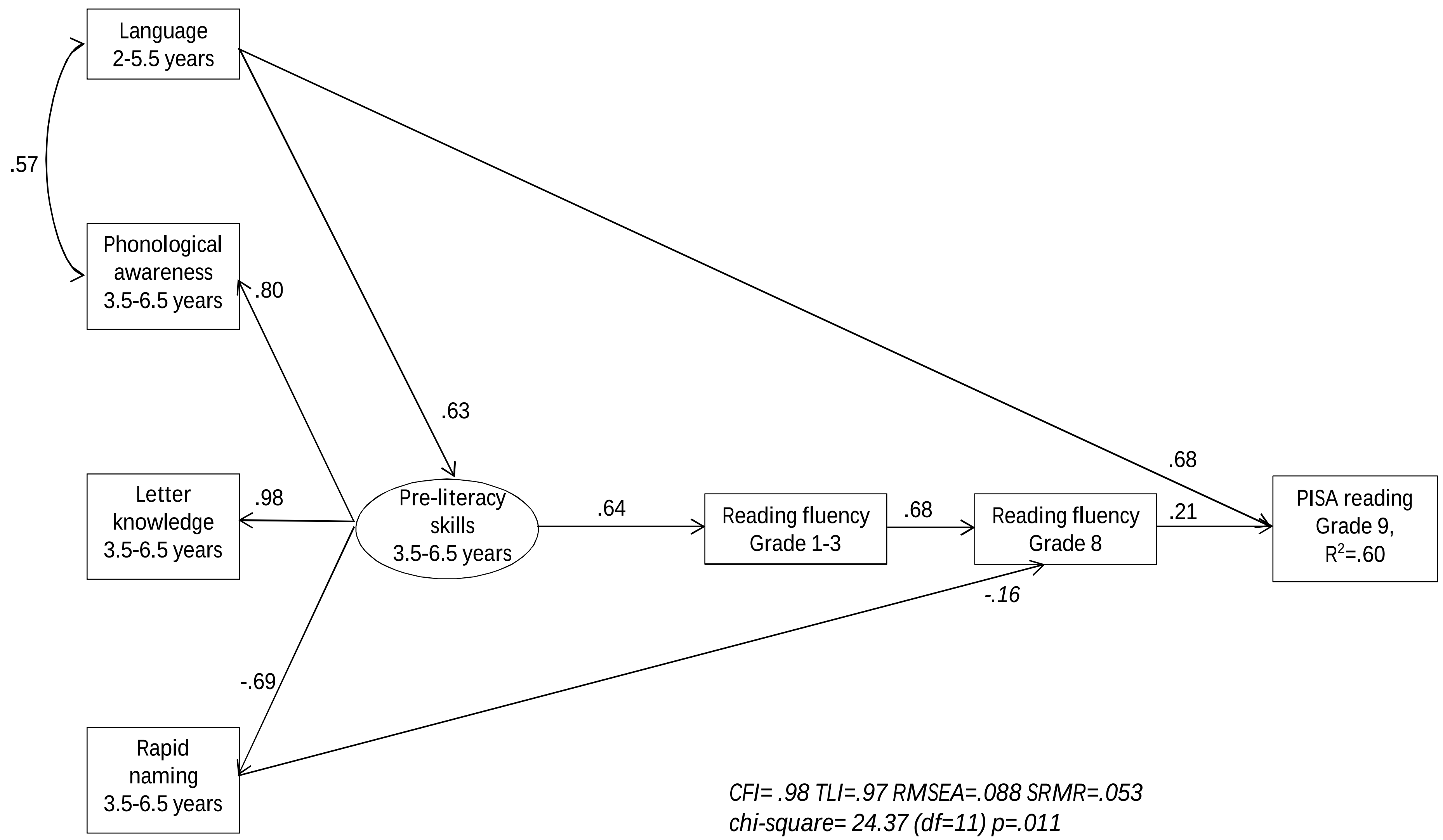

Figure 1. Structural equation model for the prediction of PISA reading literacy.

Note: Children in the Family-risk and the No family-risk group pooled together (N=158). All significant paths with standardized estimates of the loadings are presented. Loadings separately for the Family-risk and the No family-risk group are presented in Table 4.

Table 4. Factor Loadings for the PISA Reading Literacy Prediction Model (see Figure 1) separately for the Family-risk and the No Family-risk Group.

	Group			
	Family-risk (n = 88)		No family-risk (n = 70)	
Path	*Loading*	*SE*	*Loading*	*SE*
Language skills, 2–5.5 years ON				
Pre-literacy skills, 3.5–6.5 years	.64***	.06	.57***	.09
PISA reading, Grade 9	.73***	.06	.56***	.09
Pre-literacy skills 3.5–6.5 years ON				
Reading fluency, Grade 1-3	.61***	.09	.61***	.10
Reading fluency, Grade 1-3 ON				
Reading fluency, Grade 8	.67***	.07	.70***	.05
Rapid naming, 3.5–6.5 years ON				
Reading fluency, Grade 8	-.21**	.07	-.05	.08
Reading fluency, Grade 8 ON				
PISA reading, Grade 9	.21**	.07	.23*	.12
PISA reading	R^2=.68***		R^2=.44***	

* $p < .05$, ** $p < .01$, *** $p < .001$