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Research Article

Delayed Early Vocabulary Development in Children at Family Risk of Dyslexia

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Purpose: This study aimed to gain more insight into the relation between vocabulary and reading acquisition by examining early growth trajectories in the vocabulary of children at family risk (FR) of dyslexia longitudinally.
Method: The sample included 212 children from the Dutch Dyslexia Program with and without an FR. Parents reported on their children's receptive and expressive vocabulary size at ages 17, 23, 29, and 35 months using the Dutch MacArthur Communicative Development Inventories. Dyslexia status at the end of Grade 2 (8 years) rendered 3 groups: FR-dyslexic (*n* = 51), FR-nondyslexic (*n* = 92), and typically developing–nondyslexic (TD) children (*n* = 69).
Results: Repeated measures analyses showed that FR-dyslexic children had lower receptive vocabulary scores from 23 months onward and lower expressive scores from 17 months onward than FR-nondyslexic children. Latent growth curve modeling showed lower initial growth rates in FR-dyslexic children, followed by partial recovery, indicating a delayed increase in receptive and expressive vocabulary. FR-nondyslexic and TD children did not differ.
Conclusions: Early deficits in receptive and expressive vocabulary are associated with later reading. Early vocabulary growth of FR-dyslexic children is characterized by a delay but not deviance of growth. Vocabulary can be considered an additional risk factor for dyslexia.

Vocabulary is a fundamental part of the development of (early) language skills. It is proposed to be a prerequisite for the emergence of higher-order language skills such as grammar and morphological awareness (e.g., Bates & Goodman, 2001; Torppa, Lyytinen, Erskine, Eklund, & Lyytinen, 2010). Vocabulary is also believed to influence word reading acquisition through its effects on literacy-related abilities such as phonological awareness, phonological memory, and the acquisition of letter knowledge (e.g., Bates & Goodman, 2001; Lee, 2011; Metsala, 1999; Metsala & Walley, 1998; Nation & Snowling, 2004; Share, 1995; Torppa et al., 2010). In the current study, we focused on the role of early vocabulary development in later word reading ability; particularly, we examined differences in vocabulary development between children at family risk (FR) of dyslexia who did or did not go on to become dyslexic.

Dyslexia is a developmental learning disability characterized by severe and persistent reading and/or spelling difficulties at word level (e.g., Vellutino, Fletcher, Snowling, & Scanlon, 2004). Dyslexia has been found to be highly heritable and to run in families (Snowling & Melby-Lervåg, 2016; van Bergen, van der Leij, & de Jong, 2014). Deficits in phonological processing are generally assumed to lie at the core of dyslexia (de Jong & van der Leij, 2003; Vellutino et al., 2004). Impairments in phonological awareness (i.e., detection and manipulation of speech sounds; Snowling, 2001) are especially thought to hamper reading acquisition. Although it is still debated what underlies this phonological deficit, several theories link early vocabulary growth to (impairments in) the development of phonological skills and later literacy difficulties.

At least two prominent theories predict a relation between early vocabulary development and later word reading ability. The lexical restructuring theory (LRT; e.g., Metsala & Walley, 1998) proposes that vocabulary growth is instrumental in the development of phonological awareness through phonological representations. As new words are added to the mental lexicon of a child and neighborhood density increases, segmental restructuring of lexical items occurs, resulting in more detailed phonological representations

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(Metsala, 1999). These fine-grained phonological representations facilitate a child's discrimination between words with a similar sound and store them in a more discernable form in long-term memory (Metsala, 1999). According to the LRT, the phonological problems associated with dyslexia would result from impaired or delayed growth in early vocabulary. The segmentation theory (e.g., Boada & Pennington, 2006) proposes auditory perception/speech processing as the foundation of later phonological skills and word reading ability, instead of vocabulary growth. As phonological representations become more detailed through a process of increasing segmentation of speech sounds, phonological awareness emerges, also enabling vocabulary growth. In line with this theory, delays or deviations in speech sound segmentation form the basis of the (linguistic) problems generally associated with the development of dyslexia. The segmentation problems negatively affect the quality of the phonological representations, leading to significant differences in phonological awareness and vocabulary growth (Boada & Pennington, 2006).

Although both theories are similar in many respects and become increasingly intertwined during development because of the reciprocal relation between vocabulary and phonological skills, there are some important nuances. First, they ascribe a different role/position to vocabulary growth in the development of phonological awareness and later reading. Second, they propose a different implied causality in the relationship between vocabulary growth and emerging phonological awareness. LRT explicitly proposes that more detailed/segmented phonological representations are constructed because of vocabulary growth. In contrast, segmentation theory suggests that vocabulary growth may be more dependent on the quality of the phonological representations as based on speech segmentation skills. Furthermore, LRT suggests that vocabulary growth has a strong effect on the emergence of phonological awareness during development, whereas segmentation theory interprets *both* vocabulary growth and the emergence of phonological awareness to be outcomes associated with speech sound segmentation. Consequently, both theories have their own implications for expected differences in early vocabulary development and its association with later reading outcome. As lexical restructuring is assumed to take place as vocabulary size increases, which may extend across childhood and vary in intensity between developmental phases (Metsala, Stavrinos, & Walley, 2009; Rispens & Baker, 2012), differences may emerge or become more pronounced only as development progresses. On the other hand, segmentation theory assumes impairments to be present from the onset of vocabulary development onward. Here, we investigated possible differences in vocabulary development in the context of an FR study.

FR studies, especially those that are longitudinal and start at an early age, are well suited to test and further specify risk factors of dyslexia. Children who are at FR of dyslexia have a first degree relative (parent or sibling) with severe and persistent literacy problems. Children with FR are expected to have both a higher genetic and environmental liability to develop dyslexia than children without an FR (Pennington, 2006; van Bergen, de Jong, Maassen, & van der Leij, 2014). FR studies provide more insight into precursors of literacy difficulties and thereby enable early identification and intervention. Research has shown that children at FR of dyslexia may vary from typically developing (TD) children in reading-related cognitive skills, such as language development, from a very young age (Snowling & Melby-Lervåg, 2016). Within the FR group, a further distinction can be made between FR children who do (FR-dyslexic) and do not (FR-nondyslexic) succumb to literacy problems. For example, previous research has shown that FR-nondyslexic children may show mild impairments in literacy and underlying skills, such as phonological awareness (e.g., van Bergen, de Jong, Maassen, & van der Leij, 2014), which is illustrated by a stepwise pattern of performance (i.e., FR-dyslexic < FR-nondyslexic < TD control; e.g., Moll, Loff, & Snowling, 2013). As such, this distinction between both FR groups provides the opportunity to determine to what extent the relation between a cognitive skill and word reading ability is associated with FR status and/or with later literacy outcome (hereafter dyslexia status).

FR studies focusing on (the predictive value of) general language development in the preschool years (i.e., 4 to 7 years; e.g., Carroll, Mundy, & Cunningham, 2014; Snowling, Gallagher, & Frith, 2003) have shown that poor early language skills are associated with later literacy impairments in FR children. Several FR studies have focused on vocabulary development in an even younger age group (i.e., range, 14–31 months) using *MacArthur Communicative Development Inventories* (CDI) parent reports, which were also used in the current study (i.e., Aro, Eklund, Nurmi, & Poikkeus, 2012; de Bree, Zamuner, & Wijnen, 2014; Kerkhoff, de Bree, de Klerk, & Wijnen, 2013; Koster et al., 2005; Lyytinen et al., 2004; von Koss Torkildsen, Syversen, Simonsen, Moen, & Lindgren, 2007). Although all studies show that TD children had higher vocabulary scores than FR children, only one study found significant differences for receptive vocabulary (i.e., at 18 months; Kerkhoff et al., 2013) and one for expressive vocabulary (i.e., at 17 months; Koster et al., 2005). The nonsignificant results are possibly due to the relatively small sample sizes and associated lack of power in most of these studies. Moreover, the FR groups in these studies may show large differences in the percentages of children who later become dyslexic. If early vocabulary deficits are found only in FR-dyslexic children, these children may form the minority of the FR group, which affects the found effect sizes (see Snowling & Melby- Lervåg, 2016, for an overview of FR studies and effect sizes). Thus, the role of early vocabulary in the etiology of dyslexia has remained equivocal based on FR-only studies.

So far, only a few studies have focused on early vocabulary while discerning children with an FR who do and do not go on to become dyslexic. Scarborough (1990) found that impairments in both receptive and expressive vocabulary in FR-dyslexic children emerge at 42 months. Torppa et al. (2010) showed that differences were already attested at a younger age: Vocabulary production differentiated FR-dyslexic children from FR-nondyslexic and control children from the age of 2 years onward. Using a continuous approach to reading, Duff, Reen, Plunkett, and Nation (2015) found that the relation between vocabulary (at ages 16–24 months) and word reading ability (at ages 4–9 years) remains significant after controlling for FR status. This finding illustrates the importance of taking both children's FR status and dyslexia status into account when investigating the role of early risk factors.

Overall, the results of these studies suggest that vocabulary is mainly related to later reading outcome, as early deficits were found only in FR children who became dyslexic. However, some issues remain unresolved. The ages at which deficits in the FR-dyslexic group could be identified varied across the studies mentioned above. In addition, it is unclear whether the deficits that were found were persistent or might have been resolved at later ages closer to school entry. Moreover, although these studies are longitudinal, they did not focus on vocabulary *development*, which was often restrained because of the use of different instruments between time points. To gain more insight into vocabulary development, we examined growth trajectories in groups of FR children with and without dyslexia and a group of typical readers without an FR.

Studies on TD children suggest that vocabulary development is not (entirely) linear during infancy and toddlerhood (i.e., 0–4 years; e.g., Fenson et al., 1994; Hamilton, Plunkett, & Schafer, 2000; Kauschke & Hofmeister, 2002). For example, a sudden and rapid increase in vocabulary size during the second year of life (Bates & Goodman, 2001), the vocabulary spurt, has been regularly observed. The exact pattern of growth and acceleration is still debated (e.g., see Goldfield & Reznick, 1990; Mervis & Bertrand, 1995) and might depend on whether receptive or expressive vocabulary is involved and the time span that is covered. Fenson et al. (1994), using parent reports, have demonstrated that receptive vocabulary shows a linear increase in American children between the ages of 8 and 28 months, whereas expressive vocabulary shows a more exponential increase toward the end of the second year. These results have been replicated by Hamilton et al. (2000) in British children between the ages of 12 and 25 months. A German study by Kauschke and Hofmeister (2002), using spontaneous speech at 13, 15, 21, and 36 months, showed that the exponential increase in expressive vocabulary toward the end of the second year is followed by a further expansion but with a decreased growth rate in the third year. Based on these studies, a vocabulary spurt and subsequent deceleration can be expected for expressive vocabulary, whereas receptive vocabulary seems to grow more gradually. However, information about atypically developing populations is scarce.

In sum, we examined differences in early vocabulary development among FR-dyslexic children, FR-nondyslexic children, and TD children without an FR. Growth of early receptive and expressive vocabulary was measured longitudinally on four occasions between the ages of 17 and 35 months using CDI (Fenson et al., 1994) parent reports. Both expressive and receptive vocabulary were taken into account to get a better overview of the extent/depth of possible impairments and increase possibilities for early identification and intervention. The first aim of the study was to determine whether receptive and expressive vocabulary are associated with children's FR status and/or dyslexia status (risk versus reading). The second aim was to examine whether and/or how the growth rates of FR-dyslexic children might differ from FR-nondyslexic children and/or TD control children (delay versus deviance of growth).

Although LRT and segmentation theory were not specifically framed for the context of FR studies, expectations for both groups of FR children can be deduced from these language models. For FR-dyslexic children, impairments in vocabulary development would be expected based on both LRT and segmentation theory. However, LRT would predict more severe impairments than segmentation theory: The consequence of poor lexical restructuring is poor phoneme awareness, which is a core deficit associated with dyslexia. Furthermore, for FR-nondyslexic children, mild impairments would be anticipated according to LRT. Previous studies reported stepwise patterns (i.e., FR-dyslexic < FR-nondyslexic < TD control) for phonological awareness and later reading (e.g., Moll et al., 2013; van Bergen, de Jong, Maassen, & van der Leij, 2014). This pattern would also be expected to surface for the assumed catalyst of phoneme awareness, early vocabulary. This stepwise pattern might be present from the outset or emerge during development (e.g., Metsala & Walley, 1998). However, as speech sound segmentation is thought to be impaired only in children who later become dyslexic (e.g., Boada & Pennington, 2006), no (mild) impairments would be expected for FR-nondyslexic children throughout (early) development.

Method

Participants

The total sample consisted of 212 children from the Dutch Dyslexia Program (DDP). The DDP is a longitudinal study of children with and without an FR of dyslexia (see van der Leij et al., 2013, for a detailed description). Parents with and without a history of dyslexia were recruited when they were expecting a baby, and the children first came to the lab when they were 2 months old. FR was defined as having at least one parent and one close relative (i.e., first degree) with dyslexia. A detailed account of FR assessment in this data set is provided by van Bergen, de Jong, Plakas, Maassen, and van der Leij (2012). Dyslexia status was determined based on low achievement criteria at the end of Grade 2 (8 years). In line with Dutch dyslexia protocols (e.g., Kleijnen et al., 2008), children had to show word reading fluency scores that belonged to the lowest 10% of the population (based on individual assessment and with IQ ≥70 at time of testing). Application of these criteria resulted in three groups: (a) FR-dyslexic children (n = 51, 56.9% boys), (b) FR-nondyslexic children (n = 92, 58.7% boys), and (c) TD control children (n = 69, 60.9% boys). Four children were categorized as having dyslexia but had no FR and were omitted from the study, as this group was too small to include separately in the analyses. All parents signed written informed consent, and the project was approved by the ethical committee.

The background characteristics of the groups in the sample are displayed in Table 1. The word reading performance at the end of Grade 2 indicates a stepwise pattern of performance, with FR-nondyslexic children scoring in between FR-dyslexic and TD control children. The vocabulary measures clearly indicate that the smaller vocabulary sizes in FR-dyslexic children compared with both nondyslexic groups were present both at the preschool age (i.e., before literacy acquisition) and after several years of literacy education (i.e., end of Grade 3). Because both FR groups showed about equal levels of parental education (see Table 1), which was used as a proxy for socioeconomic status and was significantly lower than in the TD group, it can be ruled out that possible differences in early vocabulary size between both FR groups were caused by differences in socioeconomic status.

Note that this study was conducted on largely the same sample as described in van Bergen et al. (2012), van Bergen et al. (2014), and van Bergen, de Jong, Maassen, and van der Leij (2014). Small differences in the total number of participants per study and the number of participants per group are the result of occasion used for the dyslexia diagnosis (i.e., Grade 2 or Grade 3) and the available data per child for the relevant variables included in a particular paper. The data described in the current study have not been reported on in the above-mentioned studies within the DDP.

Instruments

Main Vocabulary Measure

The Dutch version (Zink & Lejaegere, 2002) of the CDI (Fenson et al., 1994) was used to assess vocabulary size at 17, 23, 29, and 35 months. The N-CDI Words and Sentences (normed for ages 16–30 months) consists of 22 semantic categories covering 702 lexical items. The N-CDI was developed in Flanders (Belgium) and adjusted slightly for the DDP study to ensure that Flemish-specific words were not used (see Koster et al., 2005, for specifics). Parents reported on their children's receptive and expressive vocabulary within a 2-week window of the targeted ages. The receptive score consisted of all words their child understood. The expressive score represented all words their child both understood and said. Internal consistency of the receptive and expressive scales is .99 and .98, respectively (Zink & Lejaegere, 2002). The correlations between the receptive and expressive vocabulary scores at 35 months and the verbal IQ score at age 4.5 years (as reported on in van Bergen, de Jong, Maassen, Krikhaar, et al., 2014) are .52 and .53 ($p < .001$), which we take to mean that the validity of the N-CDI is sufficient.

Background Measures

Verbal intelligence at the age of 53 months was estimated using the language comprehension subtest of the *Reynell* (van Eldik, Schlichting, lutje Spelberg, van der Meulen, & van der Meulen, 2001) and the expressive vocabulary, expressive syntax, and verbal short-term memory subtests of the *Schlichting* (Schlichting, van Eldik, lutje Spelberg, van der Meulen, & van der Meulen, 2003). All four subtests had a discontinuation rule. Raw scores were the number of correct items per subtest, for which norm-based standard scores were derived from the manual. The standardized scores of the four subtests were averaged to obtain a verbal IQ score. A more elaborate description of the subtests and the resulting verbal intelligence score is provided by van Bergen de Jong, Maassen, Krikhaar, et al. (2014). Cronbach's α for the subtests are .90, .90, .86, and .79, respectively.

Vocabulary knowledge/verbal reasoning ability at the end of Grade 3 (age 9) was assessed using the Dutch version (Kort et al., 2005) of the vocabulary subtest of the *Wechsler Intelligence Scale for Children–Third Edition* (Wechsler, 1991). Children were asked to describe the meaning of a given word. The subtest contains 35 items that increase in difficulty and level of abstraction. Correct answers were awarded two points and incomplete answers one point. Raw scores are transformed into

Table 1. Background characteristics of the three groups in the sample.

	FRD		FRND		TDC	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*
Word reading						
End Grade 2	34.57_a	13.11	69.98_b	16.13	75.18_c	14.73
Vocabulary						
53 months (VIQ)	102.55_a	11.55	109.06_b	10.39	111.91_b	9.10
End Grade 3	10.72_a	2.57	12.03_b	2.44	12.32_b	2.53
Parental education						
Mother	2.65_a	1.15	2.95_a	1.17	3.68_b	0.75
Father	2.47_a	1.20	2.58_a	1.20	3.57_b	0.96
Average	2.26_a	0.75	2.58_a	1.04	3.62_b	0.72

Note. FRD = family risk dyslexia; FRND = family risk no dyslexia; TDC = typically developing control; VIQ = verbal IQ. Means in the same row that do not share subscripts differ at $p < .05$.

age-referenced Wechsler standard scores ($M = 10$, $SD = 3$). Reliability of the subtest for this age group is .80.

To determine the dyslexia status of the children at the end of Grade 2, word reading fluency was measured using the Dutch timed *Drie-minuten-toets* (Verhoeven, 1995). The task comprised a list of 150 monosyllabic words, with all words containing at least one consonant cluster. Children had 1 min to read aloud as many words as possible. The raw score was the number of correctly read words within the time limit, which was transformed into a norm-based standard score for classification purposes. Reliability of the task for this age is .96.

Analyses

First, repeated measures analyses with planned contrasts ($\alpha = .05$) were conducted on the N-CDI parent report measures to investigate group differences in receptive and expressive vocabulary between 17 and 35 months. For each vocabulary type, group membership was the between-subjects factor and time point (1 to 4) the within-subject factor. Two follow-up contrasts were specified, comparing (a) FR-dyslexic children to both nondyslexic groups (i.e., FR-dyslexic children vs. FR-nondyslexic children and TD control children) and (b) both nondyslexic groups (i.e., FR-nondyslexic children vs. TD control children). Cohen's d was used as a measure of effect size (i.e., .2 = small, .5 = medium, .8 = large; Cohen, 1992).

Next, separate latent growth curve models were fitted to describe receptive and expressive vocabulary development across the four time points using the R package lavaan (R Core Team, 2015) for structural equation modeling (SEM). The baseline model contained the four time points as indicator variables (i.e., N-CDI measures at 17, 23, 29, and 35 months), an initial status factor (i.e., intercept), and a linear change factor (i.e., linear slope). The intercept represents the initial vocabulary size of the children at the start of the study, with equal factor loadings for all four indicators (i.e., fixed at 1). The linear slope reflects children's average linear growth in vocabulary between time points throughout the study, with factor loadings indicating equal intervals between time points (i.e., 0, 1, 2, 3). If the fit of the baseline model was considered insufficient, factors representing nonlinear growth (e.g., quadratic term) could be added to the model to better approximate the average growth curve of the children in the study. When model fit was considered acceptable, we regressed the latent growth curve factors on the (dummy coded) independent variables FR status (FR vs. no FR), dyslexia status (dyslexia vs. no dyslexia), and gender (boy vs. girl). Thereby we could determine the differences between the three groups (i.e., FR-dyslexic children, FR-nondyslexic children, and TD control children) in their vocabulary development. To evaluate exact and approximate model fit, we used the chi-square value (χ^2) with associated p value, root mean square error of approximation (RMSEA) including *p*close, comparative fit index (CFI), and standardized root mean square residual (SRMR; Kline, 2011; Little, 2013). For good model fit, chi-square should have a nonsignificant p-value (i.e., $> .05$), RMSEA should be $<.05$ ($<.08$ is acceptable), with *p*close $>.05$, CFI being $>.95$ ($>.90$ is acceptable), and SRMR being $<.05$ ($<.08$ is acceptable; Kline, 2011; Little, 2013).

Results

Data Screening

Outlier analysis showed no significant univariate or multivariate outliers. Each occasion contained missing receptive and expressive vocabulary scores (T1: 33 children, range across groups 8.7%–21.6%; T2: 24 children, 8.7%–13.7%; T3: 15 children, 5.8%–8.7%; T4: 20 children, 5.4%–14.5%). For the repeated measures analyses, raw scores were used and missing data were imputed using expectation maximization. Means and standard deviations were similar for the original and imputed data. The imputed data were also transformed into gender-based norm-referenced percentile scores, which were available for the first three time points (norms are available up to 30 months). For the SEM analyses, missing data were dealt with using full information maximum likelihood estimation. Raw scores were transformed into sample-based z-scores over all four time points combined to facilitate the estimation of the growth models.

Multivariate Analyses

Table 2 displays the receptive and expressive vocabulary scores of the three groups at the four time points. The group contrasts are reported for the main and interaction effects. For receptive vocabulary, the FR-dyslexic group had marginally lower vocabulary scores than both nondyslexic groups over all time points taken together, Wilks's $\lambda = 0.96$, $F(4, 206) = 1.98$, $p = .098$, as well as a smaller increase in vocabulary size over time, Wilks's $\lambda = 0.97$, $F(3, 207) = 2.50$, $p = .06$. The FR-nondyslexic and TD control groups did not differ on either of the effects. For the individual time points, both nondyslexic groups outperformed the FR-dyslexic group in receptive vocabulary size at 23 ($p = .022$), 29 ($p = .016$), and 35 months ($p = .042$) but not at the youngest age of 17 months ($p = .352$). The effect sizes are all considered small. There were no significant differences between the FR-nondyslexic and the TD control group at any time point (see also Figure 1).

For expressive vocabulary, the FR-dyslexic group had significantly lower vocabulary scores than both nondyslexic groups for all time points overall, Wilks's $\lambda = 0.94$, $F(4, 206) = 3.04$, $p = .02$, as well as a smaller increase in vocabulary size over time, Wilks's $\lambda = 0.94$, $F(3, 207) = 4.00$, $p = .008$. The FR-nondyslexic and TD control children groups did not differ significantly on either of the effects. Contrasts at the individual time points confirmed that the FR-dyslexic group had a significantly smaller expressive vocabulary size than both nondyslexic groups at all four occasions ($p < .05$). Effect sizes were small to medium. There were no significant differences between the FR-nondyslexic and TD control group (see also Figure 1).

Table 2. Means, standard deviations, and group comparisons of the receptive and expressive vocabulary scores and percentiles.

	FRD (n = 51)		FRND (n = 92)		TDC (n = 69)		FRD vs. FRND	FRD vs. TDC	FRND vs. TDC
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	Effect size (Cohen's *d*)		
Receptive vocabulary									
17 months†	161.39$_a$	89.65	178.49$_a$	95.99	172.07$_a$	89.54	−0.18	−0.12	0.07
23 months	348.40$_a$	133.90	393.80$_b$	116.53	391.77$_b$	113.02	−0.36	−0.35	0.02
29 months	504.59$_a$	114.11	548.18$_b$	105.88	543.32$_b$	96.70	−0.40	−0.37	0.05
35 months	605.29$_a$	78.95	625.08$_b$	69.43	631.19$_b$	60.46	−0.27	−0.37	−0.09
Percentiles									
% ≤25 percentile‡	41.8$_a$		25.0$_b$		25.6$_b$				
% ≤10 percentile‡	17.0$_a$		9.8$_a$		8.2$_a$				
Expressive vocabulary									
17 months†	25.74$_a$	22.78	34.93$_b$	37.36	41.37$_b$	33.19	−0.30	−0.55	−0.18
23 months	160.33$_a$	124.75	225.52$_b$	145.52	243.48$_b$	143.46	−0.48	−0.62	−0.12
29 months	389.87$_a$	155.44	473.37$_b$	134.32	455.61$_b$	141.77	−0.28	−0.44	0.13
35 months	550.82$_a$	110.37	594.36$_b$	85.66	585.49$_b$	102.17	−0.44	−0.33	0.09
Percentiles									
% ≤25 percentile‡	39.2$_a$		26.1$_a$		24.1$_a$				
% ≤10 percentile‡	18.9$_a$		11.9$_a$		10.1$_a$				

Note. FRD = family risk dyslexia; FRND = family risk no dyslexia; TDC = typically developing control. Means in the same row that do not share subscripts differ at $p < .05$.

‡Data of this time point is partly described in Koster et al. (2005). †Average percentage over the first three time points.

The small mean group differences in vocabulary size were partly supported by the mean percentages of children with mild (i.e., ≤25th percentile) and severe (i.e., ≤10th percentile) vocabulary impairments (see Table 2). For receptive vocabulary, the FR-dyslexic group contained significantly more children with mild vocabulary impairments than both nondyslexic groups (p = .03) but not more children with severe impairments. For expressive vocabulary, differences between the FR-dyslexic group and both nondyslexic groups were marginally significant for mild vocabulary impairments (p = .06) and not significant for the percentage of severe impairments.

Latent Growth Curve Modeling

Table 3 provides the correlations among receptive and expressive vocabulary at the four time points, FR status, dyslexia status, and gender. The correlations of receptive and expressive vocabulary across consecutive occasions were strong, indicating substantial stability of individual differences in vocabulary development. Except for receptive vocabulary at 17 months, dyslexia status correlated significantly with receptive and expressive vocabulary. FR status was associated with expressive vocabulary at the first two time points only and also related to dyslexia status. Gender was significantly related to expressive vocabulary at the last three time points.

Receptive Vocabulary

The baseline model for receptive vocabulary could not be fitted because of a negative variance (i.e., Heywood case) of the T4 indicator. Therefore, the residual variance of T4 was constrained to be larger than zero. The fit of this baseline model was poor, $\chi^2(6) = 321.49$, $p < .001$, RMSEA = .50, *p*close = .00, CFI = .39, SRMR = .26. Based

Figure 1. Mean development of receptive (left) and expressive (right) vocabulary size in the three groups across four time points. FRD = family risk dyslexia; FRND = family risk no dyslexia; TDC = typically developing control. See also Table 2.

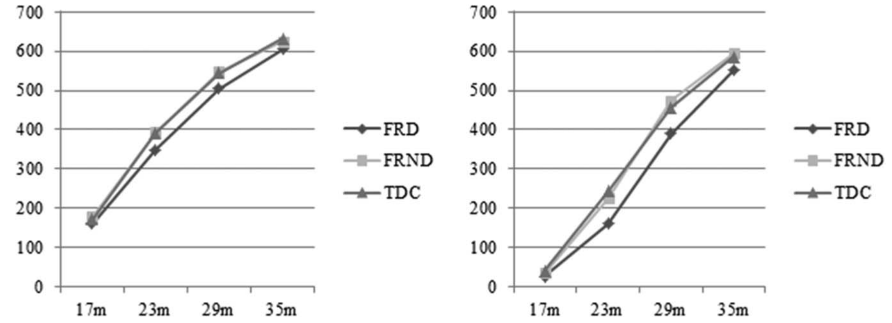

Table 3. Pearson's correlations between receptive and expressive vocabulary measures and independent variables per time point.

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Receptive 17 months	1.00										
2. Receptive 23 months	.79**	1.00									
3. Receptive 29 months	.58**	.80**	1.00								
4. Receptive 35 months	.46**	.68**	.84**	1.00							
5. Expressive 17 months	.52**	.54**	.40**	.32**	1.00						
6. Expressive 23 months	.56**	.74**	.61**	.51**	.76**	1.00					
7. Expressive 29 months	.53**	.72**	.85**	.71**	.54**	.75**	1.00				
8. Expressive 35 months	.38**	.61**	.77**	.84**	.34**	.56**	.85**	1.00			
9. Family risk status	.00	−.06	−.05	−.09	−.14*	−.14*	−.04	−.03	1.00		
10. Dyslexia status	−.07	−.16*	−.17*	−.14*	−.15*	−.22**	−.22**	−.17*	.39**	1.00	
11. Gender	.08	.12	.11	.14*	.08	.15*	.17*	.16*	.03	.02	1.00

Note. For family risk status, 0 = no family risk, 1 = family risk; for dyslexia status, 0 = no dyslexia, 1 = dyslexia; for gender, 0 = boy, 1 = girl. Correlations are based on expectation maximization imputed data.

*$p < .05$. **$p < .01$.

on the expected developmental trajectory and the shape of the growth curves displayed in Figure 1, a quadratic term was added to the model (factor loadings fixed at 0, 1, 4, and 9), indicating nonlinear growth. This model could not be fitted because of a negative variance of the T1 indicator. After restricting this variance to be larger than zero, the model fit the data significantly better than the model without the quadratic growth parameter, $\Delta\chi^2(3) = 312.76$, $p < .001$, and demonstrated the following fit: $\chi^2(3) = 8.73$, $p = .03$, RMSEA = .095, *p*close = .12, CFI = .99, SRMR = .03. Although the model fit is not optimal given the significant chi-square value and the RMSEA exceeding .08, it was considered acceptable for the purposes of our analyses based on the good CFI and SRMR values (Kline, 2011; Little, 2013). In addition, the parameter estimates showed no indication of systematic patterns of misfit.

The variance (0.24, *SE* = .03) of the intercept was significant ($p < .001$), indicating that the children showed significant variability in receptive vocabulary size at 17 months. Also, the variances of the linear (0.18, *SE* = .03) and the quadratic slope (0.02, *SE* = .003) were significant ($p < .001$), indicating individual differences in developmental trajectories. Overall, the quadratic growth model explains about 85% of the observed total standardized variance in vocabulary growth between 17 and 35 months.

For the final model, the latent growth curve factors were regressed on the independent variables FR status, dyslexia status, and gender to assess group differences in receptive vocabulary development. This final model demonstrated good model fit, $\chi^2(6) = 10.79$, $p = .10$, RMSEA = .06, *p*close = .32, CFI = .99, SRMR = .02. There was a significant effect of dyslexia status on both the linear slope and the quadratic slope but not on the intercept. There were no significant effects of FR status and gender on receptive vocabulary development. The standardized coefficients in Figure 2 indicate that, when controlling for FR status and gender, FR-dyslexic children had lower levels of linear growth in receptive vocabulary than nondyslexic children. However, they also had higher overall quadratic growth, indicating more change in the rate of growth over time (Bollen & Curran, 2006). Overall, the three independent variables explained 1.1% of the variance in the intercept, 4.1% in the linear slope, and 5.0% in the quadratic slope. A detailed overview of the parameter estimates is provided in Appendix A.

Expressive Vocabulary

The fit of the baseline model for expressive vocabulary, after constraining the residual variances of T1 and T4 to be larger than zero, was poor, $\chi^2(7) = 245.33$, $p < .001$, RMSEA = .40, *p*close < .001, CFI = .50, SRMR = .27. In line with the model for receptive vocabulary, a quadratic growth parameter was added to the model (factor loadings fixed at 0, 1, 4, and 9). This model fit the data significantly better than the model without the quadratic term, $\Delta\chi^2(4) = 170.98$, $p < .001$, but the fit was still unacceptable, $\chi^2(3) = 74.35$, $p < .001$, RMSEA = .34, *p*close < .001, CFI = .85, SRMR = .08. Given the severe nonlinearity of the mean development displayed in Figure 1, a separate logistic curve[1] (following an S-shape) was fitted to the data using the R package OpenMx (R Core Team, 2015). This logistic curve model, which was not nested under the previous model (so without the linear and quadratic slopes), fitted the data better than the previous model. Based on the CFI and SRMR values and plausible parameter estimates (Kline, 2011; Little, 2013), this model fit was considered sufficient for the final baseline model, $\chi^2(1) = 17.58$, $p < .001$, RMSEA = .28, *p*close < .001, CFI = .96, SRMR = .069.

The variance of both the intercept (0.02, *SE* = .002) and change factor (2.06, *SE* = .75) was significant ($p < .05$),

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[1] Browne (1993) shows how a logistic curve can be used in latent growth curve modeling. The logistic latent curve model is defined using three latent factors, in which the parameterization is chosen such that the first factor (alpha) represents potential performance (i.e., asymptote), the second (beta) represents initial performance (i.e., intercept), and the third (rho) represents learning speed (i.e., change factor). The factor loadings of these three factors are modeled using a target function and three specific basic functions that are given by Browne (1993, p. 179).

Figure 2. Latent growth curve model of receptive vocabulary with family risk status, dyslexia status, and gender as predictors. (Cor)relations between latent factors and predictors are standardized. To aid visibility, error terms are not displayed. Solid lines and bold numbers indicate significant effects ($p < .05$). T = time point.

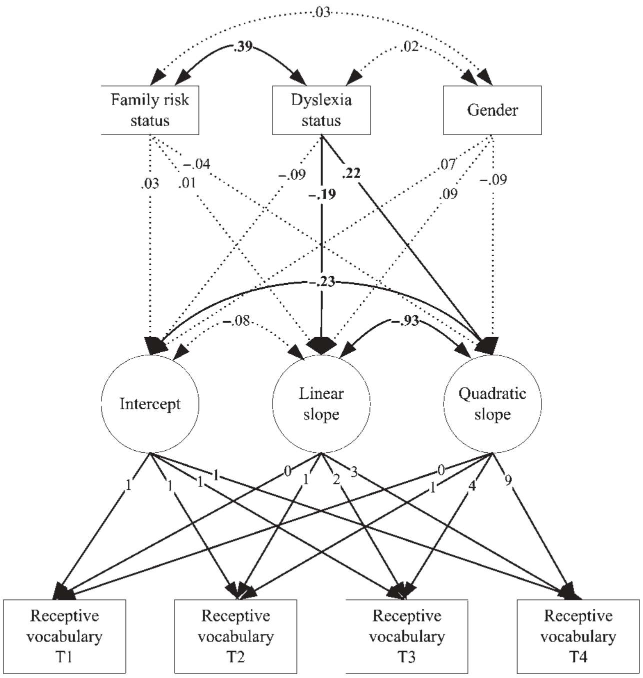
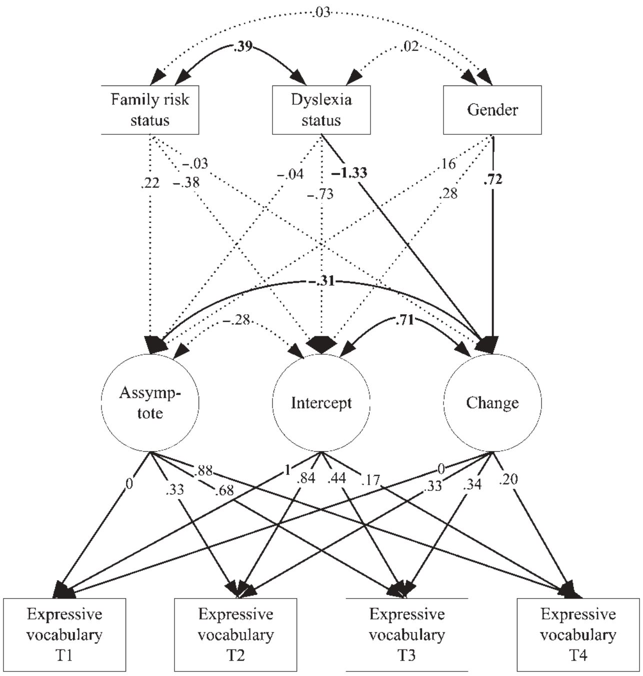


Figure 3. Logistic latent growth curve model of expressive vocabulary with family risk status, dyslexia status, and gender as predictors. (Cor)relations between latent factors and predictors are standardized. To aid visibility, error terms are not displayed. Solid lines and bold numbers indicate significant effects ($p < .05$). 3T = time point.



indicating that children showed significant variability in expressive vocabulary size at 17 months as well as individual variability in developmental trajectories. Overall, the logistic curve model explains about 82% of the observed total standardized variance in vocabulary growth between 17 and 35 months.

The latent growth curve factors were regressed on FR status, dyslexia status, and gender to assess group differences in expressive vocabulary development. The fit of this final model was considered acceptable,[2] $\chi^2(4) = 20.38$, $p < .001$, RMSEA = .139, *p*close = .006, CFI = .97, SRMR = .045. The results showed a significant effect of both gender and dyslexia status on the change factor. There was no significant effect of FR status on expressive vocabulary development. The standardized coefficients in Figure 3 show that girls had higher growth rates than boys. When controlling for FR status and gender, FR-dyslexic children had lower levels of growth in expressive vocabulary than nondyslexic children. Overall, the three independent variables explained 0.4% of the variance in the asymptote, 3.8% in the intercept, and 8.8% in the change factor. See Appendix B for an overview of the parameter estimates.

Discussion

This study examined vocabulary development among children with an FR of dyslexia who became dyslexic (FR-dyslexic), FR children who did not become dyslexic (FR-nondyslexic), and TD control children. Growth of early receptive and expressive vocabulary was assessed longitudinally at four occasions between the ages of 17 and 35 months using parent reports. The first aim of the study was to determine whether receptive and expressive vocabulary were associated with FR or with dyslexia status (risk versus reading). The second aim was to examine whether and how the vocabulary growth curves of FR-dyslexic children differ from FR-nondyslexic children and/or TD control children (delay versus deviance of growth).

Consistent with the results of previous studies (Duff et al., 2015; Scarborough, 1990; Torppa et al., 2010), neither receptive nor expressive vocabulary development differed between FR-nondyslexic and TD control children. The overall vocabulary size of FR-dyslexic children was smaller than in both nondyslexic groups (with small effect sizes for receptive and small to medium for expressive vocabulary). These results support earlier findings that infant vocabulary

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[2] Given that linear, quadratic, and logistic growth factors cannot be combined into one latent growth curve model and that the mean development of the groups in Figure 1 shows that the S-curve is not as clearly defined in the TD control group as in both FR groups, optimal model fit cannot be obtained. The logistic curve model was chosen as the final model because it fitted the data significantly better than the linear + quadratic curve model, model fit was acceptable based on the CFI and SRMR, and the parameter estimates showed no indication of systematic patterns of misfit.

development is related to dyslexia status and not to FR. However, unlike previous studies (Scarborough, 1990; Torppa et al., 2010), we found lower receptive vocabulary in FR-dyslexic children at 23 months and lower expressive vocabulary at 17 months. Moreover, our results showed that the differences between the FR-dyslexic children and both nondyslexic groups were persistent, at least between the ages of 17 and 35 months, as lower scores were present at all subsequent time points after the first occurrence.

In addition to these mean differences, latent growth curve modeling showed differences in growth trajectories between FR-dyslexic and FR-nondyslexic/TD children. For receptive vocabulary, growth curves were nonlinear and showed a gradual increase and subsequent shallowing of the slope. This suggests that our study started somewhere halfway in the vocabulary spurt and extended past the peak in growth rate toward the end of the spurt. Based on the finding that FR-dyslexic children showed more change in the rate of growth over time, it can be concluded that receptive vocabulary development in these children was characterized by lower initial growth followed by a weaker deceleration of the growth rate (see also Figure 1). This pattern was supported by the change in effect sizes between time points, indicating an increase in differences between FR-dyslexic and nondyslexic children in receptive vocabulary size, followed by a decrease in mean differences. Thus, the expansion of receptive vocabulary during the second year of life was slower in the group of FR-dyslexic children. Their growth was protracted and the deceleration reduced toward the start of their third year. As a result, they partly resolved their lag. These findings are not in line with previous studies by Fenson et al. (1994) and Hamilton et al. (2000), who found a linear increase in early receptive vocabulary growth. However, both studies focused on a different time span (i.e., 8 to 28 months and 12 to 25 months, respectively), partly involving younger children than in our study. As a result, these studies might have captured neither the start nor the end of the vocabulary spurt and thus missed the deceleration in vocabulary growth after the 28-month mark.

For expressive vocabulary, growth curves were also nonlinear and seemed to cover the full vocabulary spurt, with an acceleration in growth during the second year and subsequent deceleration during the third year. Expressive vocabulary development in FR-dyslexic children was characterized by a later onset of the spurt. Receptive and expressive vocabulary growth curves of FR-dyslexic children differ from those of FR-nondyslexic and TD children based on lower initial growth rates, indicating delayed vocabulary development, followed by partial recovery. This nonlinearity in early expressive vocabulary was also attested in studies by Fenson et al. (1994), Hamilton et al. (2000), and Kauschke and Hofmeister (2002). Only the latter found the full vocabulary spurt. This is probably due to the time window included (i.e., 13 to 36 months), which is more comparable with the one covered in the current study.

The findings of the current study speak to theories linking early vocabulary growth to (impairments in) the development of phonological skills and later literacy. The smaller vocabulary size and delayed development in FR-dyslexic children was expected based on both the LRT and segmentation theory. However, our findings on the severity of these deficits and findings for the FR-nondyslexic children do not seem to be in line with the direct causal relation between vocabulary growth and emerging phonological awareness proposed in the LRT (e.g., Metsala & Walley, 1998). Because FR-nondyslexic children have no vocabulary impairment, LRT predicts that these children would not have phonological awareness deficits either. Yet, multiple studies have shown a stepwise pattern for phonological awareness (i.e., FR-dyslexic < FR-nondyslexic < TD control children; e.g., Moll et al., 2013), including our own longitudinal study on largely the same sample (van Bergen, de Jong, Maassen, & van der Leij, 2014). The mild phonological awareness impairments that may arise in FR-nondyslexic children thus do not seem to be caused by vocabulary only but also by other cognitive skills. This is further supported by the continual absence of mild vocabulary deficits in the FR-nondyslexic group at later ages (e.g., van Bergen, de Jong, Maassen, Krikhaar, et al., 2014; see also Table 1).

Furthermore, on the basis of the LRT, the vocabulary delay of the FR-dyslexic children would be anticipated to be more severe or even clinical in order to causally relate the development of phonological awareness to vocabulary growth. However, the majority of the children in our study did not show clinical levels of vocabulary impairment. Although lexical restructuring is an ongoing process that extends across childhood and may vary per developmental phase (Metsala et al., 2009; Rispens & Baker, 2012), it seems unlikely that small deficits in infant vocabulary increase during early childhood, explaining the larger deficits in phonological awareness; the FR-dyslexic children had partly recovered from their acquired lag toward the end of their third year. Accordingly, the relation between vocabulary and phonological awareness seems to be less straightforward than suggested in LRT.

The patterns of vocabulary development observed in the current study seem more in line with the segmentation theory (e.g., Boada & Pennington, 2006). For FR-dyslexic children, problems with speech sound segmentation hamper the formation of high-quality phonological representations, which is associated with more negative outcomes for vocabulary growth and phonological awareness. The vocabulary deficits in this group, despite their stability, are based on small effects. These results, combined with the absence of mild impairments in FR-nondyslexic children, are in line with the limited causality implied by this theory. Consequently, it could be that phonological representations only partly account for vocabulary and that other factors, such as syntactic complexity, lexical richness, and input clues to word meaning (see Hoff, 2006, for an overview), play a substantial role. The segmentation theory could also account for the finding that not all children with dyslexia have vocabulary difficulties and that vocabulary might even be a source of compensation for some children (e.g., Snowling et al., 2003; van Viersen, Kroesbergen, Slot, & de Bree, 2016).

The results of the current study also suggest reasons why early vocabulary deficits were often not found in previous FR studies. First, the current findings clearly show that delays in vocabulary development are found only in FR-dyslexic children. A comparison between only TD and FR children is less likely to yield group differences; the effect of early vocabulary is small and found in only a small part of the FR group. Second, previous FR studies often suffered from lack of power because of small sample sizes and potentially large variety in the percentage of FR children who would later become dyslexic in the at-risk group (see Aro et al., 2012, for an exception), affecting replicability of effects. Our results show that, based on a developmental approach and a larger sample than in previous studies, vocabulary is indeed a small, additional risk factor for the development of later reading impairment.

Concerning practical implications, our study suggests that early screening of vocabulary development based on parent reports may be valuable for detecting language delays but might be of lower predictive value for the detection of (being at risk for) later word reading deficits. Yet, the co-occurrence of deficits in receptive and expressive vocabulary and/or accumulation of vocabulary deficits and other risk factors might increase the impact on later literacy development. As vocabulary is relevant not only for word reading ability but also for reading comprehension (Lee, 2011; Muter, Hulme, Snowling, & Stevenson, 2004; Ricketts, Nation, & Bishop, 2007), early screening might be beneficial. Although the delay in vocabulary growth of FR-dyslexic children may seem to be (partly) resolved toward the end of the third year of life (see also Rescorla, 2011), deficits may increase in predictive value for literacy development around the age of school entry (e.g., Thompson et al., 2015). They may also arise again when children start learning to read, illustrating the reciprocal nature of the relation between vocabulary, phonology, and literacy at later ages (e.g., Snowling, Hulme, & Nation, 1997; see also Snowling, Duff, Nash, & Hulme, 2015).

Overall, this study has shown that vocabulary is weakly related to the etiology of dyslexia. Early deficits are associated with children's dyslexia status and not with their FR. Vocabulary development of FR-dyslexic children is characterized by a delay compared with FR-nondyslexic and TD control children and does not seem deviant. As such, vocabulary may function as an additional risk factor for the development of later reading impairments rather than as a proximal cause of dyslexia.

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Appendix A

Parameter Estimates of the Final Latent Growth Curve Model of Receptive Vocabulary

Parameter	Unstandardized	*SE*	Standardized
Predictor means			
Family risk	0.675***	.032	—
Dyslexia	0.241***	.029	—
Gender	0.410***	.034	—
Latent factor means			
IS	−1.335***	.035	—
LS	1.241***	.036	—
QS	−0.159***	.011	—
Predicted means			
Vocabulary T1	−1.335***	.035	—
Vocabulary T2	−0.253***	.039	—
Vocabulary T3	0.511***	.037	—
Vocabulary T4	0.957***	.025	—
Predictor variances and covariances			
Family risk	0.220***	.021	1.000
Dyslexia	0.183***	.018	1.000
Gender	0.242***	.024	1.000
Family risk ←→ Dyslexia	0.078***	.015	.391
Family risk ←→ Gender	0.006	.016	.027
Dyslexia ←→ Gender	0.005	.014	.024
Latent factor residual variances and covariances			
IS	0.237***	.025	.989
LS	0.174***	.027	.959
QS	0.014***	.003	.950
IS ←→ LS	−0.015	.018	−.076
IS ←→ QS	−0.013*	.005	−.227
LS ←→ QS	−0.046***	.008	−.931
Direct effects			
Family risk → IS	0.031	.081	.030
Dyslexia → IS	−0.099	.091	−.086
Gender → IS	0.072	.071	.072
Family risk → LS	0.012	.081	.013
Dyslexia → LS	−0.189*	.091	−.190
Gender → LS	0.077	.071	.089
Family risk → QS	−0.011	.024	−.043
Dyslexia → QS	0.062*	.027	.219
Gender → QS	−0.022	.021	−.088
Error variances			
E_{T1}	0.000	.000	.000
E_{T2}	0.071***	.011	.198
E_{T3}	0.043***	.008	.138
E_{T4}	0.000	.000	.000

Note. T = time point; IS = intercept; LS = linear slope; QS = quadratic slope. Standardized estimates for residual variances and error variances are proportions of unexplained variance.

**p* < .05. ****p* < .001.

Appendix B

Parameter Estimates of the Final Latent Growth Curve Model of Expressive Vocabulary

Parameter	Unstandardized	*SE*	Standardized
Predictor means			
Family risk	1.675***	.032	—
Dyslexia	1.241***	.029	—
Gender	1.410***	.034	—
Latent factor means			
AS	1.40***	—	—
IS	−1.23***	—	—
CF	0.23	—	—
Predicted means			
Vocabulary T1	−1.234	—	—
Vocabulary T2	−0.479	—	—
Vocabulary T3	0.515	—	—
Vocabulary T4	1.072	—	—
Predictor variances and covariances			
Family risk	0.220***	.021	1.000
Dyslexia	0.183***	.018	1.000
Gender	0.242***	.024	1.000
Family risk ←→ Dyslexia	0.078**	.015	.391
Family risk ←→ Gender	0.006	.016	.027
Dyslexia ←→ Gender	0.005	.014	.024
Latent factor residual variances and covariances			
AS	0.201***	.035	.996
IS	0.021***	.002	.962
CF	2.059*	.748	.912
AS ←→ IS	−0.018	.012	−.276
AS ←→ CF	−0.213*	.104	−.312
IS ←→ CF	0.147**	.037	.710
Direct effects			
Family risk → AS	0.045	.084	.215
Dyslexia → AS	−0.008	.113	−.044
Gender → AS	0.036	.082	.161
Family risk →IS	−0.027	.024	−.382
Dyslexia → IS	−0.046	.027	−.731
Gender → IS	0.021	.021	.282
Family risk → CF	−0.018	.285	−.025
Dyslexia → CF	−0.854*	.314	−1.330
Gender → CF	0.532*	.246	.720
Error variances			
E_{T1}	0.000	.000	.000
E_{T2}	0.081***	.018	.205
E_{T3}	0.058***	.058	.162
E_{T4}	0.000	.000	.000

Note. T = time point; AS = asymptote; IS = intercept; CF = change factor. Standardized estimates for residual variances and error variances are proportions of unexplained variance.

*p < .05. **p < .01. ***p < .001.