ASHA American Speech-Language-Hearing Association

JSLHR

Research Article

Early Productive Vocabulary Composition as Precursor of Dyslexia

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ARTICLE INFO

Article History:
Received October 9, 2020
Revision received April 6, 2021
Accepted October 22, 2021

Editor-in-Chief: Stephen M. Camarata
Editor: Krystal L. Werfel

https://doi.org/10.1044/2021_JSLHR-20-00599

ABSTRACT

Purpose: The aim of this study was to gain more insight into the linguistic characterization of dyslexia by investigating vocabulary acquisition. In a previous study, vocabulary at 17 months of age appeared to be related to familial risk (FR) of dyslexia. The aim of this study was to investigate how the differences in lexical composition further develop up to 3 years (35 months) of age and, more importantly, to what extent these differences can be considered specific precursors of dyslexia later on.

Method: In a total number of 262 children from the Dutch Dyslexia Program, 169 with and 93 without FR for dyslexia, productive vocabulary was assessed with the Dutch version of the MacArthur Communicative Development Inventories at ages 17, 23, 29, and 35 months. Reading tests were administered in Grades 2 and 3, resulting in dyslexia diagnosis in 60 FR children (FR-dys), leaving 109 FR children who developed normal reading skills (FR-nondys) and 93 control children. Children's expressive vocabulary was scored according to the total number of words produced and according to the different major linguistic word categories: nouns, predicates, and closed-class words. The analyses comprised a comparison of total productive vocabulary and the number of words per grammatical category at four different ages for the three groups (FR-dys, FR-nondys, and control). Also, correlations were calculated between vocabulary scores and reading scores.

Results: Up to 29 months of age, the total numbers of nouns, predicates, and closed-class words are significantly lower for the FR-dys group as compared with the FR-nondys and control groups; for closed-class words at 23 and 35 months of age, the FR-nondys group's mean values are in between the mean of the FR-dys and control groups. Weak correlations were found between total vocabulary size, number of verbs, number and proportion of predicates at 23 months of age, and word and pseudoword reading fluency in Grades 2 and 3.

Conclusions: These results indicate that development of vocabulary is a significant though weak predictor of reading fluency and dyslexia; vocabulary size and proportion of verbs at 23 months of age, as well as proportion of closed-class words up to 35 months of age, seem to be the most sensitive indicators of delayed vocabulary development and later reading difficulties. There is no indication that FR for dyslexia by itself is related to vocabulary development.

Studies in search of very early precursors of developmental dyslexia in the preschool years have predominantly focused on the development of early language skills and basic visual and auditory processing (Leppanen et al., 2010; Molfese, 2000). Precursors in the domain of language have been specifically searched for in the development

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Disclosure: *The authors have declared that no competing financial or nonfinancial interests existed at the time of publication.*

of phonological skills, such as categorical perception of speech sounds, and phonological awareness. This focus on phonology is inspired by the phonological deficit hypothesis, a widely accepted explanation for dyslexia, claiming that the primary cause of specific reading difficulties resides in a phonological deficit (Goswami, 2000; Ramus et al., 2003; Vellutino et al., 2004). Several versions of the phonological deficit hypothesis have been formulated, but the basic assumption of all these proposals is that poor phonological representations are a core characteristic of dyslexia. On the other hand, it has been argued that a more general linguistic deficit, such as observed in children with developmental language disorder (DLD), is present in children with (a risk of) dyslexia as well. Clinical studies have shown dyslexia and DLD to be strongly related (Bishop, 2004; Catts et al., 2005; McArthur et al., 2000), although there is still no consensus on the hypothesized shared underlying causal factors. Recent studies have specifically suggested delays or deviances in vocabulary development (Stoel-Gammon, 2011) and the use of morphosyntactic elements (P. Lyytinen & Lyytinen, 2004).

A relatively recent model that can be used to explain the clinical overlap between DLD and dyslexia is the multiple deficit model (MDM) for dyslexia proposed, among others, by Pennington (2006). The MDM was primarily based on a series of genetic studies showing that the etiology of DLDs, in general, and dyslexia, in particular, is genetically complex, implying that many genes act in a probabilistic manner, each having only a small contribution in determining the disorder. Realizing multifactorial determination at the genetic level, Pennington and van Bergen, van der Leij, and de Jong (2014) argued that single deficit models of dyslexia must be abandoned at the behavioral level as well. Three arguments in favor of the MDM were brought to the floor. First, not even the most seriously considered single candidate deficit underlying dyslexia, namely, deficient phonological skills or phonological awareness, shows a distinct one-to-one mapping with dyslexia. That is, there are children with a phonological deficit without dyslexia and children with dyslexia who do not have a phonological deficit (Pennington et al., 2012). The second reason to adopt the MDM is the considerably higher comorbidity rates between developmental disorders than would be expected on the basis of independent, single deficits. Thus, comorbidity rates around 30% have been reported for dyslexia, on the one hand, and attention-deficit/hyperactivity disorder (Czamara et al., 2013) and dyscalculia (Landerl et al., 2009), on the other. McArthur et al. (2000) reported a comorbidity rate between DLD and dyslexia in the order of 50%. The third reason to adopt the MDM is that familial liability is not discrete but continuously distributed. Familial risk (FR) studies have shown that the occurrence of dyslexia in a child depends not only on whether or not one parent has dyslexia but also on the severity of the dyslexia of that parent and whether or not the other parent also has dyslexia (van Bergen et al., 2011). In addition, the distribution of linguistic factors that are related to dyslexia, such as phonological deficits and poor rapid automatized naming, has been shown to be continuous rather than discrete. The MDM can explain such inheritance patterns in assuming a continuous distribution of the number of disadvantageous gene variants a child can inherit, resulting in a continuum of reading skill from severe or mild dyslexia to poor or fluent reader. Such an inheritance pattern has been confirmed in the longitudinal study in the Netherlands, called the Dutch Dyslexia Program (DDP; van der Leij et al., 2013), in that the distribution of reading fluency scores of the subgroup of FR children without dyslexia is shifted to the left as compared with the non-FR children without dyslexia (van der Leij et al., 2013). Such a stepwise performance pattern, in which at-risk nondyslexic children score in between at-risk dyslexic and not at-risk nondyslexic children, has also been found for the reading-related measures phonological awareness, nonword repetition, and auditory memory. In contrast, at-risk nondyslexic children performed at least as well as controls with respect to rapid naming, and both groups performed much better than at-risk dyslexic children, which can be interpreted as rapid naming being a protective factor for developing dyslexia (van Bergen et al., 2012).

In a meta-analysis and review, Snowling and Melby-Lervåg (2016) report that, as a group, children with FR for dyslexia have significant difficulties in a broad range of language skills, including the foundations of decoding skill. The extent to which these skills are precursors of dyslexia and thus could be used for early detection of dyslexia, however, is not straightforward at all. Risk and protective factors interact in a complicated manner. This study focuses on the role of vocabulary development. The aim of this study is to gain more insight into one of the linguistic characteristics in the MDM of dyslexia by investigating vocabulary acquisition. The focus is on the development of the lexicon by means of analyses of productive vocabulary in children with and without an FR for dyslexia. By relating the vocabulary development at ages 2–3 years to children's reading and spelling scores around 9 years of age (Grade 3), the predictive strength of early productive vocabulary for dyslexia is investigated. The analyses consider not only the development of vocabulary size but also qualitative aspects with a focus on the composition of the vocabulary in terms of grammatical categories.

The size of a child's productive vocabulary, as well as the composition of the lexicon in terms of word classes, has been found to be a good predictor of the child's general linguistic progress (Caselli et al., 1995, 1999). Children start out with the predominant use of object words or nouns, but after the 100- to 200-word level, this overrepresentation decreases until it reaches about 40% of the child's

vocabulary at the 600-word level. The number of predicates (verbs and adjectives) shows a slow and steady increase and reaches the adult ratio of 25% by the 400-word level. Nouns, verbs, and adjectives are so-called content or open-class words and can be contrasted with function or closed-class words, such as prepositions, determiners, and pronouns. The latter category of words increases slowly and reaches the adult 14% ratio by the 600-word level. The above described pattern of productive lexical acquisition was originally documented for children learning English but was confirmed to be also typical for children learning other languages, such as Italian (Caselli et al., 1999), Hebrew (Maitel et al., 2000), and—despite earlier contrastive findings concerning the absence of a so-called early noun bias—even Mandarin Chinese (Tardif et al., 1999) and Korean (Au et al., 1994; Choi & Gopnik, 1995).

Different patterns of vocabulary acquisition have been described for children with DLD, many of whom can be identified relatively early as "late talkers." These children do not start talking "on time," that is, at around 2 years of age or earlier (Rescorla, 1989; Thal et al., 1997). Several studies have found distinctive linguistic profiles of early communicative development for children with DLD as compared with typically developing populations at two levels. Not only is there a delay in lexical acquisition, but there are also signs of deviance in lexical composition. The robust and stable patterns in lexical acquisition that are evident in typically developing children are not necessarily characteristic for atypical populations.

Children with developmental dyslexia are identified at a much later age than late talkers and children with DLD. According to the MDM, an investigation of their early language acquisition could supply invaluable information, such as predicting dyslexia at an early age. In the past 2 decades, longitudinal research programs investigating early precursors of developmental dyslexia have been carried out in Finland and in the Netherlands. Both projects aimed at discovering the earliest signs of future dyslexia by recruiting babies for participation in separate control and at-risk groups. Babies in the at-risk group were selected from families with a history of dyslexia, such that the incidence of dyslexia in the study population is increased by a factor 5–7 (Grigorenko, 2001; Snowling & Melby-Lervåg, 2016). For review publications regarding both the Finnish and Dutch longitudinal programs, see Eklund et al. (2013) and van der Leij et al. (2013).

This study focuses on the role of vocabulary development and aims to determine to what extent the previously reported poorer vocabulary in the FR group as a whole shows a continuous, stepwise distribution similar to phonological skills or should be considered a more specific precursor of dyslexia, in that the at-risk nondyslexic group develops like the not at-risk children. Results concerning vocabulary development within the longitudinal study in the Netherlands (DDP) were first reported in Koster et al. (2005). At that moment, only data from the first vocabulary measurement (at the age of 17 months) were available. The Dutch version of the MacArthur Communicative Development Inventories (N-CDI): Words and Sentences (Zink & Lejaegere, 2002; Zink & Schaerlaekens, 1998) was administered to the parents of both groups of children when their children were 17, 23, 29, and 35 months old. Koster et al. found significant group differences for the children with FR as compared with the nonrisk controls at the age of 17 months, with respect not only to the total number of words produced but also to the linguistic composition of their productive vocabulary, with relatively fewer verbs and closed-class words being produced by the FR children. In this study and most studies addressing not only size but also composition of the vocabulary, the focus is on productive vocabulary. An important methodological reason is that assessing whether particular classes of words, such as pronouns, question words, and especially prepositions, locatives, quantifiers, and articles, which all belong to the category of closed-class words (see Table 1), are in the receptive vocabulary of a child if they are not in the productive vocabulary is not possible from parents' observation but requires specific experimentation.

The aim of this study is to investigate how the differences in lexical composition further develop up to the age of 3 years (35 months) and, more importantly, to what extent these differences can be considered specific precursors of dyslexia later on. Since the diagnostic data concerning the development of reading difficulties and dyslexia have all been collected now—while the children were in third grade in school and reached the age of 9 years—the FR group can be divided into two subgroups: dyslexic versus nondyslexic FR children. Comparing vocabulary development of dyslexic and nondyslexic FR children, as well as nondyslexic controls, allows us to distinguish between those vocabulary patterns that are specifically linked to later reading difficulties and those that are related to FR only, if any. A recent analysis of vocabulary growth of the children in the DDP gives part of the answer (van Viersen et al., 2017). This study did not address the vocabulary composition but modeled the growth rate of total receptive and productive vocabulary size. The results showed similar growth curves for all three groups, but the curve for the dyslexic FR children was significantly delayed as compared with the nondyslexic FR children and the no-FR control children. Different developmental patterns of reading-related language precursors in the DDP cohort, such as phonological processing, phoneme awareness, and nonword repetition skills, were earlier reported, showing that dyslexic FR children performed significantly poorer than fluently reading no-FR children, with the nondyslexic FR children in between,

Table 1. Word categories in the Dutch version of the MacArthur Communicative Development Inventories (N-CDI; sections with words with specific semantic references) and their specific regrouping into linguistic categories for the purpose of this study (Dutch Dyslexia Program [DDP]) and the category status as suggested for CDI studies (Bates et al., 1994).

N-CDI semantic category CDI category name	No. of words (types)	DDP category	CDI–Bates category
1. Sound effects and animal sounds	21	Rest	Social words
2. Animals	47	N	Common nouns
3. Vehicles	17	N	Common nouns
4. Toys	19	N	Common nouns
5. Clothing	29	N	Common nouns
6. Food and drink	69	N	Common nouns
7. Body parts	31	N	Common nouns
8. Small household items	52	N	Common nouns
9. Furniture and rooms	34	N	Common nouns
10. Objects outside	28	N	Common nouns
11. Places to go	23	Excluded	Heterogeneous-ambiguous
12. Names for people	29	Rest	Social words
13. Games and routines	26	Rest	Social words
14. Descriptive words (adjectives)	60	Adj	Predicates
15. Verbs	106	V	Predicates
16. Time words	15	Excluded	Heterogeneous-ambiguous
17. Pronouns	23	ClCl	Closed-class words
18. Question words	7	ClCl	Closed-class words
19. Prepositions and locations	25	ClCl	Closed-class words
20. Quantifiers and articles	16	ClCl	Closed-class words
21. Helping verbs	19	ClCl	Closed-class words
22. Connecting words	6	ClCl	Closed-class words

Note. N = noun; Adj = adjective; V = verb; ClCl = closed class.

despite their approximately equal reading scores and nondyslexic status (van Bergen et al., 2012; van der Leij et al., 2013). This study population yields the unique opportunity to make a similar distinction regarding early vocabulary development, that is, to differentiate between family risk status and later dyslexia underlying poor vocabulary development. Thus, the aim of this study is to specify the main quantitative (size) and qualitative (composition) characteristics of vocabulary development and the pattern of differences between three groups of children: FR children who develop dyslexia (FR-dys), FR children who do not develop dyslexia (FR-nondys), and typically developing nonrisk control children who do not develop dyslexia (nonrisk children who did develop dyslexia were not included).

Method

Participants

The DDP included 322 children, 201 with an FR of dyslexia and 121 no-FR children. FR was defined as at least one parent and one other family member with self-reported dyslexia, which was confirmed by administering a small test battery (for further details, see van der Leij et al., 2013). From the age of 2 months, these children had participated in extensive assessments twice a year, with focus on language and other reading-related developmental domains. Children who were diagnosed with a neurological, psychiatric, or serious behavioral disorder and/or a persistent speech or language disorder, such as DLD, were excluded from the main stream study. The latter group was excluded because a persistent speech or language disorder could affect vocabulary development irrespective of FR of dyslexia. These diagnoses were made independently from our study according to the regular health care and educational system in the Netherlands. In addition, some children left the study for other reasons. As a result, of the total sample, 176 FR children and 101 controls participated up to the reading assessments in Grades 2 and 3. Within the FR group, 62 children (35%) developed severe reading difficulties and were diagnosed with dyslexia (see criteria below). This group of children is called the FR-dys group, whereas the remaining 114 FR children who developed normal reading skills are called the FR-nondys group. Seven children (7%) from nondyslexic families were diagnosed with dyslexia as well; these children were not included in this study. Furthermore, not included were those children for whom less than two out of the four (at ages 17, 23, 29, and 35 months; see below) vocabulary assessments were available (two FR-dys, five FR-nondys, and one control child), thus leaving 60 FR-dys, 109 FR-nondys, and 93 control children in this study.

Assessments had started at 2 months of age, and from the age of 5 months, assessments had been repeated

every 6 months. For this study, vocabulary assessments at ages 17, 23, 29, and 35 months were used and related to results of reading tests administered in Grade 2 and Grade 3, when most children reached the age of 9 years. For the assessment of reading fluency, in Grade 2, the *Drie-Minuten-Toets* (DMT2: List 2; Verhoeven, 1995) was administered, and in Grade 3, the *Eén-Minuut-Toets* (Brus & Voeten, 1979) was administered to assess word reading fluency and the *Klepel* (van den Bos et al., 1994) for pseudoword reading fluency.

Since reading fluency is a continuous rather than categorical characteristic, the diagnostic criterion for dyslexia can only be defined as a certain proportion in the lower tail of the distribution (van der Leij et al., 2013). Recent studies apply as diagnostic criterion a performance at or below the 10th percentile in one or more reading and/or spelling tests (Torppa et al., 2010; van Bergen, de Jong, et al., 2014). The Dutch Dyslexia Foundation advocates to diagnose a child with dyslexia if scores on word or nonword reading tests are at or below the 10th percentile on at least two consecutive occasions over an interval of at least 6 months, despite adequate instruction, and with the exclusion of other neurodevelopmental causes (P. F. de Jong et al., 2016). In this study, criteria for the diagnosis dyslexia were word reading fluency below the 10th percentile in Grade 2 (DMT2; Verhoeven, 1995), combined with either word or nonword reading fluency below the 10th percentile in Grade 3.

All parents signed written informed consent, and the project was approved by the Central Committee on Research Involving Human Subjects, to which the medical research ethics committees of the universities involved are affiliated.

Materials

The N-CDI was developed and standardized in Belgium by Zink and Lejaegere (2002), according to the MacArthur–Bates Communicative Development Inventories. The N-CDI contains 22 semantic categories that are equivalent in type to the American version, with a total of 702 lexical items that are comparable to the 680 items in the American version (Fenson et al., 1994). For use in the Dutch longitudinal study, the N-CDI: Words and Sentences was slightly modified by the dyslexia team, in consultation with the Belgian authors. Instruction to parents and general layout of the inventory were adapted slightly to make the task easier for parents with dyslexia. This adaptation included, for example, less complex instruction sentences and use of larger letter type for word lists. This version of the N-CDI was sent to the parents' homes 2 weeks before the children's lab visit. Parents were asked to complete the N-CDIs at home. They were encouraged to take their time, and they were free to confer with each other or with other caretakers. By filling out the N-CDI under these circumstances, all families were given the opportunity to optimally fulfill the task. The inventory was handed in to a test assistant during the lab visit. Any problems the parents had encountered could be discussed at that time.

Scoring and Collapsing Semantic Categories

Children's expressive vocabulary was scored according to the total number of words produced and according to the different major linguistic groups of words produced. Total vocabulary production of each child was obtained by adding up items marked by parents across all word categories. Only the items marked as "spoken" words—the so-called active or productive vocabulary—were counted, whereas the items marked as "understood but not spoken"—also known as the passive or receptive vocabulary—were left out in this analysis. Although the validity of the CDI has been established (e.g., Dale et al., 1989), there are methodological issues regarding the reliability of parents' estimates of the relative frequency of verbs and nouns, but these concern the receptive lexicons mostly (Caselli et al., 1995).

A first analysis of the differences between the groups of children was made on the basis of their total number of unique words produced based on the N-CDI. A second, more specific, analysis was carried out on three major word group categories based on operational definitions provided by Bates et al. (1994). The first major group category, "common nouns," included the following semantic categories with an obvious naming function: "animals," "vehicles," "toys," "food and drink," "clothing," "body parts," "small household items," and "furniture and rooms." The second major group category, "predicates," included two semantic categories: "action words (verbs)" and "descriptive words (adjectives)." Since DLD has been related to developmental dyslexia (McArthur et al., 2000) and a restricted set of verbs has been proposed as an early marker of DLD (J. de Jong, 1999), the two subcategories, verbs and adjectives, were also analyzed separately. The third major group category, "closed-class words," included the following semantic categories: "pronouns," "question words," "prepositions and locations," "quantifiers and articles," "helping verbs," and "connecting words." A fourth major group category, "social words" (containing the semantic categories "sound effects and animal sounds," "names for people," and "games and routines"), was not part of the present analysis. Other researchers excluded these words from the "common nouns" group to provide a conservative estimate of words with a clear naming function and reference to a class of nameable objects. The semantic categories "places to go" and "time words" were also excluded because words in these categories are heterogeneous and ambiguous as to membership in the open- or closed-class category (Bates et al., 1994; Caselli et al.,

Table 2. Number of words (and percentages of the total numbers of listed words) per linguistic category in the Dutch version of the MacArthur Communicative Development Inventories, as used in this study.

Variable	No. of words	% of listed words
Nouns	326	49.1
Verbs	106	16
Adjectives	60	9
Closed class	96	14.5
Rest	76	11.4
Total	664	100

1999). See Tables 1 and 2 for an overview of the regrouped categories and their number of word types.

Statistical Analyses

The first analyses comprised a comparison of total productive vocabulary and number of words per grammatical category: nouns, predicates (verbs and adjectives), and closed-class words at four different ages (17, 23, 29, and 35 months) for the three groups (FR-dys, FR-nondys, and control). Conditions for parametric testing were examined, and if satisfied, analyses of variance (ANOVAs) were conducted.

In order to more closely examine vocabulary composition, proportions of nouns, predicates, and closed-class words were calculated, and differences between the three groups were tested. Predicates include verbs and adjectives; verbs were also analyzed separately as category, because the category of verbs is grammatically salient and makes up the large majority (around 2/3) of the predicates. Next, in order to examine whether vocabulary composition was related to group, irrespective of vocabulary size, at each age, the participants were divided into four quartiles according to total vocabulary size. Numbers of participants within each quartile were compared between the three groups, and vocabulary composition analyses were conducted for the quartiles separately. In the latter analyses, differences between quartiles and between groups with respect to the proportions of nouns, predicates, and closed-class words were tested with total vocabulary as a covariate. Finally, correlations were calculated between vocabulary scores and reading scores on two tasks (word and pseudoword reading fluency) administered in Grades 2 and 3, at ages 8–9 years.

Results

In the description of the results below, we present first the overall vocabulary size and pattern across ages and then the separate analyses addressing the specific research questions related to vocabulary composition. Comprehensive comparisons of vocabulary data between groups of children (FR-dys, FR-nondys, and controls) are presented in Table 3.

At 17 months of age, the expressive vocabulary of the FR-nondys and control children is significantly larger than that of the FR-dys children. Because the equality of variance condition was violated (Levene's test), a nonparametric test was also applied, which corroborates this result (Kruskal–Wallis: $\chi^2 = 11.15$, $df = 2$, $p = .004$). Numbers of nouns ($\chi^2 = 13.59$, $df = 2$, $p = .001$) and adjectives ($\chi^2 = 6.32$, $df = 2$, $p = .043$) showed the same pattern: FR-dys children stay behind control and FR-nondys children. Numbers of verbs were small and not significantly different between groups ($p = .081$).

At 23 months of age, a clear pattern emerges, showing that total vocabulary and the major word classes nouns, verbs, and predicates are significantly smaller for FR-dys children than for FR-nondys and control children. Note that the category predicates consists of verbs and adjectives. With respect to the total number of closed-class words, a significant difference between FR-dys children and control children was found, with the FR-nondys children scoring in between.

At 29 months of age, differences between total vocabulary size are smaller than at 23 months of age but still significant, with FR-dys vocabulary being significantly smaller than the FR-nondys and control groups. The total numbers of verbs and closed-class words at this age show the same, distinct pattern, with FR-dys producing less types than the FR-nondys and control groups. For nouns and predicates, the control group showed slightly lower numbers than the FR-nondys group, such that the difference between the FR-dys and FR-nondys groups reached significance, but the difference between the FR-dys and control groups did not.

At 35 months of age, differences between groups have disappeared for total vocabulary size, as well as total number of nouns, verbs, and predicates. However, the pattern for closed-class words persisted at 35 months of age, with FR-dys children showing lower numbers than control children and FR-nondys in between.

An additional analysis was conducted, comparing the combined FR-dys and FR-nondys groups with the control group; these analyses showed a marginally significant difference for total vocabulary size at 23 months of age, $F(1, 224) = 3.75$, $p = .054$, and proportions of closed-class words at ages 23 months, $F(1, 224) = 6.36$, $p = .012$; 29 months, $F(1, 230) = 8.37$, $p = .004$; and 35 months, $F(1, 219) = 7.84$, $p = .006$. Figure 1 shows that vocabulary size is a relatively stable characteristic of children, with most correlations between adjacent ages being .70 or higher.

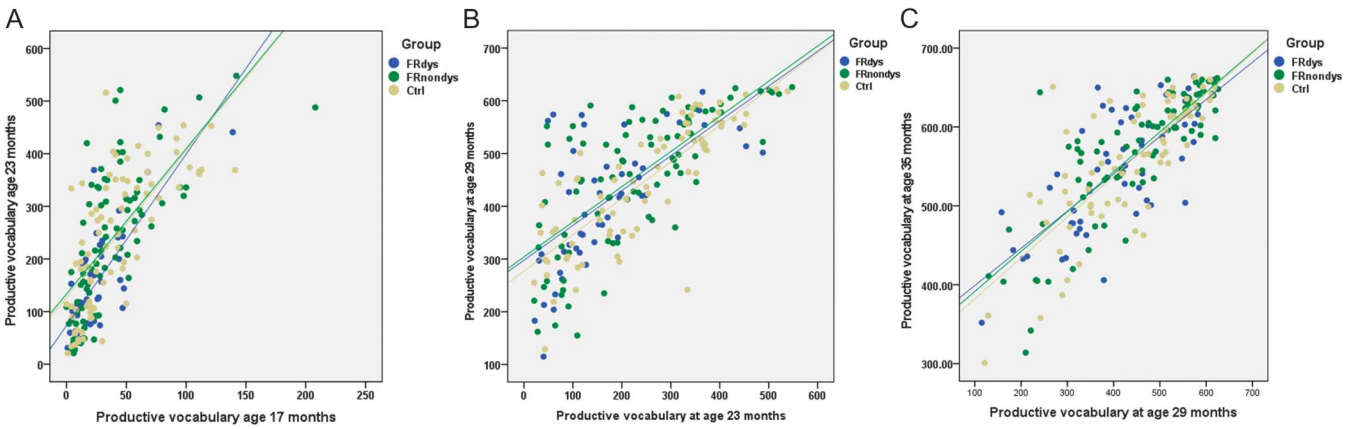
To get more insight into the distributions of vocabulary sizes per group (i.e., FR-dys, FR-nondys, and control), Table 4 shows the quartile ranges of vocabulary size determined across groups and the numbers of children per group with a vocabulary size within each of the quartiles. By definition, the total number of children is equally

Table 3. Vocabulary sizes and compositions at ages 17, 23, 29, and 35 months for the children with familial risk who later develop dyslexia (FR-dys) or not (FR-nondys) and typically developing control children.

		Familial risk											
		FR-dys			FR-nondys			Control					
Age	Variable	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	χ^2	*p*	*Levene*
17 months	Vocab ToT	47	21.8	18.1	90	40.1	37.2	83	40.9	32.5	11.15	.004	.002
	Noun_Tot		6.9	9.60		18.5	24.7		18.4	19.2	13.59	.001	.000
	Verb Tot		1.04	1.63		1.59	2.92		2.24	3.21			.007
	Pred_Tot		2.32	2.70		3.51	4.54		4.31	4.67			.020
	Closed_Tot		1.06	1.52		1.67	2.43		2.38	2.8			.001
	prop_Pred		.097	.086		.075	.056		.090	.057	2.17	.117	.001
	prop_Closed		.039	.065		.038	.048		.046	.048	0.56	.572	.553
		n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*F*(2, 223)	*p*	*Levene*
23 months	Vocab ToT	48	170.5_{a}	120.8	94	225.9_{b}	134.1	84	242.6_{b}	133.4	4.76	.009	.192
	Noun_Tot		97.8_{a}	70.5		128.3_{b}	70.2		125.8_{b}	68.5	3.96	.020	.351
	Verb Tot		29.2_{a}	21.2		31.0_{b}	25.0		33.0_{b}	24.1	5.65	.004	.156
	Pred_Tot		29.7_{a}	29.9		47.5_{b}	36.4		51.3_{b}	35.4	6.29	.002	.102
	Closed_Tot		10.6_{a}	14.5		12.4_{ab}	11.6		16.7_{b}	13.1	4.14	.017	.347
	prop_Pred		$.139_{a}$	.070		$.184_{b}$	.060		$.181_{b}$	.061	8.88	.000	.090
	prop_Closed		$.049_{a}$	.046		$.050_{ab}$	.030		$.062_{b}$	.030	3.19	.043	.034
		n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*F*(2, 229)	*p*	*Levene*
29 months	Vocab ToT	53	395.6_{a}	124.9	95	457.9_{b}	93.7	84	441.0_{b}	119.4	4.46	.013	.968
	Noun_Tot		213.3_{a}	63.2		245.9_{b}	57.6		233.3_{ab}	54.6	5.40	.005	.536
	Verb Tot		63.1_{a}	28.5		75.1_{b}	24.9		71.9_{b}	23.1	3.93	.021	.163
	Pred_Tot		95.8_{a}	41.6		113.4_{b}	38.9		108.9_{ab}	36.4	3.558	.030	.563
	Closed_Tot		30.0_{a}	21.7		40.8_{b}	22.7		43.5_{b}	22.9	6.12	.003	.695
	prop_Pred		.223	.058		.232	.041		.233	.035	0.91	.440	.017
	prop_Closed		$.068_{a}$	.033		$.0805_{b}$	.032		$.089_{b}$	.035	6.83	.001	.967
		n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*F*(2, 218)	*p*	*Levene*
35 months	Vocab ToT	51	544.2	81.1	97	567.1	77.9	73	564.2	80.9	1.44	.240	.730
	Noun_Tot		281.6	38.0		291.9	31.4		285.6	34.8	1.65	.194	.335
	Verb Tot		90.9	14.0		93.7	13.0		92.5	13.9	0.71	.494	.527
	Pred_Tot		138.8	21.7		143.5	22.8		142.4	22.5	0.74	.477	.892
	Closed_Tot		57.2_{a}	24.6		63.7_{ab}	22.4		68.6_{b}	21.8	3.78	.024	.462
	prop_Pred		.244	.020		.240	.015		.241	.015	0.89	.411	.037
	prop_Closed		$.097_{a}$	.032		$.104_{ab}$	.028		$.113_{b}$	.026	4.96	.008	.059

Note. In the final columns, tests of differences between groups, corresponding *p* values, and *p* values of Levene's test of equality of variance are given. If the Levene's test is significant, nonparametric tests are applied, or the Greenhouse–Geisser correction is applied (prop_Pred at ages 29 and 35 months). Numbers and means in the same row that do not share letters differ at $p < .05$ on Tukey's post hoc test. Vocab ToT = total number of words in vocabulary; Noun_Tot = total number of nouns; Verb Tot = total number of verbs; Pred_Tot = total number of predicates; Closed_Tot = total number of closed-class words; prop_Pred = proportion of predicates (Pred_Tot/VocabTot); prop_Closed = proportion of closed-class words (Closed_Tot/VocabTot).

Figure 1. Scatter plots of vocabulary sizes across ages: (A) 17 months plotted against 23 months, (B) 23 months plotted against 29 months, and (C) 29 months plotted against 35 months. Groups of children are color-coded: blue, FR-dys; green, FR-nondys; beige, control. R^2s range between .4 and .7. FR-dys = familial risk with dyslexia; FR-nondys = familial risk without dyslexia; Ctrl = control: no familial, no dyslexia.



divided across quartiles. Notably, at ages 17 and 23 months, significant differences between the number of FR-dys, FR-nondys, and control children regarding their distribution over quartiles were found (17 months of age: $\chi^2 = 15.93$, $df = 6$, $p = .014$; 23 months of age: $\chi^2 = 14.48$, $df = 6$, $p = .025$). At 17 months of age, especially few FR-dys children's vocabulary sizes fall within Quartile 4; at 23 months of age, both Quartiles 3 and 4 are less well represented by FR-dys children. At ages 29 and 35 months, distributions of groups across quartiles are more similar and no longer significantly different.

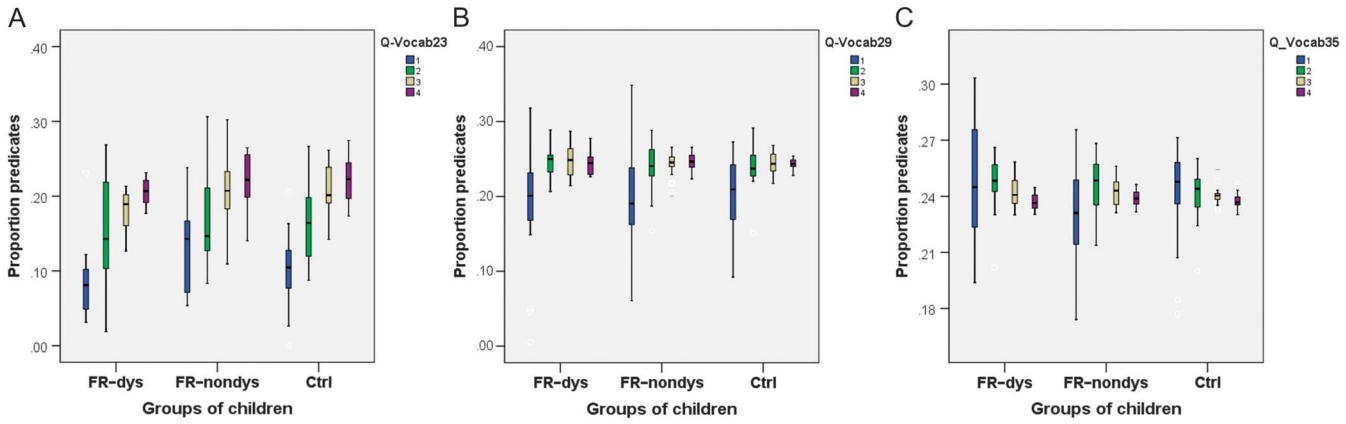
Table 4. Numbers of children in each vocabulary size quartile, for each of the three groups (children with familial risk [FR] who develop dyslexia [FR-dys], children with FR who do not develop dyslexia [FR-nondys], and control), at each of the four ages of assessment (17, 23, 29, and 35 months).

Variable		Group			Total
		FR-dys	FR-nondys	Control	
Age of 17 months					
Vocabulary quartile	1	17	19	19	55
	2	17	20	18	55
	3	10	27	19	56
	4	3	24	27	54
Total		47	90	83	220
χ^2 test: $p = .014$					
Age of 23 months					
Vocabulary quartile	1	17	21	18	56
	2	17	22	17	56
	3	8	29	20	57
	4	6	22	29	57
Total		48	94	84	226
χ^2 test: $p = .025$					
Age of 29 months					
Vocabulary quartile	1	20	19	19	58
	2	13	22	23	58
	3	11	25	22	58
	4	9	29	20	58
Total		53	95	84	232
χ^2 test: *ns*					
Age of 35 months					
Vocabulary quartile	1	18	19	18	55
	2	13	24	18	55
	3	10	29	17	56
	4	10	25	20	55
Total		51	97	73	221
χ^2 test: *ns*					

As to the question whether FR-dys children stay *specifically* behind with respect to verbs, predicates, and closed-class words, proportions of these classes relative to total vocabulary were also examined. As can be seen in Table 3, at 23 months of age, not only the total numbers of predicates and closed-class words but also the corresponding proportions are significantly lower for the FR-dys group as compared with both other groups. At 29 months of age, the total number of predicates and closed-class words is lowest for the FR-dys group (for predicates, the control group scores in between); comparing the proportions at 29 months of age, only the set of closed-class words is significantly lower for the FR-dys group. This difference in proportions of closed-class words persisted at 35 months of age: The FR-dys group scores lower than the control group, with the FR-nondys group in between.

In the analyses above, differences between groups were found for vocabulary size and vocabulary composition. Thus, vocabulary size and composition might be confounded. This raises the question whether the differences in vocabulary composition between the groups are fully accounted for by the differences in vocabulary size, in such a way that, in typically developing children, predicates and closed-class words are also less well represented in the smaller vocabulary sizes. If so, the differences in vocabulary composition between the FR-dys group as compared with the FR-nondys and control groups reported above could be due to the smaller overall vocabulary size of the FR-dys

Figure 2. At each assessment age, all children were divided into quartiles according to total vocabulary size. Next, within each of the study groups FR-dys, FR-nondys, and control, the mean proportions of predicates were calculated separately for the children within each of the four vocabulary size quartiles. These means per assessment age and per study group are plotted in blue (first quartile), green (second quartile), beige (third quartile), and purple (fourth quartile). Results at (A) 23, (B) 29, and (C) 35 months of age. Q-Vocab23, Q-Vocab29, Q-Vocab35 = Quartiles 1–4 of total vocabulary size at ages 23, 29, and 35 months, respectively; FR-dys = familial risk with dyslexia; FR-nondys = familial risk without dyslexia; Ctrl = control: no familial, no dyslexia.



group, especially expressed in the relatively small number of FR-dys children in the higher quartile ranges. In the next analysis, the hypothesis is tested that the children with FR-dys are specifically delayed with respect to the acquisition of the categories predicates and closed-class words, irrespective of their total vocabulary size.

Figures 2 and 3 give box plots of the proportions of predicates and closed-class words per group (FR-dys, FR-nondys, and control), indicating that indeed within each group, the proportion of these word classes is smaller for the lower vocabulary quartiles. An exception is the proportions of predicates at 35 months of age; at this age, average proportions are approximately equal across quartile groups. A second observation is that the standard deviations of proportions are much larger in the lower than in the higher quartiles. In order to determine whether the FR-dys children stay specifically behind with respect to these proportions irrespective of vocabulary quartile, the ANOVAs on proportions were rerun with vocabulary size as a covariate. Because Levene's test showed unequal variances between groups for most proportions, all analyses were conducted with the bootstrap procedure (Field, 2013).

Table 5 gives the F ratios and p values of all significant tests of the factor group (FR-dys, FR-nondys, and control) and the covariate vocabulary size for the proportions of predicates and closed-class words at each age. This analysis

Figure 3. At each assessment age, all children were divided into quartiles according to total vocabulary size. Next, within each of the study groups FR-dys, FR-nondys, and control, the mean proportions of closed-class words were calculated separately for the children within each of the four vocabulary size quartiles. These means per assessment age and per study group are plotted in blue (first quartile), green (second quartile), beige (third quartile), and purple (fourth quartile). Results at (A) 23, (B) 29, and (C) 35 months of age. Q-Vocab23, Q-Vocab29, Q-Vocab35 = Quartiles 1–4 of total vocabulary size at ages 23, 29, and 35 months, respectively; FR-dys = familial risk with dyslexia; FR-nondys = familial risk without dyslexia; Ctrl = control: no familial, no dyslexia.

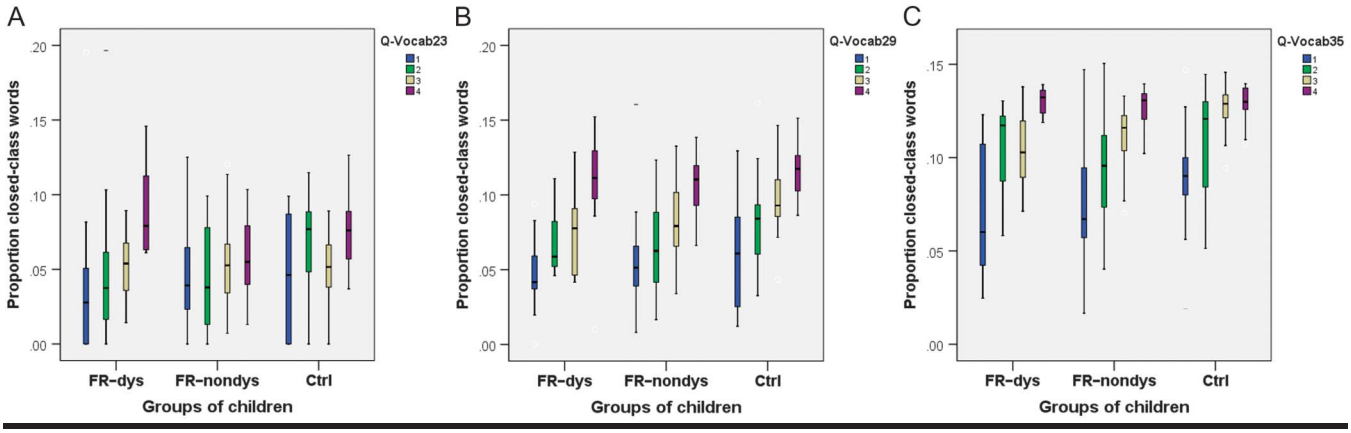


Table 5. *F* ratios and *p* values of analyses of covariance on proportions of predicates and closed-class words corrected for vocabulary size at ages 23, 29, and 35 months.

Variable	Vocabulary size			Group		
Age of 23 months	***F*(1, 222)**	***p***	**ES**	***F*(2, 222)**	***p***	**ES**
Prop. Predicates	159.90	< .001	0.248	4.984	< .01	0.043
Prop. Closed-class	15.50	< .001	0.065	2.215	*ns*	0.020
Age of 29 months	***F*(1, 228)**	***p***	**ES**	***F*(2, 228)**	***p***	**ES**
Prop. Predicates	75.12	< .001	0.248	0.241	*ns*	0.002
Prop. Closed-class	113.3	< .001	0.332	5.77	< .01	0.048
Age of 35 months	***F*(1, 217)**	***p***	**ES**	***F*(2, 217)**	***p***	**ES**
Prop. Predicates	1.17	*ns*	0.005	1.05	*ns*	0.010
Prop. Closed-class	167.6	< .001	0.436	5.68	< .01	0.050

Note. ES = effect size; Prop. = proportion; *ns* = not significant ($p > .10$).

was not conducted at 17 months of age because conditions for parametric testing were violated.

The covariate vocabulary size is significant for both proportions at ages 23 and 29 months and for proportion of closed-class words at 35 months of age; effect sizes vary from small (for the proportion of closed-class words at 23 months of age) to large (for the other significant proportions). Thus, a large part of the differences between proportions can indeed be ascribed to vocabulary size. In addition, group is significant for proportion of predicates at 23 months of age and for proportion of closed-class words at ages 29 and 35 months; effect sizes are small.

Finally, correlations were calculated between vocabulary measures and reading fluency in Grades 2 and 3. Significant but weak correlations were found between total vocabulary size, number of verbs, number and proportion of predicates at 23 months of age, and word and pseudoword reading fluency in Grades 2 and 3 ($r = .25–.29$, $p < .005$, $n = 226$). At ages 29 and 35 months, only the number of closed-class words and, at 35 months of age, also the proportion of closed-class words showed a significant but weak correlation with word reading fluency in Grades 2 and 3 ($r = .22–.24$, $p < .005$, $n = 232$ and 221, respectively). Within diagnostic groups, correlations were lower; most were below .20, and none of which reached significance for the FR-dys group. For the FR-nondys group, the correlations between proportion of closed-class words at 35 months of age and word and pseudoword reading in Grades 2 and 3 were slightly higher than for the diagnostic groups combined and reached significance ($r = .22–.27$, $p < .03$, $n = 100$). Since no Bonferroni correction was applied, these results should be interpreted with caution.

Discussion

The aim of this study was to specify the pattern of differences with respect to vocabulary development between three groups of children: FR children who develop dyslexia (FR-dys), FR children who do not develop dyslexia (FR-nondys), and fluently reading nonrisk control children. To this end, vocabulary size and vocabulary composition were longitudinally assessed at four time points: at ages 17, 23, 29, and 35 months, such that developmental trajectories of the three groups could be compared.

The results clearly showed that children with an FR of dyslexia, who later develop dyslexia (FR-dys group), tend to stay behind with respect to total vocabulary size up to and including 29 months of age; at 35 months of age, this measure has practically normalized. In a previous growth analysis of the same data, in which both receptive and productive lexicons, but no grammatical categories, were analyzed, this pattern was previously reported by van Viersen et al. (2017). This study showed that all major word classes contribute to these vocabulary size differences between groups. Up to 29 months of age, in most of the comparisons, the total numbers of nouns, verbs, predicates, and closed-class words are significantly lower for the FR-dys group as compared with the FR-nondys and control groups. For some of the comparisons, namely, closed-class words at ages 23 and 35 months, the FR-nondys group's mean values are in between the means of the FR-dys and control groups. Importantly, at none of the ages examined, the FR-nondys group significantly differs from controls, so the poorer vocabulary development is more related to reading outcome than to FR. This issue is further discussed below. At 35 months of age, vocabulary size seems practically normalized, but the class of closed-class words still is smallest in the FR-dys group.

A similar assessment of vocabulary development was conducted within the Finnish Jyväskylä Longitudinal Study of Dyslexia (JLD). This study included 107 at-risk and 93 control children, for whom the Finnish version of the CDI (H. Lyytinen et al., 2001; P. Lyytinen et al., 2001) was administered, in addition to various other

cognitive and linguistic assessments. Parents filled out the CDI when their children were 12, 14, 18, 24, and 30 months old. No significant differences in vocabulary size related to FR were found at any age. This directly contrasts with our earlier findings at 17 months of age (Koster et al., 2005), which showed that vocabulary size and composition stayed behind in the FR group. It also contrasts with the additional analysis we conducted, comparing the combined FR-dys and FR-nondys groups with the control group; these analyses showed a marginally significant difference for total vocabulary size at 23 months of age and proportions of closed-class words at ages 23, 29, and 35 months. Similarly, based on machine learning techniques, Chen et al. (2017) found differences in total vocabulary size between FR and control children, particularly at ages 19–20 months. However, whether or not the difference between FR and non-FR is significant is not the crucial point. As we saw in our data, for most comparisons, the difference between FR and non-FR is due to the FR-dys group only, with the FR-nondys group performing (almost) equal to the control group. Given this pattern of results and given that, in most studies, approximately only 33%–50% of the FR children actually develop dyslexia, whether or not a significant difference is found between FR and non-FR groups is, first of all, related to sample size. In our study, we compared 169 FR children with 93 control children; in the JLD, 107 FR and 93 control children were included, resulting in less power. In addition, whether or not FR-nondys children obtain poorer scores than control children depends on the diagnostic criteria applied. Applying more severe criteria would reduce the number of children diagnosed with dyslexia and thus leave more poor readers who score just above the criterion, in the FR-nondys group and possibly also the control group, thereby potentially lowering the performance level in these groups. However, no differences in proportion of children diagnosed with dyslexia were observed between the JLD and the DDP. Torppa et al. (2010) reported that out of 105 FR children, 37 (35%) were diagnosed with dyslexia at the end of second grade. This figure is remarkably similar to our study (62 of 169, 35%). Furthermore, the pattern of vocabulary sizes of the three groups of children in the Finnish study corresponded to our results: The FR-dys group showed smaller vocabulary size than the FR-nondys and control groups; the latter two did not significantly differ. Further analyses of vocabulary development and later reading fluency in the same JLD cohort were conducted by Torppa et al. The largest differences between FR-dys and control children were found for productive vocabulary, as measured by means of the Finnish CDI up to 2.5 years of age and the Boston Naming Test administered at ages 3.5, 5.0, and 5.5 years. Systematic differences between FR-nondys and control children were also found, but few reached significance. In almost all comparisons on factors related to language and vocabulary, the FR-dys group performed poorer than both the FR-nondys and control groups; in most comparisons, including those for vocabulary, performance of the FR-nondys group was just slightly below that of the control group. Thus, all analyses converge in that any differences in vocabulary size and vocabulary composition between FR and non-FR groups are due to the poorer vocabulary development of the children among the FR group who later develop dyslexia.

The developmental patterns seem to indicate the phenomenon of illusory recovery (Bishop & Snowling, 2004; Scarborough, 1990). In the age range from 1.5 to 3 years investigated in this study, the FR-dys children first stay behind with respect to all measures (total vocabulary and proportion of predicates and closed-class words) at ages 17 and 23 months, then with respect to predicates and closed-class words at 29 months of age, and finally with respect only to closed-class words at 35 months of age. Thus, the children tend to catch up, first in the more global measures and later in the vocabulary classes that are related to the more complex aspects of vocabulary development, leaving only the proportion of closed-class words not completely resolved at 35 months of age. In particular, the proportion of predicates of the three groups is close to the values typically reached by children with a total N-CDI productive vocabulary between 500 and 600 (Caselli et al., 1999; Hansen, 2017). Thus, it seems that the recovery of the FR-dys group at 35 months of age is due to reaching the adult proportions with respect to verbs and predicates.

At the age of 35 months, the mean total vocabulary size, the mean proportion of predicates, and the mean proportion of closed-class words of the FR-nondys and control groups are close to 1 *SD* below the respective maximum number and maximum proportion of the N-CDI scale. Reaching values close to the maximum of the N-CDI scale might indicate a weakness of the study. In the N-CDI response form, all words are listed; it cannot be determined how many words children produce that are not on the list, let alone what their relative frequency is. This implies that for the older age groups, the sensitivity of the scale might be seriously diminished.

In a previous publication, we argued that the delayed vocabulary development in FR-dys children could not be based on the lexical restructuring theory (van Viersen et al., 2017). The argumentation is that the lexical restructuring theory is related to phonological impairment, and for phonological skills, the stepwise pattern has been found in several studies (FR-dys < FR-nondys < control group), indicating that phonological impairment is related to both later reading fluency (dyslexia) and FR (Moll et al., 2014; van Bergen, de Jong, et al., 2014). This stepwise pattern, however, does not match the vocabulary development, where the FR-nondys

group was found to closely follow the level of the control group, with the FR-dys group staying significantly behind.

Thus, of the vocabulary measures discussed in this article, the most sensitive predictors of later reading development are the total vocabulary size and the proportion of predicates at 23 months of age, the number of predicates and the proportion of closed-class words at 29 months of age, as well as the proportion of closed-class words at 35 months of age. Hansen (2017) introduced the notion of vocabulary size of acquisition (VSoA) as an alternative for age of acquisition and found consistent growth patterns of word classes in relation to vocabulary size. VSoA is the smallest vocabulary span where at least 50% of the children produce a given word. Thus, nominals (VSoA median = 300) are acquired in a smaller vocabulary than predicates (VSoA median = 380), which are in turn acquired before closed-class items (VSoA median = 500). Likewise, Trudeau and Sutton (2011) found a developmental trend that acquisition of "grammatical words" starts later based on a particular vocabulary size. We conducted separate analyses, in which groups were divided into quartiles of vocabulary size, and, completely in line with this trend, found smaller proportions of predicates and closed-class words in the lower vocabulary quartiles across groups. However, over and above this vocabulary size effect—that is, when vocabulary size was entered as a covariate—we found that the FR-dys group stayed specifically behind in the proportion of predicates and closed-class words at ages 23 and 29 months and in the proportion of predicates at the age of 35 months. In addition, overall vocabulary at 23 months of age and number of closed-class words at ages 29 and 35 months show a weak but highly significant correlation with later reading fluency. It should be noted that these significant correlations are mainly driven by between-groups variance; if calculated within diagnostic groups, correlations are lower in general, except for the correlations between the proportion of closed-class words at 35 months of age and word and pseudoword reading in Grades 2 and 3 in the FR-nondys group. It is difficult to explain these differences in word class acquisition purely on the basis of phonological characteristics of the predicates and closed-class words. For instance, Hansen found that frequency in child-directed speech, followed by imageability, seems to account for the dominance of nominals over predicates. Labrell et al. (2014) found a relation between the composition of the vocabulary in word classes and grammatical development, and Devescovi et al. (2005) found a much stronger correlation in 2-year-olds of vocabulary size with mean length of utterance than with age. Thus, other linguistic factors than phonological skills seem to play a role in the slower vocabulary development in FR-dys as compared with FR-nondys and control children in our study.

These results indicate that an early delay in vocabulary development is a specific though weak predictor of reading fluency and dyslexia. According to the MDM, risk and protective factors interact in a complicated manner not only at the child level but also at the family level. That is, FR increases the prevalence of dyslexia from a base rate of 3%–7% to 45% (Snowling & Melby-Lervåg, 2016) but also affects the mean and distribution of the FR-nondys subgroup, in that the distribution of reading fluency as well as some language- and reading-related cognitive functions is shifted to the left in comparison with not at-risk typically developing children. At the same time, whereas there is no single cognitive deficit that is one-to-one related to dyslexia, a distinction can be made between cognitive factors that are continuously distributed among FR children and risk factors more specifically related to dyslexia risk factors, which are at the level of typically developing children in the FR-nondys children and thus can be considered protective factors. Examples of cognitive deficits that show the same stepwise performance pattern as reading fluency, in which at-risk nondyslexic children score in between at-risk dyslexic and not at-risk nondyslexic children, are the reading-related measures phonological awareness, nonword repetition, and auditory memory. In contrast, a risk factor that is more specifically related to dyslexia, such that at-risk nondyslexic children perform as well as controls, is rapid naming; above, we argued that adequate rapid naming skills can be considered a protective factor for developing dyslexia (van Bergen et al., 2012). This study shows that vocabulary size and proportion of verbs at 23 months of age, as well as proportion of closed-class words up to 35 months of age, seem to be the most sensitive indicators of delayed vocabulary development. In addition, this delay is specifically related to later reading difficulties, which suggests that an adequate vocabulary development can be considered a protective factor against dyslexia. An interpretation might be that some underlying grammatical weakness in the FR-dys group underlies the specific differences in relative frequency of grammatical categories, which—given the close-to-normal levels at 35 months of age—shows illusory recovery at 35 months of age. A few years later during development, this grammatical weakness might become manifest again in the reading acquisition process. This would further support the MDM in that multiple language factors are involved in the risk of developing dyslexia. Earlier studies (Bishop & Adams, 1990; P. Lyytinen et al., 2005) reported that late talkers have a higher risk of developing dyslexia, especially if the language delay is persistent. In this study, we showed that a slight delay in vocabulary development, especially regarding the syntactic categories predicates and closed-class words, can be considered a risk factor for developing dyslexia. The effect is weak but specific, in that FR-nondys children are similar to controls. Further research is needed to address the question whether this might imply that stimulating the acquisition of these grammatical categories contributes to preventing dyslexia.

Author Contributions

Ben Maassen: Funding acquisition (Lead), Conceptualization (Equal), Investigation (Supporting), Methodology (Lead), Supervision (Lead), Writing – original draft (Equal), Writing – review & editing (Lead). **Evelien Krikhaar:** Conceptualization (Equal), Investigation (Lead), Methodology (Equal), Project administration (Lead), Writing – original draft (Equal), Writing – review & editing (Supporting). **Aryan van der Leij:** Funding acquisition (Lead), Conceptualization (Equal), Investigation (Supporting), Methodology (Supporting), Supervision (Lead), Writing – review & editing (Supporting). **Paula Fikkert:** Conceptualization (Equal), Methodology (Supporting), Supervision (Equal), Writing – review & editing (Equal).

Acknowledgments

The reported research was part of the Dutch Dyslexia Program that was funded by Grants 200-62-302/303/304 from the Netherlands Organization for Scientific Research under the title "Early Precursors of Familial Dyslexia: A Prospective Longitudinal Study" as part of the research program "Identifying the Core Features of Developmental Dyslexia."

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