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Research Note

The Language Environment at Home of Children With (a Suspicion of) a Developmental Language Disorder and Relations With Standardized Language Measures

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ABSTRACT

Purpose: This study compares the home language environments of children with (a suspicion of) developmental language disorder (DLD) with that of children with typical development (TD). It does so by adopting new technology that automatically provides metrics about children's language environment (Language ENvironment Analysis [LENA]). In addition, relationships between LENA metrics and standardized language tests are explored in the DLD group.
Method: Ninety-nine 2- to 4-year-old toddlers participated: 59 with (a suspicion of) DLD and 40 with TD. LENA metrics on adult word count, conversational turn count, and child vocalization count were obtained. For all children, data on parental education and multilingualism were available. In the DLD group, data were collected on receptive and expressive vocabulary and grammar, and on nonverbal intelligence, using standardized tests.
Results: We found lower adult word count, conversational turn count, and child vocalization count in the DLD group, independent of multilingualism but not of parental education. In the DLD group, receptive vocabulary was related to conversational turn count and child vocalization count, but not to adult word count. Expressive vocabulary, receptive grammar, and expressive grammar were not related to LENA metrics.
Conclusions: Toddlers with (a suspicion of) DLD vocalize less at home than children with TD. They also hear fewer adult words and experience fewer conversational turns. Children with DLD's language outcomes are to a limited extent related to language environment at home. Conversational turns and child vocalizations are in this respect more important than adult words, in line with findings for TD populations.

Over the past decades, research on child language development has paid considerable attention to children's language environment at home (Blom & Soderstrom, 2020; Hoff, 2006). At the same time, a new technology has been developed to easily monitor children's language environment and provide metrics about the number of words adults use, conversational turns, and child vocalizations: Language ENvironment Analysis or LENA (LENA Research Foundation). Most studies that have used this technology have focused on children with a typical language development (TD). Strikingly, little is known about the language environment in the homes of children with (a suspicion of) a developmental language disorder (DLD).

DLD is a congenital and persistent disorder that affects children's ability to learn language (Leonard, 2014). Its prevalence is estimated at about 7% (Norbury

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et al., 2016; Tomblin et al., 1997), which is 7 times more common than autism and 46 times more common than permanent childhood hearing loss (McGregor et al., 2020). Evidence suggests that there are multiple genetic risk factors, in addition to environmental risks, which interact and together impact early brain development and the neurocognitive mechanisms underlying language learning (Bishop, 2009; Fisher, 2019). Although poor language input does not cause DLD, the treatment of DLD focuses, among other things, on parent–child interactions and providing a rich (home) language environment. Previous research has evaluated the effect of parent-implemented interventions and found these to have positive effects on the linguistic outcomes of children with suspected DLD (Heidlage et al., 2020). Nevertheless, it is unknown whether daily language experiences at home, as measured using LENA technology, are related to the language skills of children with (a suspicion of) DLD.

The twofold aim of this study is (a) to compare LENA measures about children's language environment collected in the homes of children with (a suspicion of) DLD and TD, and (b) to investigate relationships between these LENA measures and language outcomes in children with (a suspicion of) DLD.

Language Environment and Experiences at Home in TD

Child language development is determined by child-internal genetic factors and child-external environmental factors (e.g., Dale et al., 2000; Kuvač-Kraljević et al., 2021). Although the role of family socioeconomic status (SES) has attracted much attention in the literature (Hoff, 2006), factors in children's close environment, such as parental educational behaviors, have been found to be more important for children's language outcomes (Bergelson et al., 2022; Rindermann & Baumeister, 2015). For example, several studies found that the amount of language input that parents provide is positively related to children's vocabulary size (Hart & Risley, 1995; Hoff & Naigles, 2002; Huttenlocher et al., 1991; Weisleder & Fernald, 2013). Other research emphasized the importance of input quality (Hoff, 2003, 2013; Rowe, 2012) and highlighted the role of interactional features such as back-and-forth communicative exchanges (Hirsh-Pasek et al., 2015; Rowe & Snow, 2020). A recent meta-analysis of 52 studies confirmed significant associations between both parental input quantity and quality and children's language skill (Anderson et al., 2021). This study also revealed that effect sizes were larger for studies that assessed parental input in a naturalistic setting as compared with parental input during free-play or semistructured tasks in a lab setting.

Interestingly, findings in the literature suggest that, in addition to input quantity and quality, children's *own* output is a crucial experience that may impact on their language skill (Bohman et al., 2010; Hoff, 2020). In the field of adult second language acquisition, the importance of language output for language learning has been acknowledged for a long time (Swain, 2000). Regarding underlying mechanisms, it has been suggested that output pushes a learner to process language more deeply, which, in turn, supports language learning and development. Although young children acquiring a first language will be less able to reflect on their own output than adults learning a second language, there are indications that they use their self-created words as a source of input for linguistic analysis and generalization (Elbers, 1995). For this study, we therefore focused on LENA measures that represent the amount of adult input, parent–child interaction, and child output.

LENA Measures and Relations With Language Outcomes

The LENA system consists of hardware and software. LENA hardware is a digital language recording device worn by the child in a t-shirt or vest with a small front pocket. LENA software segments recordings and calculates an estimated adult word count, a conversational turn count, and a child vocalization count, providing insight into respectively amount of input, interactive dimensions of input quality (back-and-forth exchanges), and child language output.

A growing body of work has investigated whether LENA's automatically generated metrics predict variability in children's language skills. For example, Gilkerson et al. (2018) found that adult word count and conversational turn count metrics collected at between 18 and 24 months of age accounted for 3%–30% of variance in expressive and receptive vocabulary outcomes 10 years later. Analyses using metrics collected at the age of 2–17 months and $\geq$ 25 months did not reveal significant relationships. However, following children from 9 until 24 months in a longitudinal study, Donnelly and Kidd (2021) demonstrated that increases in conversational turn count predicted increases in child vocabulary size, and vice versa. In a study with children between 12 and 20 months of age, Greenwood et al. (2011) report significant correlations between both child vocalization count and conversational turn count metrics and a standardized measure of children's comprehension and expressive communication. In a meta-analysis of 17 studies including TD participants, Wang et al. (2020) showed that there were overall medium associations between both conversational turn count and child vocalization count and children's language skills, and a small-to-medium association between adult word count and language skills. Wang et al. included language modality as a moderator but found that expressive versus receptive modality did not have a significant effect. Furthermore, combining LENA and fMRI in a study with 4- to 6-year-old children, Romeo et al. (2018) found that larger conversational turn count estimates were related to stronger, more coherent white matter connectivity in the left hemisphere pathway that connects two language regions.

Although LENA has been used with children who have a variety of communication disorders, hardly any research has used LENA to investigate the home environment of children with DLD (Ganek & Eriks-Brophy, 2018). In the next section, we will expand on this specific and substantial population of language learners.

DLD and the Role of Home Environment

Given the weak language abilities of the child, and the fact that there is a genetic risk factor involved in DLD, the language environment at home and parent–child interactions in families with DLD children may differ from families with children with TD. The evidence for such differences is scarce, although there are indications that children with DLD initiate fewer conversational turns (e.g., Blackwell et al., 2015; Van Balkom et al., 2010). Different parental language use in families with DLD children, and different parenting behaviors more broadly, have been suggested to reflect the parents' adjustment to the children's lower linguistic abilities (e.g., Blackwell et al., 2015; Conti-Ramsden & Friel-Patti, 1983; Hammer, 2002; Hammer et al., 2001). For example, parents of children with weak language skills may use more directive language, more nonverbal strategies, and language that is less demanding for the child to comprehend (Hammer et al., 2001; Pellegrini et al., 1985). An alternative explanation for these observations is that caregivers of children with DLD may themselves carry genetic predisposition for DLD, and hence, their language level may be lower and they may show fewer turn-taking irrespective of their children's DLD. Further investigations of the home language environment of children with DLD are needed to establish if and how the home language environments of children with DLD and TD differ.

This Study

This study aimed to compare aspects of the language environment and experiences at home (input quantity, input quality, and output) of children with (a suspicion of) DLD and TD using the automatized LENA system metrics (adult word count, conversational turn count, and child vocalization count) derived from day-long recordings in the home. The second aim was to examine relationships between these home environment measures and a variety of language outcomes of standardized language tests (i.e., receptive vocabulary, expressive vocabulary, receptive grammar, and expressive grammar) in children with (a suspicion of) DLD.

Research Questions

1. Do the DLD and TD groups differ in adult word count, conversational turn count, and child vocalization count
2. Are adult word count, conversational turn count, and child vocalization count related to the language skills of children with DLD?

Predictions

1. We predicted lower adult word count, conversational turn count, and child vocalization count in the DLD compared with the TD sample. Parents in the DLD group may use fewer words to adapt to the language level of their children or because they have a low language level themselves (which may not be unlikely given the genetic component of DLD). Fewer conversational turns were expected because of turn-taking difficulties of children with DLD. Moreover, there are some indications that parents of children with DLD are somewhat less responsive and that children with DLD initiate fewer conversational turns, which may translate in fewer parent–child turns in conversations (Blackwell et al., 2015; Hammer, 2002). Fewer child vocalizations were expected because previous research found that 16- to 31-month-old children with DLD vocalized less than their peers with TD during the administration of a tablet-based app (Tenenbaum et al., 2020). In another study, it was found that at the age of 24 months toddlers with expressive language impairment vocalized less than TD controls (Rescorla & Bernstein-Ratner, 1996). At 30 months, there was, however, no significant difference in number of vocalizations (Roberts et al., 1998).
2. Based on empirical findings in studies about TD, we expected that conversational turn count, child vocalization count, and, to a lesser extent, adult word count would be significantly related to vocabulary and grammar outcomes of children with DLD (Wang et al., 2020). Conceivably, adult word count, which is a *word* count, is more relevant for vocabulary (which concerns words) than grammar (which concerns relations between words and word order). We had no specific expectations regarding differential effects on receptive versus expressive language skills (Wang et al., 2020).

Method

Participants

In total, 116 families were recruited to take part in this study with their children. The group of participating children consisted of 75 toddlers with (a suspicion of) DLD and 41 toddlers with TD. Children in the DLD group were recruited from special treatment groups for toddlers with DLD within the Royal Kentalis. LENA recordings of 11 children in the DLD group were excluded from further analyses, because parents did not manage to make the recording within the given time frame. Furthermore, five families returned a recording that appeared to be shorter than 8 hr (four DLD and one TD) and one child (DLD) fell ill during the day of recording. The final data set that we used for the statistical analyses consisted of a DLD group of 59 children and a TD group of 40 children.

The average age of both the DLD group (49 boys and 10 girls) and TD group (30 boys and 10 girls) was 42 months (DLD: range 29–53 months, SD = 5.6; TD: range 29–58 months, SD = 5.6). All children lived in the Netherlands. As on average 20% of all children in the Netherlands are multilingual (CBS, 2021) and we wanted our sample to reflect the clinical reality in the Netherlands, we did not exclude multilingual children. In our sample, 21% of the children with DLD and 15% of the children with TD were multilingual, that is, grew up in a family in which at least one other language was spoken, in addition to Dutch. The groups did not differ in gender distribution, $\chi^2(1) = .96$, $p = .33$; mean age, $F(1, 97) = 0.042$, $p = .84$; or multilingualism, $\chi^2(1) = .76$, $p = .38$. The two groups did differ in the educational level of the mothers, which was significantly lower for the mothers of the children with DLD (DLD: 31% low, 34% middle, and 36% high) than for the mothers of the children with TD (TD 5% low, 10% middle, and 85% high; $U = 1779$, $p < .001$). Mother's education was available for all children. The two groups also differed in the educational level of fathers, which was significantly lower for the fathers of the children with DLD (DLD: 35% low, 31% middle, and 35% high) than for the fathers of the children with TD (TD 8% low, 26% middle, and 66% high; $U = 1{,}441$, $p < .001$). Father's education was available for 55 children in the DLD sample and 38 children in the TD sample. In our analyses, we included parental education as a control variable.[1]

All children in the DLD group were diagnosed by a speech and language pathologist as having severe language difficulties in the context of nonverbal intelligence within the normal range. As part of the diagnostic procedure, children were assessed by means of a battery of standardized (language) tests: Nonverbal cognitive skills were estimated with a Dutch nonverbal intelligence test (SON-R 2.5–7; Tellegen et al., 1998), receptive language skills were evaluated with the Peabody Picture Vocabulary Test–Dutch Version (Schlichting, 2005) and the Schlichting Test for Language Comprehension (Schlichting & Lutje Spelberg, 2010a), and expressive language skills were measured by the Schlichting Test for Language Production (Schlichting & Lutje Spelberg, 2010b). Furthermore, hearing was assessed by an audiologist to make sure that the language problems were not caused by any severe hearing loss. All children in the DLD group had at least one expressive and/or receptive language score of 1 *SD* or more below the mean. Some children mainly had expressive language problems while their receptive language abilities were in the normal range, whereas other children had a combination of expressive and receptive language problems. Children with TD were recruited from the subject pool of the Baby & Child Research Center of Radboud University in Nijmegen. Children could only participate if there was no indication of any developmental disorder based on an intake questionnaire with parents (e.g., familial risk of language problems, whether children had seen a speech and language therapist). Participant characteristics are presented in Table 1.

Procedure

Data collection for this study took place as part of a larger research project. This research was approved by the Standing Ethical Assessment Committee of the Behavioural Science Institute at Radboud University in Nijmegen. Parents of children gave their written informed consent for their participation in this research project. Parents received an online questionnaire asking information regarding background variables, such as the educational level of the parents. Each parent received a LENA recording device, two custom LENA shirts (with a pocket to hold the recording device), and instruction about how to make the recording (personally and on paper). Parents were asked to make a daylong uninterrupted recording of at least 8 hr at home with their child. They were instructed to start the recording as soon as the child woke up in the morning and stop the recording when the child went to sleep at the end of the day. When the shirt could not be worn (e.g., during nap time or bath time), parents were instructed to put the shirt with the (running) recording device near the child. In addition, they were asked to fill out a one-page logbook and indicate per hour if the

[1]Low educational level is comparable with less than high school or the lowest level of high school. Middle educational level is comparable with high school (higher than lowest level) or community college, and high educational level is comparable with college or university.

Table 1. Participant characteristics.

Variable	DLD	TD
Number	59	40
Gender	10 girls/49 boys	10 girls/30 boys
Age mean (*SD*) in months	41.86 (5.59)	42.10 (5.58)
Age min–max in months	29–53	29–58
Education mother (median)[a]	2	3
Education father (median)[a]	2	3
Multilingual family	13	6
Nonverbal intelligence mean (*SD*)	100.33 (12.86)	NA
Receptive vocabulary mean (*SD*)	92 (17.20)	NA
Receptive grammar mean (*SD*)	83.30 (14.70)	NA
Expressive vocabulary mean (*SD*)	68 (15.42)	NA
Expressive grammar mean (*SD*)	71.09 (7.79)	NA

Note. Nonverbal intelligence was measured with the SON-R, receptive vocabulary with the Peabody Picture Vocabulary Test, receptive grammar with the Schlichting Test for Language Comprehension, and expressive vocabulary and grammar with the Schlichting Test for Language Production; all standardized measures are quotient scores. DLD = developmental language disorder; TD = typical development; NA = not applicable.

[a]Education was measured on a three-point scale.

child was wearing the shirt, where the child was (e.g., inside at home, outside in the garden, and in the supermarket), what activity the child was involved in (e.g., sleeping, eating, and playing), and with whom (e.g., father, mother, siblings, and other children). Parents could also indicate when the child was ill or feeling bad that day or when they thought it was not a representative day for any other reason. The recording device and (anonymous) logbook were sent back to the researchers per mail.

LENA System and Measures

The LENA system consists of a recording device (DLP: Digital Language Processor) and LENA software with which the data from the DLP can be processed and analyzed. The DLP weights around 57 g and fits into the pocket of a specially designed T-shirt and can record up to 16 hr of audio in encrypted format to onboard solid-state memory. For each daylong recording of at least 8 hr, three LENA metrics reflecting the language environment were included in the analysis (Gilkerson & Richards, 2008): adult word count, conversational turn count between adult(s) and key child, and key child vocalization count.

Based on audio features such as the pitch and volume, speech segments are assigned to different LENA metrics. Adult word count is the outcome of an algorithm including the speech segments that are categorized as produced by a male adult speaker or female adult speaker in the vicinity of the child. This algorithm gives an estimation of the number of words, which is derived from the estimated phone counts by the LENA/Sphinx ASR Phone Decoder (Richards et al., 2008). Similarly, child vocalization count includes the speech segments categorized as vocalizations by the key child (i.e., excluding sounds such as sneezing, burping, crying, and laughing). Conversational turn count is calculated as the number of conversational interactions between the child and an adult, in which one speaker initiates a conversation and the other speaker responds within 5 s.

Results

Raw data and SPSS syntax and output files detailing all analyses can be accessed through the following link: https://osf.io/jstxy/.

LENA Measures in DLD and TD

The three LENA metrics are presented in Table 2. The descriptive statistics showed a lower adult word count, conversational turn count, and child vocalization count in the DLD group compared with the TD group. Adult word count correlated positively and strongly with conversational turn count, $r(99) = .77$; adult word count correlated positively but weakly with child vocalization count, $r(99) = .29$; and conversational turn count and child vocalization count showed a strong positive correlation, $r(99) = .73$. All correlations reached statistical significance.

Because of significant correlations between the three LENA metrics, a multivariate analysis of variance (MANOVA) analysis was performed. Box's M was not significant. Pillai's Trace showed a significant effect of Group, $F(3, 95) = 4.57$, $p = .005$, $\eta_p^2 = .13$. Inspection of univariate ANOVA's revealed that children with DLD heard fewer adult words, $F(1, 97) = 9.75$, $p = .002$,

Table 2. Means (*SD*) of Language ENvironment Analysis (LENA) automated measures in DLD and TD.

Count	DLD	TD
Adult words	13,071 (5,678)	16,744 (5,840)
Conversational turns	740 (299)	974 (375)
Child vocalizations	3,519 (1,319)	4,278 (1,435)

Note. DLD = developmental language disorder; TD = typical development.

Table 3. Correlations between Language ENvironment Analysis (LENA) automated home environment language measures and standardized language measures in developmental language disorder (DLD).

Count	Receptive vocabulary	Expressive vocabulary	Receptive grammar	Expressive grammar
1. Adult words	.11	−.10	.03	−.05
2. Conversational turns	.33*	−.03	.11	.05
3. Child vocalizations	.31*	.003	.09	.10

Note. Receptive vocabulary was measured with the Peabody Picture Vocabulary Test, receptive grammar with the Schlichting Test for Language Comprehension, and expressive vocabulary and grammar with the Schlichting Test for Language Production.
*$p < .05$.

$\eta_p^2 = .09$; experienced fewer conversational turns, $F(1, 97) = 11.88$, $p < .001$, $\eta_p^2 = .11$; and produced fewer vocalizations, $F(1, 97) = 7.34$, $p = .008$, $\eta_p^2 = .07$, than children in the TD group. The MANOVA was followed by three MANCOVAs, in which we added parental education as covariate. First, education mother was entered as covariate. This enabled including the full sample and comparing our study to other research in the field, which typically investigates maternal education (Hoff, 2006). It turned out that the effect of group became less strong, but in terms of statistical significance, the results remained unaltered. Second, education father was covaried, in line with increasing attention for father language input (Leech et al., 2013; Pancsofar et al., 2010). Covarying education father led to a nonsignificant effect of group, $F(3, 88) = 2.34$, $p = .079$, $\eta_p^2 = .07$. Third, we reran the MANCOVA with education mother as covariate excluding the six children for whom education father was not available. This time, the effect of group did not reach significance, $F(3, 88) = 2.12$, $p = .092$, $\eta_p^2 = .07$, suggesting that lower LENA metrics in the DLD sample are related to lower parental education, and that there is no differential effect of covarying education mother versus education father. Addition of multilingualism as covariate did not affect the results.

LENA Automated Home Environment Measures and Child Language Skill in DLD

Correlations between LENA language environment measures and receptive vocabulary, expressive vocabulary, receptive grammar, and expressive grammar scores of the children with DLD are presented in Table 3.

Correlations between conversational turn count and child vocalization count, on the one hand, and child receptive vocabulary, on the other hand, were significant. Therefore, we performed a multiple linear regression analysis with receptive vocabulary as dependent variable, the control variables nonverbal intelligence, education mother,[2] and multilingualism added in Step 1, and the predictor variables conversational turn count and child vocalization count added in Step 2 (see Table 4). Both in Step 1, $F(3, 52) = 11.06$, $p < .001$, and Step 2, $F(5, 50) = 9.38$, $p < .001$, a significant amount of variance was explained. In Step 2, significantly more variance was explained compared with Step 1, $\Delta R^2 = .09$, $F(2, 50) = 4.58$, $p = .015$. Multicollinearity diagnostics indicated a variance inflation factor value of 2.22 and a tolerance value of .45 for conversational turn count and child vocalization count, which indicated that no multicollinearity exists. The residuals were normally distributed and homoscedastic. Using Mahalanobis distances, we could not detect any multivariate outliers. As the results in Table 4 demonstrate, conversational turn count and child vocalization count did not have a unique effect on receptive vocabulary. Nonverbal intelligence was a significant control variable, indicating that children with a higher nonverbal intelligence score had larger receptive vocabularies.

Discussion and Conclusions

Many studies have investigated language outcomes of children with DLD, but few studies have explored the home language environments of this group of children even though recent research suggests that language experience at home is linked to children's language outcomes (Wang et al., 2020). Therefore, this study aimed at comparing the home language environment of children with (a suspicion of) DLD and TD. To this end, we used the automated LENA metrics about adult words, conversational turns, and child vocalizations. The results showed that, compared with TD controls, children with (a suspicion of) DLD are exposed to fewer adult words at home. They also experience fewer conversational turns and vocalize less than their TD peers. Parents of children with DLD may talk less, because they themselves experience language limitations. Another possibility is that parents of children with DLD use fewer words to adapt to their children's language level (Blackwell et al., 2015; Conti-Ramsden & Friel-Patti, 1983; Hammer, 2002; Hammer et al., 2001). In the same vein, limited turn taking in the DLD group may be child initiated (Blackwell et al., 2015; Hammer, 2002; Van Balkom et al., 2010).

[2]Results were the same when education father was added as control variable.

Table 4. Regression model predicting receptive vocabulary outcomes in developmental language disorder (DLD).

Steps	*B*	*SE*	Β	*t*	*p*	Adj. R^2
Step 1						.35
Nonverbal intelligence	0.825	0.152	.588	5.415	< .001	
Education mother	1.476	2.299	.070	0.642	.524	
Multilingualism	−7.876	4.476	−.192	−1.760	.084	
Step 2						.43
Nonverbal intelligence	0.822	0.144	.586	5.709	< .001	
Education mother	1.161	2.158	.055	0.538	.593	
Multilingualism	−6.856	4.213	−.167	−1.627	.110	
Conversational turn count	0.017	0.009	.288	1.901	.063	
Child vocalization count	0.000	0.002	.028	0.183	.855	

Note. *SE* = standard error.

In the literature, lower input quantity and quality at home has been linked to lower maternal education (Hoff, 2006; Piot et al., 2021). A series of covariance analyses suggested that lower adult word count, conversational turn count, and child vocalization count in the DLD group was related to lower parental education, irrespective of whether maternal or paternal education was covaried. Note that both lower education of the parents in the DLD sample and lower LENA metrics could be related to the genetic component of DLD and originate in parental language limitations. Previous studies investigating potential differences in the home language environment between DLD and TD groups have not always included a measure of SES, such as parental education (e.g., Tenenbaum et al., 2020). Other studies matched groups on measures of SES but did not report on the potential role of SES in the relationship between characteristics of the home language environment and group status (e.g., Rescorla & Bernstein-Ratner, 1996; Roberts et al., 1998). The present results confirm that effects of parental education (or other measures of SES) are relevant, in line with a recent meta-analysis that revealed an effect of SES on children's home language environment as measured using LENA metrics (r = .186; Piot et al., 2021).

Our second aim was to explore whether adult word count, conversational turn count, and child vocalization count are associated with DLD children's language outcomes, measured with standardized language tests. This is relevant in light of previous research that identified family history of DLD as a major risk factor for DLD but found that environmental input has some predictive power as well (Sansavini et al., 2021). We observed that receptive vocabulary was related to conversational turn count, but not to adult word count, which resembles findings for TD populations (Wang et al., 2020), and suggests that qualitative, interactive aspects of the input are more important than sheer quantity at this age (Hirsh-Pasek et al., 2015; Hoff, 2003; Rowe, 2012). These results are in line with a recent study that has suggested that qualitative aspects of parent–child interactions are associated with better receptive language ability in children with DLD specifically (Jokihaka et al., 2022). Furthermore, the observation that child vocalization count was related to receptive vocabulary confirms the importance of child output (Bohman et al., 2010; Elbers, 1995; Hoff, 2020), suggesting that, also for child language learners with (a suspicion of) DLD, children's own output promotes their language development.

Although statistically significant, relationships between conversational turn count/child vocalization count, on the one hand, and receptive vocabulary scores, on the other hand, were relatively weak, and conversational turn count and child vocalization count had no unique separate contribution. It is possible that these weak relationships are specific to DLD and are related to the processing limitations that children with DLD experience. For example, children with DLD process sentences slower (Montgomery, 2006), are less able to retain information in phonological memory (Archibald & Gathercole, 2006), are slower to predict upcoming words in a sentence (van Alphen et al., 2021), and have difficulties sustaining attention to audio-linguistic stimuli (Ebert & Kohnert, 2011). These processing and attentional limitations may hamper using linguistic experiences for language learning resulting in weaker relations between home language environment measures and language skill. Future research should point out if relationships between home language environment and language outcomes are indeed weaker for children with DLD compared with children with TD.

Finally, we wish to acknowledge several limitations. First, although LENA metrics have been shown to have predictive value in the English-speaking context (13 out of 15 studies in the meta-analysis were conducted with English-speaking children; Wang et al., 2020), the reliability of LENA child vocalization count and conversational turn count metrics in Dutch-speaking children aged between

5 and 14 months has been shown to be rather low (r = .38 and r = .24, respectively), while the overall accuracy of adult word count was good (r = .78; Bruyneel et al., 2021). More work is needed to reach conclusions about the reliability and validity of the LENA system in languages other than English, including Dutch, and in older children. Second, regarding their language outcomes, many children in the DLD group perform at the lowest end of the distribution. Limited variation in language outcomes, particularly in expressive grammar outcomes, may have hampered detecting significant correlations with LENA metrics. Third, nonverbal intelligence and language measures were not collected for the TD group in this study, which means we were unable to compare groups with respect to the relationship between LENA metrics and language outcomes. Fourth, due to the correlational results of this study, we cannot establish the direction of the relationship between LENA metrics and language outcomes in children with DLD. Future studies could adopt a longitudinal design, and compare DLD with TD, to further elucidate the potential causal effects of (LENA) home language environment measures on child language proficiency.

Author Contributions

Elma Blom: Conceptualization (Lead), Formal analysis, Writing – original draft (Lead), Writing – review & editing (Equal). **Paula Fikkert:** Conceptualization (Supporting), Investigation (Equal), Writing – review & editing (Equal). **Annette Scheper:** Conceptualization (Supporting), Writing – review & editing (Equal). **Merel van Witteloostuijn:** Conceptualization (Supporting), Writing – original draft (Equal), Writing – review & editing (Equal). **Petra van Alphen:** Conceptualization (Supporting), Data curation, Funding acquisition, Investigation (Equal), Supervision, Writing – original draft (Equal), Writing – review & editing (Equal).

Data Availability Statement

The data that support the findings of this study are openly available on the Open Science Framework (OSF): https://osf.io/jstxy/. ITS files and metadata of daylong LENA recordings used in this study are also publicly available on OSF: https://osf.io/ymv7b.

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