The LENA System in Parent-Child Interaction in Dutch Preschool Children with Language Delay

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Introduction

Developmental language delay is not uncommon in preschool children.[1] According to Law et.al.[2], most preschoolers recover without intervention. However, when language problems are persistent, it can result into a specific language impairment (SLI). SLI is a significant language delay in absence of cognitive deficits, hearing loss or frank neurological problems and affects about 7% of children.[3-5] Morphosyntactic and phonologic problems, accompanied by a weakness of working memory are frequently present in SLI and can impact considerably on lower social wellbeing and limited educational or employment opportunities.[5,6] To prevent these negative effects, children up to five years of age with severe language delay may be eligible to attend an early intervention program. This program provides intensive language therapy from a multidisciplinary perspective.

Attending an early intervention program increases verbal skills of children with language delay.[7,8] However, linguistic skills and social interaction of both typically developing children and children with language delay can primarily be predicted from language input in home environment.[9-13] Therefore, speech and language pathologists (SLP's) in early intervention programs teach parents how to enhance the language skills of their child by applying a parent-child interaction program (PCIP), such as the Hanen Parent Program.[9,14-20] PCIP's start with encouraging parents to be attentive to all communicative attempts of children. Subsequently, parents learn to apply the OWL-principles (Observe, Wait, Listen)[21] in interaction with their child. The ultimate goal is that parents will be responsive in their verbal behavior, to create a joint conversation at the language level of the child.[9,14,22-24]

Based on literature review, Levickis et.al.[18] recently defined parental responsiveness into six strategies: imitations, expansions, interpretations, labels, supportive directives, responsive questions. These concepts of responsiveness are basic principles of PCIP's. Besides, when parents are involved in a PCIP , they need to learn to transfer the PCIP-strategies into their home environments, because Roberts et.al. state that responsiveness is only effective when practiced in the context of daily activities.[9] Parental responsiveness in parent-child interaction is known to increase the child's language skills.[24,25] Baxendale[22] questions whether all parents of children with SLI are in need of a PCIP, since some parents spontaneously apply responsive behavior in interaction. Moreover, previous studies showed that parent-child background characteristics, for example the language skills of the child, the number of children in the family and educational level of the parent, influence the effectiveness of a PCIP or the quantity of responsive behavior.[1,10,13,15,18,22,26,27]

Most PCIP's evaluate parental responsiveness using video recordings. Usually, a structured-play situation or shared book-reading in therapy or home environment is analyzed and discussed.[6,11,15,26,28,29] The presence of a video camera as well as an imposed structured-play situation are likely to create a situation unrepresentative of parent-child

interaction in every-day life. Moreover, in-depth analysis of video recordings requires either human transcription of language, or evaluation of the whole recording. Both are extremely time-consuming.[6,11,18] Therefore, there is a strong need for another way to evaluate parental responsiveness that is less time consuming and more representative for parent-child interaction in daily life. The LENA (short for Language ENvironment Analysis) system may be filling this gap by providing an automatic language collection device that is collecting all language input in the environment of the child.

In 2006, the LENA Research Foundation developed an automatic language collection and analysis device.[10] A digital language processor (DLP) is worn by the child for 10-16hrs consecutively. Recorded data stored in the DLP is transferred to a computer with LENA software for further analysis. Algorithmic models based on acoustic measurements and segmentation first separate sounds from silence. More refined analysis separates sounds from male adult, female adult, key-child, other child and overlapping noise (OLN) and later on it separates speech-related sounds from vegetative sounds. Finally, the main categories adult word count (AWC), child vocalizations count (CVC), conversational turns count (CTC) are displayed by estimations based on these algorithms. A more in-depth analysis can be performed with LENA's software to gather more information, for example on which speaker initiates the interaction (ITT).[10,30] A major advantage of LENA is the timesaving analysis compared to manual transcription of other language samples. Furthermore, the collected LENA-data represents the child's language experience in a home environment during an entire day, which is more representative of daily input than a brief structured-play situation.

In the past five years, LENA has been proven to be a useful tool to explore the language environment of American English children with SLI, hearing loss or autism.[10,13,17,24,27,31,32] More recently, studies started to explore the possibilities of the LENA system in cross-linguistic environments.[33,34] In the Netherlands, Royal Dutch Kentalis (Kentalis)[35] and the Dutch Foundation of Deaf and Hard of Hearing Children (NSDSK)[36] perform an ongoing study to explore possibilities of the LENA system in providing an overview of language input in home environments of Dutch children with language delay attending an early intervention program.

LENA's estimated counts contribute to a better understanding of the language input in home environments.[10,30] Nevertheless, an efficient screening tool for parental responsiveness is presently lacking.[22] Therefore, this current study aimed to explore the usefulness of LENA in analyzing parental responsiveness during parent-child interaction in Dutch children with language delay. The CTC is thought to be essential in analyzing parental responsiveness, as it estimates the amount of parent-child interaction. So far, LENA's CTC has not been investigated in the Kentalis/NSDSK-study. Therefore, conversational turns were the main focus of the current study. Those are estimated by LENA by predetermined rules: (1) a

speaker responded within 5 seconds to the initiated utterance, (2) the interaction was not interrupted by other speakers and (3) there was no significant overlap of the complete utterance between speakers. For example: 'Child initiation–Parent response' results in one conversational turn, if the response occurs within five seconds. In addition to CTC, other LENA output variables were studied to explore whether combining LENA-estimated outcomes with parent-child background characteristics may contribute to better selection of parents in need of a PCIP.

For this study three specific research questions were addressed: (1) Is the automatically estimated CTC from LENA related to manual count of conversational turns? Based on the assumption that universal cross-linguistic features in turn taking exist[37], and former studies in USA[33] and China[34] where the LENA system showed reliability in cross-linguistic contexts, it is expected that the conversational turns count is a reliable measurement tool for the Dutch language.

(2) Are automatically estimated LENA output variables related to the degree of parental responsiveness during parent-child interaction in preschool children with language delay? In concordance with studies without the use of the LENA system[15,16,22], it is hypothesized that LENA's output variables CVC, CTC and ITT show a strong positive relationship and the variable AWC a moderate negative relationship with parental responsiveness.

(3) Which automatically estimated LENA output variables and parent-child background characteristics are predictive of low parental responsiveness during parent-child interaction in preschool children with language delay? At least the LENA output variables CVC, CTC and AWC and the child's language skills are assumed to predict parental responsiveness, based on studies with and without the use of LENA.[10-12]
When a relationship as well as predictive variables can be established in this study, this would support the application of the LENA system as a screening tool for parents in need of a PCIP.

Method

Setting and participants

The current exploratory study examined the accuracy of LENA in estimating the number of conversational turns in Dutch and the association between parental responsiveness and automatically estimated LENA variables. Recordings obtained in the ongoing Kentalis/NSDSK-study were used for further analysis. Therefore this study is classified as a secondary analysis with a cross-sectional design.

Parents of children attending early intervention groups of Kentalis and NSDSK were asked to participate in the Kentalis/NSDSK-study when they had not (yet) participated in a PCIP and were native Dutch speakers. All children were between age 2;6-3;6, suspected of SLI, not suspected of autism and monolingual raised. All parent-child pairs who agreed to participate before March 31st 2015 were included in the current study. Since only a convenient sample of 14 parent-child pairs could be included, this study was designed as a pilot study.

Participating parents filled out a questionnaire with additional background characteristics and kept an activity journal during the day of recording. Table 1 summarizes the characteristics of included parent-child pairs. All children wore LENA's DLP for at least 10hrs consecutively. Parents were strongly advised to record on a typical day at home, preferably with (one of) the parents present. Recordings on a school day were not recommended because of the collection of language input in home environments. Afterwards, the recordings were uploaded into a laptop with the LENA analysis software.

The current research was conducted according to the principles of the Declaration of Helsinki (version 64th, October 2013)[38] and in accordance with the Medical Research Involving Human Subjects Act of the Dutch Law Medical-Scientific Research (WMO).

INSERT TABLE 1 ABOUT HERE

Procedures

LENA software analysis. Estimated numbers of AWC, CVC, CTC of the entire recording were easily extracted from the LENA Pro software and were displayed in monthly, daily, hourly and 5-minute segments. More in-depth analyses of all LENA variables, including ITT, were extracted from the LENA Advanced Data Extractor (ADEX). All mentioned LENA output variables are displayed in absolute numbers.

Conversational turns. In the LENA ADEX software, the number of conversational turns was sorted from the highest to the lowest number per 5-min. segment. Then, a sample of 60 conversational turns was selected. The 5-min. segments with the highest number of conversational turns were selected first, until a total of 60 for every parent-child pair was

reached. This way, all conversational turns were selected independent of activities. Sixty conversational turns provide sufficient utterances to perform a language sample analysis.[14,15,39-41]

A key-parent was established for each parent-child pair. Either the parent most present according to the activity journal or the parent most present in the selected 5-min. segments was designated as key-parent. As LENA combines female and male utterances for the estimated AWC, some selected segments did not capture interaction between the child and key-parent. In that situation, the subsequent segment with the key-parent present in the recording was selected. After selection of all 5-min. segments, the actual audio files were downloaded from the LENA Pro software.

Manual transcription. All recorded speech in the retrieved audio files was orthographically transcribed, using a Sennheiser HDR 160 headphone. As most language sample analysis sheets are meant for calculation of linguistic variables rather than exploration of conversational turns, a specially designed spreadsheet was used for this purpose. After transcription, conversational turns were manually counted based on the aforementioned rules of LENA. When an utterance was not intelligible after three listening attempts it was marked as unintelligible and excluded from further analysis. Additionally, conversational turns between the child and other adults or children were excluded from further analysis.

Comparison of conversational turns. After manual transcription, the oscillogram with labelled segments of the LENA analysis software was studied in Transcriber 1.5.1.[42] All utterances labelled as conversational turns between key-parent and child in the selected segments were reported in the aforementioned spreadsheet. Then, the total number of manual conversational turns was compared with LENA's CTC.

Parental responsiveness. All utterances of key-parents during parent-child interaction in the manual transcription were categorized into responsive or no-responsive behavior. Table 2 presents examples and definitions of the five categories used, where responsiveness is based upon the study of Levickis et.al.[18]

As explained, LENA only counts a conversational turn when an utterance is followed by a response. Some adult utterances, however, are replies to a child's utterance but are not followed by a child's utterance. Those utterances were not labelled as 'Adult Initiation' (AI) or 'Adult Response' (AR) nor were they counted as a conversational turn. LENA labelled these utterances as 'Adult End' (AE), as illustrated in Table 3. The assumption is that parents are more responsive when replying to a child's utterance. Therefore, all utterances of key-parents classified by LENA as AE were added to the analysis of parental responsiveness. Following this, PARESP was calculated as the percentage of responsive verbal behavior from the total number of intelligible parental utterances during interaction.[22]

INSERT TABLE 2 & 3 ABOUT HERE

Background characteristics. Based on previous research[10,13,15,18,22,26,27] and the content of the questionnaire from the Kentalis/NSDSK-study, five background characteristics were included. The educational level of the key-parent (ELP) and the number of children in the family (NCF) were provided by parents in the questionnaire.

From early intervention groups, documented scores of expressive and receptive language skills assessments were available. All parents were asked for permission to retrieve four quotients of language tests: TBQ (Schlichting Receptive Language Test[43]) and WBQ (Dutch version of the Peabody Picture Vocabulary Test[44]) both indicated receptive language skills. WQ and ZQ (Schlichting Expressive Language Test – word level and sentence level[45]) indicated expressive language skills. The lowest receptive quotient (RLQ) and the lowest expressive quotient (ELQ) were used in predicting parental responsiveness.

For each child, the mean length of utterance (MLU) was calculated by identifying the number of understandable words in intelligible utterances in the manually transcribed language samples. Symbolic noises, single word responses, repetition of the same word or phrase (>3) and rote passages (e.g. counting) were excluded. The remaining number of words was divided by the total number of intelligible utterances.[22] A maximum of 100 utterances were analyzed.

LENA variables. The retrieved numbers of AWC, CTC, CVC and ITT in LENA Pro software were estimated for the total duration of the recording. To eliminate differences due to recording length, all variables were levelled to a 10hr recording for equal comparison (Figure 1).

INSERT FIGURE 1 ABOUT HERE

Blinding. All recordings of parent-child pairs were anonymized by researchers of the Kentalis/NSDSK-study. The main researcher of this study was blinded for background characteristics and LENA output variables during analysis of responsiveness and MLU calculation to maintain objectivity. Hence, obtaining children's language quotients occurred after language sample analysis.

Reliability. Intrarater and interrater* reliability of manual transcription was performed with approximately 10% of the data. Intra rater reliability of conversational turns, parental utterances and child utterances obtained good results (ICC over .90), whereas interrater

* Two raters: CJ, first author, SLP and MD, trainee SLP

reliability showed comparable outcomes for conversational turns and parental utterances (ICC over .90) and satisfactory results for child utterances (ICC .75). Outcomes of the mean content related agreement in parental and child utterances were satisfactory (69-84%). Interrater reliability of MLU and responsiveness differed (ICC .83 and .37 respectively). Cases of disagreement were resolved by discussion.

Statistical analysis. Descriptive statistics were reported by means and SD's for continuous variables and percentages and numbers for categorical data. Due to the small number of subjects, normality was not assumed and all comparisons were made using non-parametric tests. The significance level was set at .05 (2-tailed). A one-samples test was used to analyse the accuracy of the LENA system for conversational turns. Correlation between parental responsiveness and the LENA output variables was assessed with Kendall's tau, whereas a multiple linear regression analysis was carried out to predict the dependent variable PARESP from LENA variables and additional background characteristics. Missing data was handled by available case analysis. Statistical analyses were performed using SPSS 20 for Windows.[46]

Results

Accuracy of conversational turns

The most striking observation after manual transcription was the difference between manual and LENA counts of conversational turns. For each parent-child pair, 60 conversational turns were selected from LENA (SD = 0). The manual count showed a mean of 114 conversational turns (SD = 28.95, 95% CI [97.22, 130.64]). A non-parametric Kolmogorov-Smirnov test with $\mu = 60$ and SD = 28.95 indicated that the manual count was significantly higher than 60: $Z = 2.56$, $p < .000$. Figure 2 shows that not only the mean difference between LENA count and manual count was large, there were also substantial inter-subject differences.

This observation resulted in a more in-depth analysis of LENA labelling. Thirty-four types of errors were encountered in LENA's segmentation process. Figure 3 illustrates nine error types found in minimally 10 out of 14 parent-child pairs. Six error types were present in all subjects. On average, 48% of mislabeling was caused by wrong segmentation of utterances (e.g. parental speech was confused with children's speech or vice versa). Approximately 35% of errors were caused by LENA's label OLN (e.g. overlap by wind or environmental noise) while the utterances were well intelligible. Due to mislabeling and OLN-labelling, conversational turns were unnoticed and thus not included in LENA's CTC. Hence, substantial differences were found between LENA's CTC and manual CTC in some parent-child pairs.

INSERT FIGURE 2 & 3 ABOUT HERE

Association between parental responsiveness and LENA variables

Parental responsiveness was calculated for each key-parent as shown in Table 4. The mean parental responsiveness was 38%, which is in tune with the finding of Girolametto et.al. in Canadian parents.[26] Surprisingly, the number of adult words, conversational turns and child vocalizations in this sample were not significantly associated with parental responsiveness (AWC τ = -0.14, p = n.s.; CTC τ = 0.12, p = n.s.; CVC τ = 0.17, p = n.s.). A fair positive, non-significant relationship was found between parental responsiveness and initiation of turn taking (ITT τ = 0.30, p = n.s). This may suggest a tendency in which parents of children who initiate more interaction, are fairly more responsive during interaction.

Prediction of parental responsiveness

For each child, RLQ, ELQ and MLU were calculated (Table 4). Remarkably, only two children reached the required 100 analyzable utterances for MLU calculation in the transcribed files. Therefore, differences in MLU calculation with <60 and >60 analyzable utterances were preliminary tested using Mann-Whitney for independent samples. Results indicated no significant difference (Z = -1.16, p = .25) in the MLU outcome. Thus, MLU was adopted in the regression analysis with a varying number of utterances per child.

Parental responsiveness was predicted from nine variables: AWC, CTC, CVC and ITT from LENA and the background variables NCF, ELP, RLQ, ELQ and MLU (Table 5). Multicollinearity was expected based on interrelated LENA variables, therefore a stepwise backward model was used. Although a model was fitted with the variable ITT, neither the model significantly changed from zero, nor a significant partial correlation was found. Therefore, based on this sample, no regression model can be defined for predicting parental responsiveness. Hence, no evidence was found to predicted parental responsiveness from these variables.

INSERT TABLE 4 & 5 ABOUT HERE

Discussion

The aim of this pilot study was to find out whether the LENA system useful in analyzing responsive behavior of Dutch parents. To achieve this, the accuracy of the LENA system in conversational turns, the relationship between parental responsiveness and LENA variables and the prediction of parental responsiveness from LENA variables and background characteristics were analyzed.

The accuracy of the LENA system. Manual counting of conversational turns differed significantly from LENA's count. In addition, substantial differences were found between parent-child pairs. In-depth analysis showed that LENA appropriately counts the conversational turns by applying the predetermined rules for CTC. However, errors in segmentation and existing overlapping noise resulted in loss of conversational turns. The extensiveness of this finding was unexpected, although Gilkerson et.al.[34] reported CTC to be the least reliable output variable in their study as well. Acoustic differences between Dutch and American-English[47,48] might be a reason for incorrect segmentation, as LENA's algorithms were designed upon acoustic properties of American-English speakers. Moreover, LENA often labelled segments as OLN and thereafter excluding the OLN-labels from counting conversational turns. Since the development of the LENA system, segmentation processes in speech recognition systems[49,50] as well as signal-to-noise ratio's in for example hearing aids have been improved substantially.[51-53] When similar adjustments can be applied to LENA's algorithms, the accuracy of estimating conversational turns may improve.

Relationship between parental responsiveness and LENA variables. Initiation of interaction by a child reported a non-significant, fair association with the percentage of responsive utterances during parent-child interaction. The weak associations in general may be due to the small sample size. The direction of the associations was in concordance with the hypothesis. Combining this leads to the suggestion that LENA could be useful in analyzing parental responsiveness.

Predicting parental responsiveness from LENA and background variables. No prediction model could be established based on the measurements in this study. As the number of initiations of a child appear to contribute the most in this set of variables, an inclination is that the number of child initiations might be able to contribute in predicting parental responsiveness in a larger study sample. However, this tendency is not consistent with previous studies indicating that the quantity of parental language input contributes to responsive behavior during interaction.[10,13,15,18,22,26,27] Differences might be due to the high number of included variables compared to the small sample size.

Strengths and limitations. A clear limitation of this study is the small sample size. Moreover, all parents volunteered to participate and there was insufficient information about the heterogeneity of the socio-economic background of participants. Therefore it is difficult to generalize the findings to all language delayed children in the Netherlands. These limitations were due to the pilot nature of this study. Strengths of this study were that a heterogenic sample was created by including parents from different regions in the country. Furthermore, the missing data is this study was completely at random and therefore the available case analyses were not biased.

The LENA system itself has strengths and limitations as well. Since video images are lacking, non-verbal behavior during parent-child interaction cannot be analyzed. Non-verbal responsive behavior is as valuable as verbal responsive behavior in teaching parents how to interact with their language delayed child.[21,22] Consequently, the LENA device can only be supplementary in determining parental responsiveness. A practical feature of the LENA system is that the selection of the 5-min. segments based on LENA-generated counts can be easily performed. This shows that LENA can be useful to zooming in on specific segments of interest during qualitative analysis of audio files. Furthermore, all parents indicated that the amount their child talked during the recording was comparable with a normal day at home. This endorses the assumption that LENA recordings are representative for interaction in daily life.

Conclusion and recommendations. Overall, this study indicates that there are doubts about the accuracy of the segmentation process of the LENA system for the Dutch language. Errors caused by labelling and signal-to-noise ratio's affect estimated output variables. Although this study was not designed as a validation study, improvements on signal-to-noise ratio of the LENA software are recommended. Despite these imperfections, LENA is useful in selecting segments of interest. Moreover, recordings are representative of daily interaction. Both are benefits compared to usual care. Besides, LENA might be helpful in predicting parental responsiveness, even though no strong relationship between LENA outcomes measures and parental responsiveness could be established in this study. Due to the small sample size all outcomes must be interpreted carefully. For future research it is suggested to include more participants to generate more power in deduction of conclusions.

References

1. Reilly S, Wake M, Ukoumunne OC, et al. Predicting language outcomes at 4 years of age: findings from Early Language in Victoria Study. Pediatrics. 2010 Dec;126(6):e1530-7. PubMed PMID: 21059719.
2. Law J, Boyle J, Harris F, Harkness A, Nye C. Prevalence and natural history of primary speech and language delay: findings from a systematic review of the literature. International journal of language & communication disorders / Royal College of Speech & Language Therapists. 2000;35(2):165-88.
3. Law J, Garret Z, Nye C. Speech and language therapy interventions for children with primary speech and language delay or disorder (Review). Cochrane Database of Systematic Reviews. 2003 (3).
4. Tomblin JB, Records NL, Buckwalter P, Zhang X, Smith E, O'Brien M. Prevalence of Specific Language Impairment in Kindergarten Children. Journal of Speech and Hearing Research. 1997;40:1245-60.
5. Leonard LB. Specific Language Impairment Across Languages. Child development perspectives. 2014 Mar 1;8(1):1-5. PubMed PMID: 24765105. Pubmed Central PMCID: 3994122.
6. Down K, Levickis P, Hudson S, Nicholls R, Wake M. Measuring maternal responsiveness in a community-based sample of slow-to-talk toddlers: a cross-sectional study. Child: care, health and development. 2014 Jul 4. PubMed PMID: 25039946. Epub 2014/07/22. Eng.
7. Glogowska M, Roulstone S, Enderby P, Peters TJ. Randomised controlled trial of community based speech and language therapy in preschool children. British Medical Journal. 2000;321:1-5.
8. Roberts MY, Kaiser AP. Early intervention for toddlers with language delays: a randomized controlled trial. Pediatrics. 2015 Apr;135(4):686-93. PubMed PMID: 25733749. Pubmed Central PMCID: 4379460.
9. Roberts MY, Kaiser AP. The Effectiveness of Parent-Implemented Language Interventions: A Meta-Analysis. American Journal of Speech-Language Pathology. 2011;20:180-99.
10. Gilkerson J, Richards JA, Warren SF. The Power of Talk. 2009.
11. Hudson S, Levickis P, Down K, Nicholls R, Wake M. Maternal responsiveness predicts child language at ages 3 and 4 in a community-based sample of slow-to-talk toddlers. International journal of language & communication disorders / Royal College of Speech & Language Therapists. 2014 Sep 11. PubMed PMID: 25208649. Epub 2014/09/12. Eng.

12. Hedenbro M, Rydelius PA. Early interaction between infants and their parents predicts social competence at the age of four. Acta paediatrica. 2014 Mar;103(3):268-74. PubMed PMID: 24669379.
13. Soderstrom M, Wittebolle K. When do caregivers talk? The influences of activity and time of day on caregiver speech and child vocalizations in two childcare environments. PloS one. 2013;8(11):e80646. PubMed PMID: 24260443. Pubmed Central PMCID: 3832484.
14. Girolametto L, Bonifacio S, Visini C, Weitzman E, Zocconi E, Pearce PS. Mother-child interactions in Canada and Italy: linguistic responsiveness to late-talking toddlers. International journal of language & communication disorders / Royal College of Speech & Language Therapists. 2002 Apr-Jun;37(2):153-71. PubMed PMID: 12012613. Epub 2002/05/16. eng.
15. Majorano M, Lavelli M. Maternal input to children with specific language impairment during shared book reading: is mothers' language in tune with their children's production? International journal of language & communication disorders / Royal College of Speech & Language Therapists. 2014 Mar-Apr;49(2):204-14. PubMed PMID: 24224893.
16. Barachetti C, Lavelli M. Responsiveness of children with specific language impairment and maternal repairs during shared book reading. International journal of language & communication disorders / Royal College of Speech & Language Therapists. 2011 Sep-Oct;46(5):579-91. PubMed PMID: 21899674.
17. Dam Mv, Ambrose SE, Moeller MP. Quantity of parental language in the home environments of hard-of-hearing 2-year-olds. Journal of deaf studies and deaf education. 2012 Fall;17(4):402-20. PubMed PMID: 22942314. Pubmed Central PMCID: 3529623.
18. Levickis P, Reilly S, Girolametto L, Ukoumunne OC, Wake M. Maternal Behaviors Promoting Language Acquisition in Slow-to-Talk Toddlers: Prospective Community-based Study. Journal of Developmental & Behavioral Pediatrics. 2014;35:274–81.
19. Landry SH, Smith KE, Swank PR, Guttentag C. A responsive parenting intervention: the optimal timing across early childhood for impacting maternal behaviors and child outcomes. Developmental psychology. 2008 Sep;44(5):1335-53. PubMed PMID: 18793067. Pubmed Central PMCID: 2570562.
20. Buschmann A, Jooss B, Rupp A, Feldhusen F, Pietz J, Philippi H. Parent based language intervention for 2-year-old children with specific expressive language delay: a randomised controlled trial. Archives of disease in childhood. 2009 Feb;94(2):110-6. PubMed PMID: 18703544. Pubmed Central PMCID: 2614563.

21. Watson C. Praten doe je met z'n tweeën. Methodiekboek voor cursusleiders. Utrecht: NIWZ/The Hanen Centre; 2001.
22. Baxendale J, Hesketh A. Comparison of the effectiveness of the Hanen Parent Programme and traditional clinic therapy. International journal of language & communication disorders / Royal College of Speech & Language Therapists. 2003 Oct-Dec;38(4):397-415. PubMed PMID: 14578050.
23. Girolametto L, Pearce PS, Weitzman E. Interactive focused stimulation for toddlers with expressive vocabulary delays. J Speech Hear Res. 1996 Dec;39(6):1274-83. PubMed PMID: 8959612. Epub 1996/12/01. eng.
24. Suskind D, Leffel KR, Hernandez MW, et al. An Exploratory Study of "Quantitative Linguistic Feedback": Effect of LENA Feedback on Adult Language Production. Communication Disorders Quarterly. 2013;34(4):199-209.
25. Topping K, Dekhinet R, Zeedyk S. Parent–infant interaction and children's language development. Educational Psychology. 2013;33(4):391-426.
26. Girolametto L, Bonifacio S, Visini C, Weitzman E, Zocconi E, Steig Pearce P. Mother–child interactions in Canada and Italy: linguistic responsiveness to late-talking toddlers. International journal of language & communication disorders / Royal College of Speech & Language Therapists. 2002;37(2):153-71.
27. Greenwood CR, Thiemann-Bourque K, Walker D, Buzhardt J, Gilkerson J. Assessing Children's Home Language Environments Using Automatic Speech Recognition Technology. Communication Disorders Quarterly. 2010;32(2):83-92.
28. Majorano M, Lavelli M. The use of sophisticated words with children with specific language impairment during shared book reading. Journal of communication disorders. 2015 Jan-Feb;53:1-16. PubMed PMID: 25465380.
29. D'Odorico L, Jacob V. Prosodic and lexical aspects of maternal linguistic input to late-talking toddlers. International journal of language & communication disorders / Royal College of Speech & Language Therapists. 2006 May-Jun;41(3):293-311. PubMed PMID: 16702095. Epub 2006/05/17. eng.
30. Ford M, Baer CT, Xu D, Yapanel U, Gray S. The LENA Language Environment Analysis System: Audio Specifications of the DLP-0121. Boulder, CO: LENA Foundation, 2008.
31. Dykstra JR, Sabatos-Devito MG, Irvin DW, Boyd BA, Hume KA, Odom SL. Using the Language Environment Analysis (LENA) system in preschool classrooms with children with autism spectrum disorders. Autism : the international journal of research and practice. 2013 Sep;17(5):582-94. PubMed PMID: 22751753.

32. Caskey M, Vohr B. Assessing language and language environment of high-risk infants and children: a new approach. Acta paediatrica. 2013 May;102(5):451-61. PubMed PMID: 23397889.
33. Weisleder A, Fernald A. Talking to children matters: early language experience strengthens processing and builds vocabulary. Psychological science. 2013 Nov 1;24(11):2143-52. PubMed PMID: 24022649.
34. Gilkerson J, Zhang Y, Xu D, et al. Evaluating LENA System Performance for Chinese: A Pilot Study in Shanghai. Journal of Speech Language and Hearing Research. 2015.
35. Koninklijke Kentalis [cited 2014 09-07]. Available from: http://www.kentalis.nl.
36. de Nederlandse Stichting voor het Dove en Slechthorende Kind 2008 [cited 2014 09-07]. Available from: http://www.nsdsk.nl.
37. Stivers T, Enfield NJ, Brown P, et al. Universals and cultural variation in turn-taking in conversation. Proceedings of the National Academy of Sciences of the United States of America. 2009 Jun 30;106(26):10587-92. PubMed PMID: 19553212. Pubmed Central PMCID: 2705608.
38. WMA. Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects 2014 [cited 2014 november]. Available from: http://www.wma.net/en/30publications/10policies/b3/.
39. Moerman-Coetsier L, Besien Fv. TOAST: TaalOnderzoek via Analyse van Spontane Taal. Amersfoort: Acco; 1987.
40. Bol G, Kuiken F. Grammaticale Analyse van Taalontwikkelingsstoornissen. Utrecht: Elinkwijk b.v.; 1988.
41. Schlichting L. TARSP: Taal Analyse Remediering en Screening Procedure. Amsterdam: Pearson Assessment and Information; 2005.
42. Barras C. Transcriber. A tool for segmenting, labeling and transcribing speech. 1.5.1 ed1998.
43. Schlichting L, Lutje-Spelberg HL. Schlichting Test voor Taalbegrip: Bohn Stafleu van Loghum; 2012.
44. Schlichting L. PPVT-III-NL | Peabody Picture Vocabulary Test-III-NL: Pearson Clinical; 2005.
45. Schlichting L, Lutje-Spelberg HL. Schlichting Test voor Taalproductie: Bohn Stafleu van Loghum; 2012.
46. IBM SPSS Statistics for Windows. Version 20.0 ed. Armonk, NY: IBM Corp.; 2011.
47. Bezooijen R. Sociocultural Aspects of Pitch Differences between Japanese and Dutch Woman. Language and Speech. 1995;38(3):253-65.

48. van der Feest SV, Swingley D. Dutch and English listeners' interpretation of vowel duration. The Journal of the Acoustical Society of America. 2011 Mar;129(3):EL57-63. PubMed PMID: 21428468. Pubmed Central PMCID: 3064679.
49. Anguera X, Bozonnet S, Evans N, Fredouille C. Speaker Diarization: A Review of Recent Research. IEEE TALSP. 2011.
50. Rouvier M, Dupuy G, Gay P, Khoury E, Merlin T, Meignier S. An Open-source State-of-the-art Toolbox for Broadcast News Diarization. 2013.
51. DiGiovanni JJ, E.A. EAD, Nagaraja NK. Effects of Transient Noise Reduction Algorithms on Speech Intelligibility and Ratings of Hearing Aid Users. American Journal of Audiology. 2011;20:140-50.
52. Kleine Punte A, De Bodt M, Van de Heyning P. Long-term improvement of speech perception with the fine structure processing coding strategy in cochlear implants. ORL; journal for oto-rhino-laryngology and its related specialties. 2014;76(1):36-43. PubMed PMID: 24685836.
53. Montazeri V, Khoubrouy SA, Panahi IMS. Evaluation of a New Approach for Speech Enhanced Algorithms in Hearing Aids. 34th International Conference of the IEEE EMBS2012.

Tables

Table 1

Characteristics of Included Parent-Child Pairs (n = 14)

Characteristic	n	%	M	(SD)	range
Child-related variables					
Male child	9	64			
Chronological age in months			37	(2.3)	35 to 41
Environmental variables					
Male key-parent	5	36			
Educational level key-parent[a]					
Secondary education (LBO/MAVO/VMBO)			21	(3)	
Tertiary education (MBO/HAVO/HBS/VWO)			57	(8)	
Higher education (HBO/Universiteit)			14	(2)	
Number of children in the family[a]			2.2	(0.4)	1 to 3

Note. Educational levels between parentheses are the Dutch levels.

[a] n = 13 due to loss of a questionnaire.

Table 2

Categories and Definitions of Verbal Responsive Behavior to review Parental Utterances.

Category	Definition	Dutch Example	English translation of example
(1) responsive verbal behavior	An **imitation** is a copy of the child's utterance, although pronunciation of the adult may be more complete. Utterance is not semantically different.	sie sefde *[si: sɛfdə]* (child) – precies dezelfde *[prəsis dəsɛlfdə]* (parent)	sac same (child) – exactly the same (parent)
	An **expansion** adds semantical or syntactical information to the childs' utterance, while part of the utterance is repeated.	da kaas *[da: kas]* (child) – daar ligt de kaas *[dar lɪɣt də kas]* (parent)	there cheese (child) – there is the cheese (parent)
	An **interpretation** is an utterance where the parent 'translates' the child's utterance by interpreting the message in a context.	da mama ja ik ook *[da: mama ja Ik ok]* (child) – wil jij ook handjes wassen? *[vɪl jɛi ok hɑntjəs vɑsən]* (parent)	there mommy yes me too (child) – you want to wash your hands too? (parent)
	When parents **label** object(s) that the child is playing with, or pointing at.	Gordijnen (parent)	Curtains (parent)
	A **supportive directive** is command from the parent in order to direct the child to act following the given command.	Doe de deksel er maar op (parent)	Put on the lid (parent)
	Responsive questions are referred to as wh-questions (e.g. who, what, where, when, how questions) in relation to the subject the child is focussed on.	Welke kleur heeft de bloem? (parent)	Which colour is the flower? (parent)
(2) non-responsive questions and statements	A yes-no question addressed to the child.	Wil jij wat te drinken? (parent)	Do you want a drink? (parent)
	A statement is a single sentence or declaration addressed to the child, where no reply is necessary.	Wacht op mama (parent)	Wait for mommy (parent)
(3) utterances excluding categories 1 & 2	All utterances that do not fit the definitions in previous categories, e.g. single word social responses, rotate passages, name calling, rhymes, songs.	Ja. Oké. Hé. Gank je wel. Goed zo. (parent)	Yes. Ok. Hey. Thanks. Well done. (parent)
(4) unintelligible utterances	All unintelligible utterances marked with [...] after three listening attempts	-	-
(5) mislabelling of LENA	All mislabelling of the LENA system	Label AR or AI (Adult Response or Adult Initiation) while the utterance belongs to a child.	-

Note. Adapted from Levickis et al.[18] Six responsive behaviors are boldfaced in the column "Definition". Dutch examples may be followed by phonetic transcription –placed between brackets– for clarification. The speaker in the examples is indicated between parentheses.

Table 3

Conversational Turns and Labelling of Parental Responsiveness.

Turn type LENA	CTC LENA	Utterance	Category responsiveness[a]
CI		Tico	
AR	*	Tico?	1
CI		Me this josse [?]	
AR	*	Well, then it will be Dora, or that one, or Boots	2
CI		Hey, me this	
AR	*	Yes, that one is ok	1
AI		And I see this one is the same	2
CR	*	[…] [overlapping noise] this same	
AE		The same? Well done, we will put it here.	1

Note. Turn type LENA indicates which speaker is participating in the interaction and which role is ascribed. CI = child initiation, AR = adult response, AI = adult initiation, CR = child response, CTC = conversational turns count, […] = unintelligible utterance, [?] = exact translation but not sure of semantical correctness, * refers to the presence of a conversational turn.

[a] based on categories of responsiveness in Table 2.

Table 4

Outcomes of Parental Responsiveness, Language Skills of Children and Mean Length of Utterance (n = 14)

Parent-child pair	PARESP (%)	RLQ	ELQ	MLU
1	36.0	88	85	3.0
2	30.5	103	55	2.6
3	32.7	103	100	2.4
4	22.2	83	65	1.4
5	34.4	92	55	2.2
6	40.2	83	69	2.2
7	51.4	95	61	2.1
8	42.5	79	57	2.0
9	57.9	96	61	1.2
10	60.7	72	55	2.4
11	34.7	90	58	1.7
12	34.0	76	55	1.4
13	22.9	104	55	1.2
14	40.6	78	58	2.2
M	38.6	88.7	63.5	2.0
SD	11.5	10.6	13.3	0.6

Note. PARESP = parental responsiveness, RLQ = receptive language quotient, ELQ = expressive language quotient, MLU= mean length of utterance.

Table 5

Stepwise Backward Multiple Regression Analysis for Prediction of Parental Responsiveness (n = 14)

	B	SE B	β	95% CI for B		p	R	R^2	ΔR^2	F	p
				LL	UL						
Model 1							0.77	0.60	-0.58	0.51	.81
Constant	59.67	100.85		-261.30	380.65	.59					
AWC	-0.00	0.00	-0.99	-0.02	0.01	.64					
CTC	0.04	0.11	1.45	-0.29	0.38	.70					
CVC	-0.01	0.02	-0.99	-0.07	0.06	.73					
ITT	0.05	0.09	0.42	-0.23	0.32	.63					
NFC[a]	4.33	29.70	0.14	-90.21	98.86	.89					
ELP[a]	-1.17	16.08	-0.07	-52.34	50.00	.95					
MLU	1.26	24.57	0.06	-76.94	79.55	.96					
RLQ	-0.31	0.98	-0.29	-3.44	2.82	.77					
ELQ	0.05	0.90	-0.06	-2.93	2.82	.96					
Model 9							0.50	0.25	0.18	3.71	.13
Constant	14.74	12.74		-13.29	42.77	.27					
ITT	0.06	0.03	0.50	-0.01	0.12	.08					

Note. CI = confidence interval, LL = lower limit, UL = upper limit. AWC, CTC, CVC, ITT are LENA output variables. NFC, ELP, RLQ, ELQ and MLU are background variables.

[a] n = 13 due to loss of questionnaire.

Figures

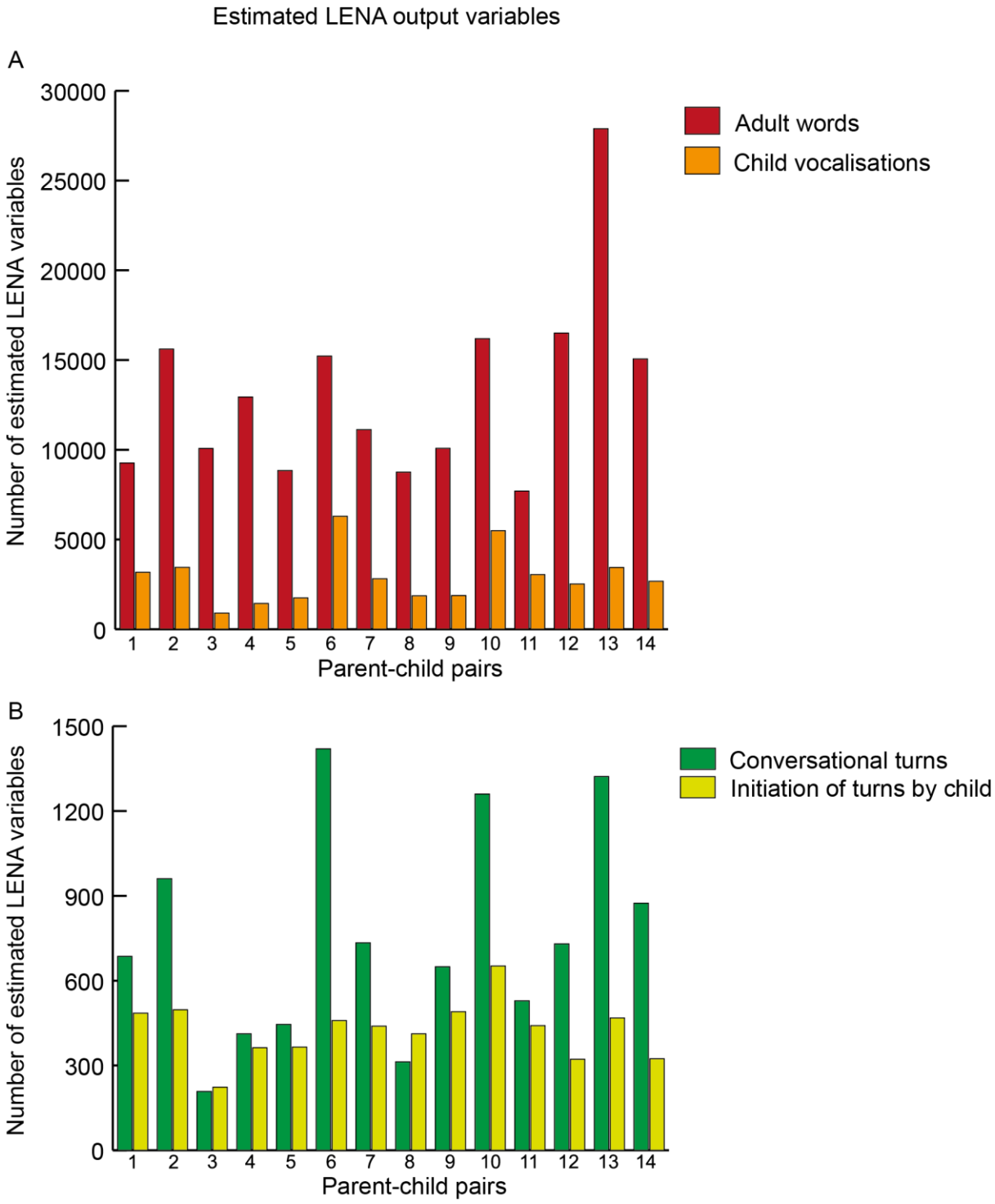

Figure 1. Estimated LENA output variables per parent-child pair, levelled on 10 hrs. 1A: Number of adult words and child vocalisations, 1B: number of conversational turns and initiated turns by the child.

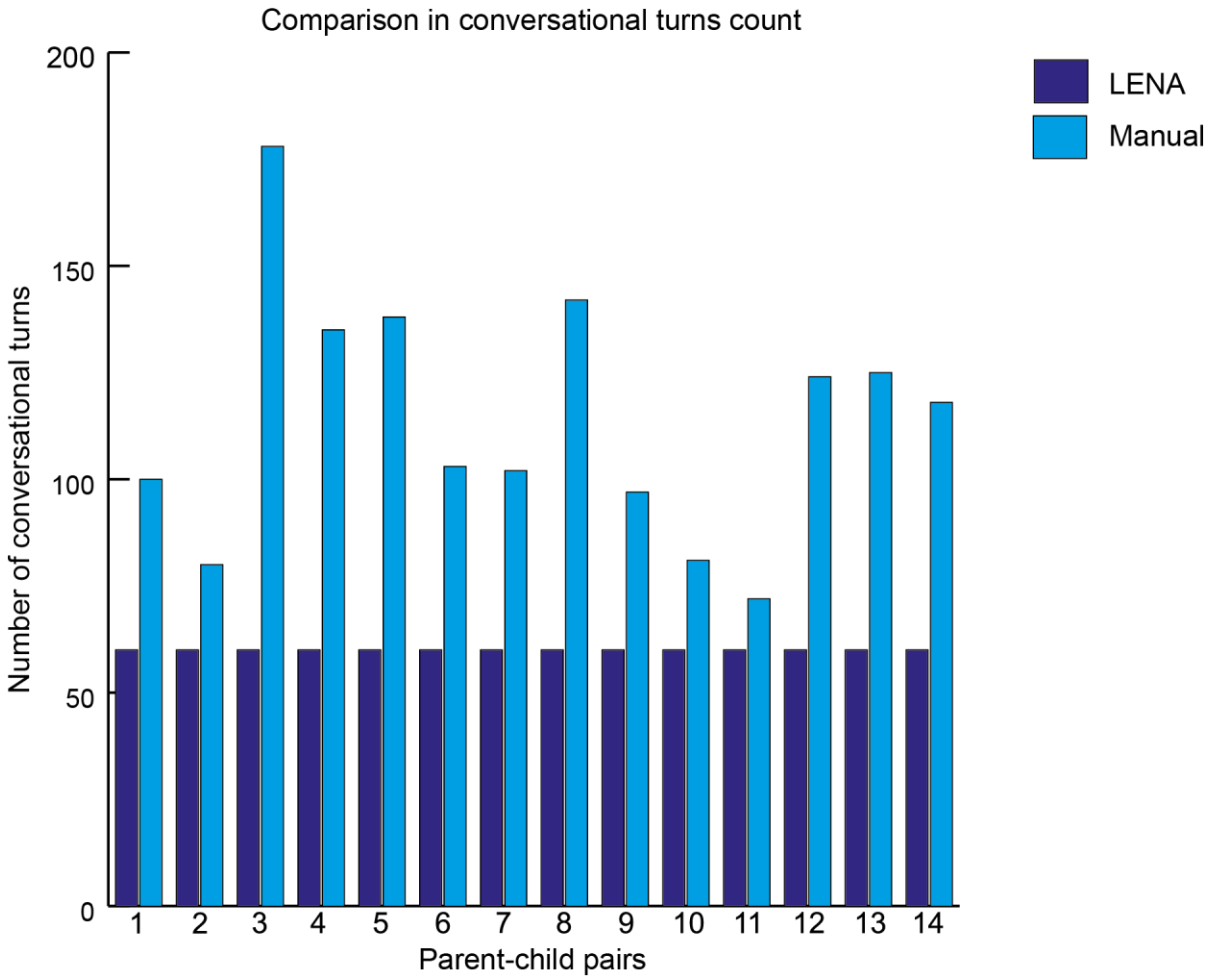

Figure 2. Comparison of LENA's estimated CTC and manual CTC of language transcripts.

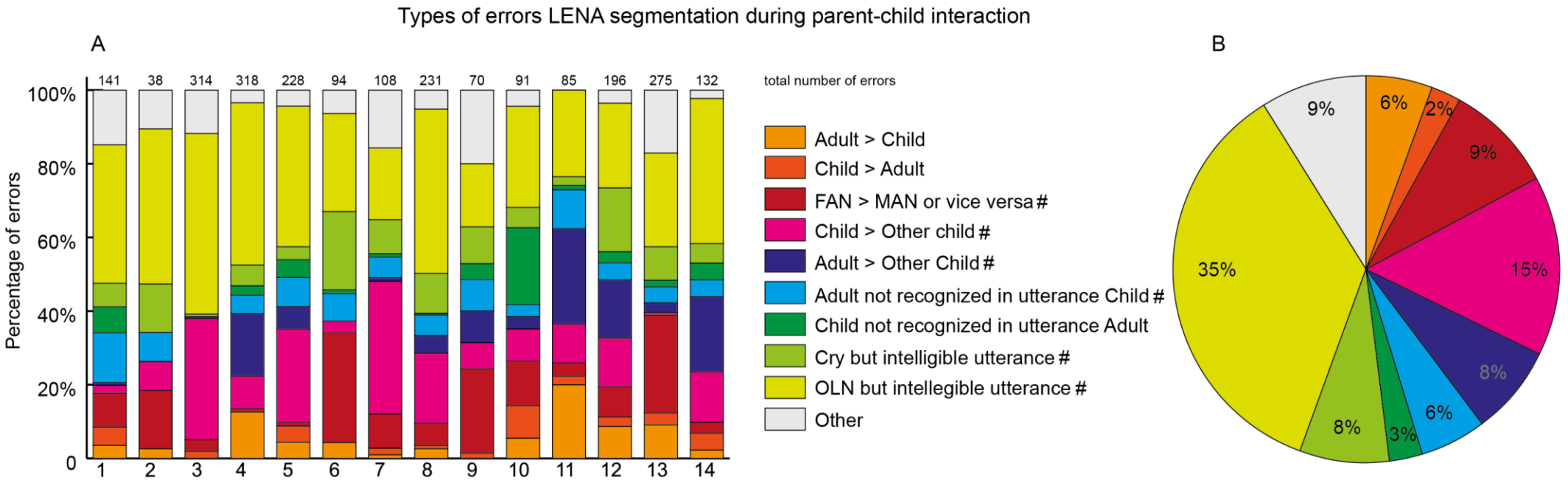

Figure 3. Types of errors in LENA segmentation during parent-child interaction. 3A: percentages of errors per parent-child pair, with the total number of errors per parent-child pair displayed. 3B: mean percentages of types of errors. # = mislabelling occurred in all parent-child pairs, > = mistaken for, FAN= female adult, MAN= male adult.

Dutch summary

Achtergrond. Door verbaal responsief te zijn, leveren ouders een belangrijke bijdrage in het stimuleren van taalvaardigheden van kinderen met een taalontwikkelingsstoornis. Video-opnames of taalsamples van gestructureerde spelsituaties worden meestal gebruikt voor het analyseren van responsiviteit, maar dit is tijdrovend en vaak geen afspiegeling van de daadwerkelijke communicatie in de thuissituatie. Daarnaast beïnvloeden verschillende achtergrondvariabelen van ouder en kind de mate van responsiviteit. Het LENA (Language ENvironment Analysis) systeem is een opnameapparaat met analysesoftware, bedoeld om inzicht te krijgen in taalaanbod in de thuissituatie. LENA kan een efficiënt middel zijn responsiviteit van ouders in de thuissituatie te analyseren.

Doel. Een pilotstudie om de bruikbaarheid van LENA voor het analyseren van verbale responsiviteit tijdens ouder-kind interactie bij Nederlandse kinderen met een taalontwikkelingsstoornis te evalueren.

Methoden. Een secundaire analyse van opnames van veertien ouders met kinderen tussen 2;6-3;6 jaar die naar een vroegbehandelingsgroep gaan. Zestig beurtwisselingen zijn geselecteerd met LENA en handmatig getranscribeerd. Het aantal handmatig getelde beurtwisselingen werd vergeleken met LENA's telling. Uitingen van de ouders werden beoordeeld op responsiviteit. De relatie tussen responsiviteit en LENA's uitkomstvariabelen werd bestudeerd, waarna responsiviteit werd voorspeld aan de hand van LENA-variabelen en achtergrond variabelen van ouder en kind.

Resultaten. Er werden grote verschillen gevonden tussen de handmatige en LENA's telling van beurtwisselingen. Verbale responsiviteit van ouders lijkt matig gecorreleerd met het aantal initiaties van beurtwisselingen door het kind. Op basis van deze analyses kan geen significant predictiemodel gepresenteerd worden voor het voorspellen van verbale responsiviteit van ouders.

Conclusie. Als LENA's segmentatieproces kan worden verbeterd, zal het identificeren van beurtwisselingen verbeteren. Ondanks het ontbreken van een sterke correlatie tussen LENA-variabelen en verbale responsiviteit in deze kleine steekproef, lijkt LENA bruikbaar in het analyseren van responsiviteit. Het geeft inzicht in taalaanbod in de thuissituatie en inzoomen op interactiemomenten tussen ouder en kind is eenvoudig.

Abstract

Background. Parental responsiveness is essential in enhancing linguistic skills of language delayed children. Video recordings and/or language sample analysis of structured-play situations are often used for evaluation of responsiveness, but are time-consuming and not representative of daily parent-child interaction. Furthermore, background characteristics of parent and child influence parental responsiveness. At this moment an efficient tool for evaluating verbal responsiveness is lacking. The language environment analysis (LENA) system is an automatic recording device with accompanying software developed for analyzing language input in home environments. LENA might be an efficient tool for evaluating parental responsiveness.

Aim. A pilot study to evaluate the usefulness of the LENA system for analyzing parental responsiveness during parent-child interaction in Dutch preschool children with language delay.

Methods. A secondary analysis of fourteen full-day LENA recordings of parents and children aged 2;6-3;6 years attending an early intervention group. Sixty conversational turns were selected with LENA software and manually transcribed. The number of manually counted conversational turns was compared with LENA's conversational turns count. Parental utterances were reviewed on responsiveness. The relationship between parental responsiveness and LENA output variables was studied and parental responsiveness was predicted from LENA variables and parent-child background characteristics.

Results. Large variety between manual and LENA conversational turns count was reported. Parental responsiveness was fairly correlated with the number of initiations of conversational turns by the child. No significant model could be established for predicting parental responsiveness.

Conclusion. LENA's segmentation process could be improved to provide a more accurate conversational turns count. Despite the lack of a strong correlation between LENA output variables and responsiveness in this small sample, LENA might be useful in analyzing parental responsiveness because of its practical way of zooming in on parent-child interaction.

Key-words. language environment analysis; specific language impairment [MeSH]; verbal responsiveness; preschool children; parent-child interaction

Appendix

List of abbreviations

AWC	Adult Word Count; an automatically estimated output variable from LENA software analysis indicating the total number of adult words in the recording.
CCMO	Central Committee on Research Involving Human Subjects; in Dutch: Centrale Commissie Mensgebonden Onderzoek.
CTC	Conversational Turns Count; an automatically estimated output variable from LENA software analysis, indicating the total number of conversational turns in the recording.
CVC	Child Vocalisations Count; an automatically estimated output variable from LENA software analysis, indicating the total number of child vocalisations in the recording.
DLP	Digital language processor; the LENA recording device worn by a child.
ELP	Educational level of the parent as indicated by parents in the questionnaire of the Kentalis/NSDSK-study.
ELQ	Expressive language quotient; the lowest quotient of two tests: Schlichting Expressive Language Test – word level and Schlichting Expressive Language Test sentence level.
FAN	LENA label for female adult utterance.
ITT	Initiation of turn taking; an automatically estimated output variable from LENA software analysis, indicating the number of initiations of conversational turns by the child.
Kentalis	Royal Dutch Kentalis; in Dutch: Koninklijke Kentalis, a Dutch organisation that provides education and care to children with a language and/or hearing impairment.
Kentalis/ NSDSK-study	Collaborative pilot study of Kentalis and NSDSK in which possibilities of LENA are explored in Dutch families with preschool children suspected of SLI (2013-2015).
LENA	Language ENvironment Analysis.
MAN	LENA label for male adult utterance.
MLU	Mean length of utterance; the number of morphological units divided by the total number of utterances.
NCF	Number of children in the family; number provided by parents in the questionnaire of the Kentalis/NSDSK-study.

NSDSK	Dutch Foundation of Deaf and Hard of Hearing Children; in Dutch: de Nederlandse Stichting voor het Dove en Slechthorende Kind, a Dutch organisation that provides education and care to children with a language and/or hearing impairment.
OLN	LENA label for overlapping noise.
PARESP	Outcome measure for parental responsiveness; percentage of imitations and expansions from total parental utterances.
PCIP	Parent-Child interaction program; for example Hanen Parent Program.
RLQ	Receptive language quotient; the lowest quotient of two tests: Schlichting Receptive Language Test or Peabody Picture Vocabulary Test.
SLI	Specific Language Impairment .
SPSS	Statistical Package for the Social Sciences; statistical analysis software, provided by IBM.
WMO	Medical Research Involving Human Subjects Act (in Dutch: Wet Medisch-wetenschappelijk Onderzoek met Mensen.