Language Environment Analysis (LENA) Trial

Investigating the home language environment in the early years: A process evaluation

Report prepared for the South Australian Department for Education and Child Development

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FRASER MUSTARD CENTRE

A COLLABORATION BETWEEN

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1. Executive Summary

1.1 Background

Language is crucial to our capacity to effectively communicate and learn. Evidence suggests that language development is a key factor underpinning later learning and development. Indeed, children with poorer language development at school entry are often ill-prepared to fully benefit from formal education and fall behind in subsequent years (1). It is widely accepted that the early learning environment can significantly influence child language and cognitive outcomes, though investigation regarding the home environment has often been limited due to requiring investigator presence or static recording devices and transcribers to code all data. Advancement in technology now enables the early home environment to be measured with a degree of precision that was previously not there.

Advanced speech recognition technology is emerging as an efficient and reliable method to obtain audio environment data. The Language Environment Analysis (LENA) system developed by the LENA Foundation is one such example that has been specifically designed for use with young children. LENA uses advanced speech recognition technology to collect, process, and analyse the audio environment. Each sound is classified by complex audio algorithms to automatically sort meaningful speech audio from other sounds such as television, noise and silence. The LENA technology can collect up to 16 hours of uninterrupted audio which allows data to be collected for an entire waking day. The software has been particularly useful for health care professionals and researchers who wish to objectively quantify the auditory and social environment of children (2-4).

The study was a process evaluation of using the Language Environment Analysis (LENA) system within the home for families with young children. Through our study, we aimed to provide the preliminary data and experience to guide future research using LENA software to quantify the audio and social environment of children in South Australia.

The investigation aimed to address the following questions:

1. What factors facilitated positive perceptions of the LENA recording device?
2. What factors were perceived barriers of the LENA recording device?
3. Did the LENA recording device influence parent-child communication?
4. What were the differences in parent perceptions using LENA for varying ages?
5. Can LENA measures successfully be used with South Australian families to obtain high quality data?
6. What are the resource and timing implications of doing this at scale?

1.2.1 Method

The evaluation used predominantly qualitative feedback from caregivers, with cogency checks achieved through quantitative analysis where applicable. Participation involved infants and toddlers wearing a Digital Language Processor (DLP) for a 16 hour duration to collect audio environment and social data. The DLP was worn inside a small front pocket of specially designed children's clothing for the day, except whilst napping or bathing. Participating caregivers completed a series of questionnaires in addition to a complimentary time-use diary for the recording day.

The DLP processed the audio from each 16 hour recording period which was automatically sorted into five (5) audio environment categories:

- Meaningful speech (near and clear to the child)
- Distant speech
- TV and electronic sound
- Noise
- Silence and background

For meaningful speech, the LENA software automatically quantified two measures of caregiver input, comprising of (1) adult words and (2) conversational turns. Conversational turns refer to when either the key child or adult has initiated communication with the other, and has resulted in a response. The software also measured child input through quantifying child vocalisations. Tallies for each of these three measures were available to be viewed and/or exported in 5-minute, hourly or daily increments.

1.3 Findings

1.3.1 Audio Environment

The study successfully obtained one 16-hour uninterrupted audio data from all participating families. Audio environments varied widely among participants for each of the five (5) audio classifications measured by LENA. The mean durations and standard deviations for the sample are listed below;

- Meaningful speech mean duration: 2hr 35mins (standard deviation: 42mins)
- Distant speech mean duration: 3hr 5mins (standard deviation: 43mins)
- Silence and background mean duration: 8hr 44mins (standard deviation: 1hr 0 mins)
- TV and electronic sounds mean duration: 59mins (standard deviation: 35mins)
- Noise mean duration: 35mins (standard deviation: 31mins)

Sleep and nap periods were calculated from parent reports and used to estimate the time that children were awake during the recording day. The durations were diverse, with the mean duration of the sample being awake for 9hr 55mins (standard deviation: 1hr 21mins).

The duration that the child was awake was used to calculate mean hourly tallies for adult words, conversational turns and child vocalisations. The mean hourly frequencies are provided below:

- Mean adult words per hour: 1,723.04 (standard deviation: 619.35);
- Mean conversational turns per hour: 61.15 (standard deviation: 34.32)
- Mean child vocalisations per hour: 212.70 (standard deviation: 96.65)

1.3.2 Process evaluation

The purpose of the study was to assess the practicality of using the LENA Digital Language Processor (DLP) within the homes of families with young children (< 25months). Findings have predominantly been based on participant feedback, with some contributions made by the researcher from first-

hand experience using the LENA data. Findings relating to the process evaluation have been categorised as either being advantageous (i.e., a facilitator) or potentially limiting (i.e., a barrier). Primary factors are summarised below.

Facilitators:

Feedback from caregivers indicated that the LENA Digital Language Processor (DLP) was well received by all parents and children. The primary factors which supported the successful use of the DLP in this pilot study are listed below:

- Participation was stated to be extremely easy due to the simplicity of the DLP as well as clear participant instructions.
- The device was unobtrusive to the participating child due to its small size and light weight.
- The DLP could be worn for the duration of the day without caregivers requiring to touch it due to the complimentary clothing housing the recorder in a small front pocket.
- Researcher presence was not required for the observation, which allowed long observation periods (16 hours).
- No transcription of recording was required due to the DLP obtaining direct measures of parental input (adult words, conversational turns) available to view in 5-minute, hourly or daily time increments.
- Data was easily exported by the researcher from the LENA software into the applicable statistical analysis software.

Barriers:

Although all participants generally had very positive experiences using the LENA Digital Language Processor (DLP), some potential barriers to using the device in research have been identified. The primary barriers are summarised below:

- Audio measures are reliant on parents remembering to switch the DLP on as soon as their child wakes up.
- Many parents were interested in the audio measures obtained from their recording. Withholding this data from individuals in future studies may reduce the appeal for participants to continue volunteering their time on multiple occasions.
- Instructions to participants may not have provided sufficient information regarding protocols for private situations and for guests that are incidentally recorded.
- Sufficient space and detail must be provided to participants within the time-use diary to improve accuracy regarding how time is spent, particularly in regards to nap time estimations.

1.3.3 Influence on communication

It is acknowledged that any observational study of the home environment may be likely to impact parent's behaviour. The majority of participants (61.1%) indicated that they were conscious of the

DLP during the recording session, whereas the remainder of participants (33.3%) were not conscious of the DLP.

Of the participants who were conscious of the DLP, there were extremely varied perceptions regarding how being conscious of the DLP influenced their communication. Participants who were conscious of the DLP reported that their communication either increased (22.2%), stayed the same (22.2%) or decreased (11.1%). The majority of participants indicated that this influence ceased by 'mid-morning' because the business of the day meant that they forgot about the recording.

Though, this finding was not particularly consistent with quantitative analysis. Analysis indicated that awareness of the DLP increased the frequency of verbal interaction between caregiver and child. The parents who were consciously aware of the DLP during the recording day engaged in a significantly greater amount of conversational turns per hour (M = 72.43, SD = 33.34) than parents who were not consciously aware of the DLP (M = 36.34, SD = 22.76), $t(14) = -2.18$, $p = 0.47$. There was no significant difference in frequency of adult words between parents who were consciously aware (M = 1914.52, SD = 566.63) and parents who were not consciously aware of the DLP during the recording day (M = 1301.79, SD = 559.63), $t(14) = -2.01$, $p = .064$.

1.3.4 Differences between ages

There was considerable overlap between comments expressed by parents of infants (5-12 months old) and parents of toddlers (18-24 months old). Consequently, the study only identified two differences in feedback from parents between the two age groups.

It was suggested that the DLP may not be particularly suitable for the very early ages. This is primarily due to the bulkiness of the device when compared to a small baby. Indeed, two parents mentioned that the DLP might be uncomfortable for babies if they lay on their chest during the recording day. It was also identified that parents would engage in a frequent amount of non-verbal communication with their young children, particularly before the child has learned to talk. This type of communication is not picked up by the DLP and therefore the audio measures only capture a portion of the wider communication that is experienced by parent and baby.

1.3.5 Administrative considerations

Obtaining direct measures of parental language input and audio environment over a 16 hour period provides a fine-grained picture of language exposure, which could be instrumental for future study investigating language development and growth. Feedback from families indicates that the Digital Language Processor (DLP) was acceptable for use inside the home and was simple to administer. Indeed, the DLP was successfully used by all parents and did not impede everyday activities.

The costs of using LENA are now well-described and offer a viable means to investigate the home audio environment for a large cohort. Until recently, investigation into the early language environment has been limited due to requiring investigator presence or static recording devices, and transcribers to code all data. These methods have restricted sample sizes, as well as duration and frequency of recordings of research designs in the past. For example, a famous three-year

longitudinal study by Hart and Risley (5) required an additional six years to enter, code and analyse thousands of pages of transcripts for 42 families. They explained that it took at least 8 hours to transcribe one hour of audio recording. Despite this dedication of time, results were based on 1 hour segments per month and thus problematic to make broad estimations of daily interactions from that data. LENA technology overcomes these restrictions because audio data is sorted much faster and for an entire waking day (up to 16 continuous hours).

Recommendations

1. **Instructions for caregivers to lay out the LENA clothing the night before the recording day.**
2. **Amend time-use diary to request precise times that child was put down for naps and bed time.**
3. **When LENA feedback cannot be provided to participants (e.g., longitudinal studies), provide advice regarding an alternative topic that is non-consequential to language development (e.g., child nutrition).**
4. **Develop a hand-out for individuals who are incidentally recorded by the DLP and provide copies of this hand out within the instruction pack given to participating parents.**
5. **Develop protocol regarding use of recording device in private areas based on whether audio recording is obtained.**
6. **Within written instructions, include reasoning regarding why caregivers are instructed to remove DLP from child's clothing during car trips.**
7. **When conducting a cross-sectional study and where possible, data collection should be taken on two occasions within the same week to reduce Hawthorn effect.**
8. **Continue to administer a standardised measure of child gesture to complement the LENA acoustic measures.**
9. **Include measures regarding participant siblings, such as birth order, age and gender.**
10. **Include measures regarding activities for the previous week, such as reading time and child care attendance.**
11. **Research Assistants involved in LENA study should have existing knowledge regarding research ethics prior to contacting any participants.**
12. **Continue to obtain caregiver feedback regarding the DLP recording device in future study.**
13. **Amend wording on study flyer to recruit families of children 5-24 months of age for data collection at 6-, 12-, 18- or 24 months of age.**

2. Purpose of Report

2.1 Core Evaluation Aims

The aims of this evaluation were to:

- Conduct a process evaluation of using Language Environment Analysis (LENA) technology in the home environment of families with young children.
- Obtain quantitative measures of parental input and child vocalisations for children aged between 6- and 24-months of age.

2.2 Purpose of the Evaluation

While current early language and literacy promotion programs are based on the best available evidence, we do not yet know enough about the extent to which language onset and growth in the first two years is responsive to specific adult inputs. Maternal education is the clearest predicator, however this information in and of itself is not enough to develop interventions to reduce social inequality. Also, the early detection of language delay may be important in the prevention of later speech disorder, however screening tools have been shown not to be very sensitive during the earliest years. This may be due to their method/form of assessment. Language Environment Analysis (LENA) could potentially provide better sensitivity and specificity for identifying children at risk for language impairment. The incredibly rich data collected by LENA (i.e., moving beyond simple word counts to conversational turns) within the natural home environment could allow for a better understanding of the mechanisms behind language acquisition.

It is prudent that the applicable methods are trialled before commencing a study involving a large sample. The main objective of the current evaluation was to trial the practicality of using LENA technology for potential future large-scale use in suburban areas of Adelaide. This study trialled LENA in homes with young children (N = 18) of varying ages (between 4- and 25-months of age). The feasibility of using LENA across age ranges was examined in this trial by obtaining 16 hour audio recordings for each participating child as well as obtaining feedback from parents. This evaluation provides the necessary 'proof of concept' platform to inform subsequent larger studies, which have the potential to develop norms and examine early intervention programs.

2.3 Background

The use of wearable speech recognition technology is steadily increasing in research investigating the home language environment. Innovations in technology are allowing day-long audio samples to be recorded and automatically processed into variables of interest to the user. One such software that is used to analyse the audio environment is Language Environment Analysis (LENA), which has been designed to examine the audio environment in the preschool years.

LENA uses a recording device called a Digital Language Processor (DLP: Appendix A) which stores and processes up to 16 hours of uninterrupted audio. The device uses complex algorithms to automatically sort meaningful audio (adult or child speech) from silence and other environmental audio, such as electronic devices and non-speech sounds (e.g., laughing, clapping). For the meaningful audio, a language-dependent statistical model estimates the number of words spoken,

but does not recognise the content nor meaning of the speech. The software categorises the meaningful audio into tallies of (1) adult words, (2) child vocalisations and (3) adult-child conversational turns.

The software has been intended for use by parents, clinicians and researchers that are interested in the early language environment of children. Subsequently, the LENA software has been designed to be easily administered and analysed by the lay person. Once an audio recording is uploaded to the computer, data reflecting the audio environment is displayed in graphs (Appendix B). The data can be viewed and played back in either 5-minute, hourly or daily increments. If the user wishes, data can then be exported into statistical or audio packages for analyses.

Data obtained from LENA is primarily used to observe and promote adult-child communication in the years prior to school entry. Indeed, the software is marketed to parents as an easy way to monitor and increase the quantity of input they provide to their children. This strategy has been adapted by groups that seek to use LENA within intervention programs. Emerging trials are complementing child development advice with individual-level feedback from LENA with an aim to promote child language development. Initial pilot studies suggest that LENA feedback allows caregivers to set tangible goals and increase their language input as the program progresses (5). These studies have mostly focused on administering the program to socially disadvantaged families (6), although one program is seeking to administer the intervention at the municipal level (7).

2.4 LENA Validity and Reliability

Investigation regarding the reliability of the LENA software has reported moderate sensitivity and high specificity (4, 8). Zimmerman, et al (8) compared seventy 12-hour audio files that were coded by human coders to corresponding LENA software classifications. Findings indicated a high degree of fidelity specifically for segments that human coders identified as adult speech (82% were correctly identified by LENA, $k = 0.65$). Therefore, the tool has a moderate probability of a positive reading for the correct classification, but a high probability of a null reading for an incorrect classification. The LENA foundation states that when developing the LENA tool, their aim was to lower the incidence of false positive classifications that would inflate final Adult Word Count and Conversation Turns estimates.

An apparent flaw of LENA is that it cannot accurately differentiate overlapping speech and thus is designed to exclude these segments of audio. The LENA Foundation reason that overlapping speech may not even be differentiated by a young child, thus excluding these sections may actually reflect a more accurate report of what the child hears.

2.5 Ethical review

Ethical review for the evaluation was conducted by the University of Western Australia Human Research Ethics Committee (EC00272). Ethical approval for the evaluation was received 5 November 2013 for a period of five (5) years, on condition that researchers submit satisfactory annual progress reports (ref: RA/4/1/6357).

3. Evaluation Methodology

3.1 Research Questions

The aim of this evaluation was to trial the LENA software in the homes of families with young children. The evaluation sought to achieve this aim by addressing the following research questions:

1. What factors facilitated positive perceptions of the LENA recording device?
2. What factors were perceived barriers of the LENA recording device?
3. Did the LENA recording device influence parent-child communication?
4. What were the differences in parent perceptions using LENA for varying ages?
5. Can LENA measures successfully be used with South Australian families to obtain high quality data?
6. What are the resource and timing implications of doing this at scale?

3.2 Materials

3.2.1 LENA Digital Language Processor (DLP) Assessments

Audio recordings were collected using the DLP (Appendix A), which has been designed to withstand heavy treatment and meets strict safety protocols (i.e. too big to swallow, water safe, colour safe). The DLP collects and stores up to 16 hours of audio data before turning itself off. Explicit consent has to be obtained from participants for researchers to retain their audio recording.

For all age groups three direct measures were collected using LENA: 1) Parent Talk – the number of words spoken to the child; 2) Child Talk – the number of child utterances, and 3) Parent-Child Talk - the number of parent-child verbal interactions[1]. LENA uses advanced speech recognition technology to automatically analyze the audio file to produce estimates of adult and child talk based on acoustic properties in the speech signal. For each of these measures, data is available for 5-minute segments, over an entire 16-hour recording period. The audio file is then uploaded into the LENA software which codes and quantifies the data. For quantitative analyses, sleep and nap times were filtered from the LENA recordings.

All three of the LENA measures have good reliability, with high consistency between the scores computed by LENA and those generated by a human transcribe (4). Findings from LENA foundation researchers have reported that LENA has moderate sensitivity and high specificity and indicate a high degree of fidelity (4, 8). With respect to classifying the audio as child, adult, TV or other, the agreement between the LENA software and a human transcriber was 82% for adults and 76% for the child. For adult word count, the correlation between the estimates produced by LENA and those by a researcher transcribing the audio file was r=0.92. For child vocalisations, the software distinguishes between actual vocalisations and non-vocalisations (crying, vegetative sounds/fixed signals). The LENA software and a human coder made consistent categorisations of child vocalisations 75% of the time.

[1] A conversational turn does not differentiate who initiated the turn (e.g., parent or child).

3.2.2 LENA clothing

Image 1: 24-month old wearing LENA overalls with Digital Language Processor (DLP) inside front pocket.

During the recording day each child wore purposely designed clothing to accommodate the Digital Language Processor (DLP). The clothing items included t-shirt, vest and overalls that had a small front pocket to hold the DLP. The pocket comprised of three sides that are permanently sewn together with one side of the pocket fastened by two snaps. This design allows the DLP to fit securely in place during the recording day. Some parents reported that the sizes on the LENA clothing (shipped from the USA) were a smaller fit than Australian sizes. Consequently, at least 2 sizes of clothing were provided to families so that they had alternative sizes to choose from.

3.2.3 Time-use diary

Parents were asked to complete an hourly time-use diary during the day of the recording to assist with reliability and validity checks and the interpretation of LENA data. Caregivers were asked to record each activity the child participated in during the day, which caregiver was present and whether any other people were present (i.e., other adults or children). The time-use diary also provided additional space if parents wished to include extra notes regarding each activity.

3.2.4 Nap and TV durations

Parents were asked to estimate the duration and time/s of day their child napped, as well as estimate the duration and time/s of day that the TV was on around the child. Child awake times were calculated by using the parent-reported nap durations in conjunction with the DLP recording categorisations.

3.2.5 Demographic information

Parents were asked to supply general demographic information regarding their age, gender and education, as well as the age and gender of the participating child. Parents were also asked whether they were the primary caregiver of the participating child and to specify how many adults lived in the home.

3.2.6 Perceived influence on communication

Caregivers were asked a series of questions regarding whether they thought the DLP recording device influenced their communication. Specifically, participants were asked “Did you feel conscious/aware of the recording device during the recording session?”, “If yes, do you feel that you were more or less communicative with your child?” and “For how long do you think that you felt

conscious or aware of the recording device in a way that influenced your normal behaviour with your child?"

3.2.7 Caregiver perceptions of LENA recording device

Caregivers were asked to provide any information regarding their experience participating in the study. Participants were asked "Did you have any concerns about the LENA recording device?" and "Do you have any feedback to the research team." There was also space provided for caregivers to write any additional comments or questions regarding their experience.

3.2.8 Language measures

Parents were asked whether the child was experiencing any illness or condition that may have impaired the amount of communication of their child for the recording day. If so, the parents selected whether their child had a "cold", "sore throat", "cough" or was "teething". The parents also completed the Macarthur-Bates Communicative Development Inventories (CDIs) which are a standardised measure of language development (not reported in this paper).

3.3 Procedure

3.3.1 Scheduling recording dates

Once families confirmed their interest to participate, parents were asked to suggest dates that would be convenient for the recording day to take place. The dates of recording were planned as close as possible to the participating child's 6, 12, 18 or 24 month age increment, on a day that is representative of an average day for the child[2]. The dates were also planned on days where caregivers were most likely to be spending the majority of the day with their child (i.e. not a day when the child would be attending child care).

3.3.2 Providing study materials and instructions

Within the week prior to the recording day, participating families met with the researcher to receive instructions and materials for participation. Dependent on family preference, this briefing session either took place within the family's home or at the Fraser Mustard Centre (Level 8, 31 Flinders Street, Adelaide). During the briefing session, each family was given an Information Sheet, Letter of Introduction and consent form. The families were then provided the Participant Questionnaire Booklet (see Appendix C) and instructed how to use the LENA recording device and specialised clothing. Each participating family was provided with a

Image 2: 6-month old wearing LENA T-shirt and Digital Language Processor (DLP)

[2] In the circumstance that extended family members and friends were planned to be present for the 12 month and 24 month birthday milestones, the recordings were scheduled to the preceding or subsequent day to avoid a misrepresentative recording.

range of clothing sizes to take with them to ensure at least one item fit the child. Additional clothing was also supplied in case clothing needed to be changed during the recording day. During this meeting the researcher also arranged a date to receive the materials back.

3.3.3 Participation

The parent completed the first section of the Participant Questionnaire Booklet in their home prior to the recording day. The questions sought general demographic information regarding the child and family, including information regarding parental age and education.

Regardless of age group, all participating children were recorded by the Digital Language Processor (DLP) for 16 hours. The recording began at the very beginning of the day, as soon as the parents became aware that their child was awake[3]. During the recording day the DLP was predominantly worn on the child, held secure within a specially designed pocket at the front of child's clothing (see picture of participant using LENA). When the child's clothing needed to be taken off (for a bath, sleep, etc), the parents were instructed to take the DLP out and place it as close as possible to the child so that audio data could still be captured. To help researchers interpret the data, a time-use diary was completed by the parent during the recording day. The DLP automatically switched off after 16 hours of recording.

After the recording day, parents completed sections 3, 4 and 5 of the Questionnaire Booklet. These sections involved a series of questions concerning the child's language development and activities during the recording time, as well as the Macarthur-Bates Communicative Development Inventories. Guardians were asked in section 5 of the Questionnaire Booklet whether they have any additional comments or questions regarding the recording session.

3.3.4 Receiving completed study materials

The study materials were received by the researcher at a mutually agreeable time. Caregivers either chose to come into the Fraser Mustard Centre (77%) or the Research Assistant came to their home for the meeting (22%). This meeting provided an opportunity for the researcher to gain verbal feedback from parents regarding their experience using LENA, and also allowed parents to ask any additional questions. Participating families were recompensed with a $30 supermarket voucher for volunteering their time. The voucher compensation for their time was not deemed a large enough value to coerce families to participate in the study.

3.3.5 Uploading recordings

Recordings from the DLP were uploaded to the computer via USB connector cable. The LENA software took approximately three and a half (3.5) hours to transfer each recording from the DLP. The software collated and summarised the information so the Research Assistant did not need to listen, transcribe and classify the audio themselves. Provided consent was given, the audio recording was retained. For each of the three direct measures collated by LENA (Parent Talk, Child Talk and Parent-Child Talk), data was available for 5-minute segments, hourly segments or for the entire 16-hour period (See Appendix B for example view of tallies). Hourly data was extracted from the LENA software into an excel file and then uploaded into SPSS for analyses.

[3] On two occasions the parent forgot to begin recording at the very beginning of the day, please see Section 7.1 for discussion relating to possible improvement for future studies.

3.3.6 Charging the DLP

The DLP was charged through the USB connector cable. It took approximately three (3) hours for a DLP to completely recharge.

3.3.7 Resource and timing estimations for future study

To estimate time considerations for conducting LENA research at scale, the Research Assistant (RA) timed the duration that was spent administering each measure to participants. Average time durations per participant were calculated to be used to calculate Full Time Equivalent (FTE) estimations for Research Assistants in the future.

To estimate resource expenditure for conducting the study at scale, the research team considered peripheral implications beyond the obvious costs for the LENA software, Digital Language Processors (DLP) and specialised clothing items. Cost estimates for items such as petrol, and services such as clothes laundering, were derived from this pilot experience in conjunction with quotes from external providers.

4. Participants

4.1 Participating children

Participants (*N* = 18) included single-born children of varying age (4.5-24.75 months old), as shown in Table 1. The study obtained an equal gender distribution (Males = 9, Females = 9). Participating families spoke English at home and children involved had not been diagnosed with a disability that may impair their speech or language.

Table 1: Age and gender of participating children

		N	%
Age (months)			
	< 6	1	5.55
	6-11	4	22.22
	12-17	2	11.11
	18-23	7	38.89
	≥ 24	4	21.05
Gender			
	Male	9	50.00
	Female	9	50.00

4.2 Parents and Carers

Demographic information of participating caregivers is provided in Table 2. Caregiver age ranged between 28 and 63 years old. The education of caregivers included: university degree or above (55.5%), TAFE graduates (16.7%) and high school completion (16.7%). The majority of participating caregivers were mothers (83.3%), with fathers (11.1%) and one grandmother (5.5%) also participating. All participating families (100%) reported to have two (2) adults living in the family home.

Table 2: Participating caregiver demographic information and family details.

		N	%
Age (years)			
	18-21	0	0.00
	22-25	0	0.00
	26-29	1	5.55
	30-34	7	38.89
	35-39	5	27.78
	40-44	4	22.22
	≥ 45	1	5.55
Relationship to child			
	Mother	15	83.33
	Father	2	11.11
	Other	1	5.55
Primary Caregiver			
	Yes	17	94.44
	No	1	5.55
Caregiver Education			
	Did not complete high school	0	0.00
	High school completion	3	16.67
	TAFE certificate	1	5.55
	TAFE diploma	2	11.11
	Bachelor's degree	5	27.78
	Master's degree	0	0.00
	Postgraduate	5	27.78
	Other	0	0.00
Number of adults living in the family home			
	1	0	0.00
	2	18	100.00
	3 or more	0	0.00

5. Findings - Audio Environment

5.1 Variations in audio environment

All participants (*N* = 18) were able to obtain one complete 16 hour recording using the DLP recording device. Composite Digital Language Processor (DLP) data is shown in Table 3.

Nap and sleep times reported by parents were used to calculate the duration that the child was awake during the 16 hour recording. Sleep times were further confirmed by examining individual silence & background approximations for bedtimes. On two (2) occasions parents did not provide nap time estimations, therefore the duration that their child was awake could not be calculated. Of the participants with sufficient data (N = 16), the duration in which the child was awake varied widely between 6hr 19min and 12hr 6min (M = 9hr 55min, SD = 1hr 21min).

Table 3: Composite audio environment estimations from participant 16-hour recordings.

	M (SD)	Range
Meaningful speech	2hr 35mins (42mins)	1hr 25mins – 4hr 16mins
Distant speech	3hr 5mins (43mins)	1hr 49mins – 4hr 15mins
Silence and background	8hr 44mins (1hr 0 mins)	6hr 41mins – 10hr 29mins
TV and electronic sounds	59mins (35mins)	6mins – 2hr 10mins
Noise	35mins (31mins)	11mins – 2hr 31mins

5.2 Meaningful speech

Nap and sleep estimations were filtered when calculating mean quantity of adult words, conversational turns and child vocalisations for the duration of the recording. As mentioned previously, on two (2) occasions parents did not provide nap time estimation and were excluded from the analysis. The hourly mean tallies for remaining participants (*N* = 16) are provided in Table 4.

Table 4: Hourly means, standard deviations and ranges for adult words, conversational turns and child vocalisations, after controlling for child sleep times.

	M (SD)	Range
Adult Words	1,723.04 (619.35)	642.01 - 2,702.52
Conversational Turns	61.15 (34.32)	14.55 – 132.66
Child Vocalisations	212.70 (96.65)	65.78 – 420.53

6. Findings – Participant feedback

Themes that emerged in parent feedback have been reported under the following headings:

1. Factors that facilitated positive perceptions of the LENA recording device;
2. Perceived barriers in using the LENA recording device;
3. Perceived influence on communication;
4. Using LENA across ages;

The analysis of themes for this study utilised notes, written responses from parent questionnaires and LENA word tallies. Substitute names have been used where quotes could potentially identify the speaker or their child.

6.1 Factors that facilitated positive perceptions of LENA recording device

6.1.1 Simplicity of use

The overwhelming consensus among participants was that the Digital Language Processor (DLP) is extremely easy to use, even when participants were having particularly busy days. Parents often commented verbally to the researcher regarding their ease of participation. When prompted to

provide any concerns or additional feedback after participation, the majority of parents (83.3%) had no concerns regarding the device.

> *"No, not at all. Very straight forward."*
>
> *"It seemed very easy and straight forward. Sarah didn't take any notice of it"*
>
> *"No concerns – Researcher explained the process and equipment very well."*
>
> *"Very stress free."*
>
> *"Easy to use. Happy to assist in the study."*
>
> *"The device was no problem."*
>
> *"It was fun!"*
>
> - *Parents*

Furthermore, all participants were provided a number on which they could contact the Research Assistant (RA) at all times if they required any additional help regarding how to use the research materials on the day. The RA was only contacted on one (1) occasion for this additional assistance.

6.1.2 Interest in Longitudinal study

Another indication of the simplicity of using LENA materials was that some parents mentioned their interest in participation in additional observation, despite knowing that the current study was a once-off data collection.

> *"Thanks for the opportunity to participate in the study. At the 18 month mark have noticed that my daughter has started to say more words and a few days after participating in this study she started putting a few words together. May be interesting to see development at the 21mth mark?"*
>
> - *Parent*

6.1.3 Specialised LENA clothing

The DLP size (8.5cm x 5.5cm x 1.5 cm), and weight (57g) paired with the specially designed clothing meant that the recording device reduced inhibition of the child.

> *"Supplied clothing was excellent."*
>
> *"Johnny was a bit interested in it at first, but got over it. The t-shirt product is a good idea."*
>
> - *Parents*

Caregivers commented on how they liked the selection of clothing; onesies, t-shirts, vests, overalls or dresses, which were provided in a range of different colours. The selection of clothing items enabled parents to choose clothing that was appropriate for the weather, for example, on cooler

days children would be dressed using the overalls or dresses and additional clothing was worn underneath.

6.2 Potential barriers of using the LENA device

6.2.1 Requests for feedback and advice

Participants often expressed their interest in receiving feedback and/or information to help support their child's development. These comments were commonly made verbally, with a number of parents including this request within their comments.

> *"The results would be interesting if that is possible?"*
>
> *"I would like to hear about study progress and any feedback on our recording day – even advice on how to support Johnny's development."*
>
> - *Parents*

6.2.2 Considerations regarding Instructions

During informed consent, some participants questioned whether they could delete recording off the device before it is uploaded by the researcher. This is not a feature of the DLP and the audio recording needs to be uploaded onto the computer in order to obtain the word tallies. However, all participants were instructed how to switch off the DLP, so that they can cease participating at any time. In the case that the participants were happy for the word tallies to be collected, but for the audio recording to be destroyed, the participants were informed that the audio recording can be immediately deleted as soon as the processing has been completed (i.e., without ever being able to playback the recording). The researcher stressed that parents have the option to change their mind as to whether or not the audio recording was retained.

As described in the procedure, written informed consent was provided by one parent on behalf of all adults living in the home of the child participant. The Research Assistant instructed the parent to inform visitors that they may be recorded, however it was impractical to expect participating families to obtain informed written consent from every visitor who may be coincidently recorded on the device. Feedback from one parent indicated that she would have preferred to have an information sheet on hand specifically developed for any other adults who were around their child during the recording day.

> *"Would be useful to have a prompt for parents to explain what to do (or not do) to other carers."*
>
> *- Parent*

On two occasions parents expressed that they were uncomfortable with the recording during private situations.

"No, except how to go to the bathroom without recording every noise since Suzie follows me everywhere!"

"(I felt a bit uncomfortable) when we were in the public toilet - afterwards when I remembered!"

- Parents

For one parent the only concern was regarding why the parents were asked to remove the DLP from the child's front pocket during car rides. The parent understood that they should remove the DLP from the child's clothing during car trips, however did not know whether this was for safety or pragmatic reasons. This feedback indicated that further explanation could have been given regarding the use of DLP in the car.

"Only (concerned) in regards to removing it when in the car. Wasn't sure if this was a safety thing or whether it was to be removed as it may cause discomfort and press into child's chest under the pressure of the seat belts on the child car seat. When we went for a walk with the pram I took the device out of the clothing as was concerned the pram straps may press against the button to turn off the device."

- Parent

Additionally, one parent suggested that the hourly activity log did not provide sufficient space for all the activities that the child participated in during the recording day.

"The time log was a challenge. Not sure it's very accurate. Needed 30 minute slots as would do 3-4 activities in an hour with a toddler!"

- Parent

6.2.3 Remembering to switch the DLP device on

The aim of obtaining the DLP recording was to capture as much of the day's language environment as possible. The majority of participants remembered to begin the recording as soon as possible at the start of the day. However, on two occasions caregivers forgot to begin the DLP recording at the very beginning of their child's day. These parents were able to remember to begin the recording by 9.00am. Additionally, one parent did mention that she would have preferred instructions to set a reminder in phone to begin the recording when she woke up.

6.3 Perceived influence on communication

6.3.1 Perceptions of Caregivers

A large portion of participants (61.1%) indicated that they were conscious of the DLP during the recording session, whereas the remainder of participants (33.3%) were not conscious of the DLP. An independent samples t-test indicated that there was no significant difference between caregivers who were consciously aware of the DLP and caregivers who were not aware of the DLP on age, $t(15) = -0.81$, p = .429, years of education, $t(15) = 1.685$, $p = .113$, or their child's age, $t(15) = -1.25$, $p = .231$.

Of the participants who were conscious of the DLP, there were extremely varied perceptions regarding how being conscious of the DLP influenced their communication (see Table 5).

Table 5: Self-reported influence on communication incidences for caregivers consciously aware of the recording device (N =11)

Duration of influence	Less communicative	More communicative	The same
Initial hour	0	0	1
Initial two (2) hours	0	2	1
Initial three (3) hours	1	0	0
Momentarily at various points of day	1	1	2
Entire recording day	0	1	0

A small number of parents perceived either an increase to their communication (22.2%), or decrease communication (11.1%) due to being conscious of the DLP. These parents typically reported that this influence would cease by *"mid-morning"*, reasoning that they simply could not maintain their unusual communication for longer than a few hours.

> *"More communicative, e.g., explaining what we were doing, encouraging him to respond. Off and on all day, particularly in the beginning. Forgot about it after an hour or so maybe, then remembered when I said something I'd rather others didn't hear!"*
>
> *"The first 2 hours. I found it made me more descriptive i.e., instead of giving Sarah her milk and saying "here you go" I'd say "Here is your milk, Sarah", as though I'd need to explain my actions to help make sense of the recording. This only lasted a short while."*
>
> *"Less likely to sing silly songs or be goofy."*
>
> *-Parents*

Though, when considering the entire sample, the majority of participants either did not notice or did not believe that the recording device influenced their communication (55%).

"Neither (more nor less communicative), tried to go about a normal day for us. Although conscious of the device tried to just go about things as per normal. Conscious of the device due to having to remove it or the clothes/device when sleeping and going in the car, and we were in and out of the car a few times through the day. If we didn't have to remove it I feel I would have been less conscious of it."

"Was aware of the device momentarily at various points of the day. However the business of life with a toddler and needing to communicate with Suzie I felt the device didn't actually change my behaviour."

"Was consciously aware of it the entire day – it probably didn't affect how I interacted with Freddy – more so how I interacted with other people!"

"I was only really conscious of it for the first hour or so and then forgot about it"

-Parents

6.3.2 Awareness of recording device influence on Meaningful Speech

After controlling for nap and sleep times, an independent samples t-test indicated that there was no significant difference in adult words between parents who were consciously aware (M = 1914.52, SD = 566.63) and parents who were not consciously aware of the DLP during the recording day (M = 1301.79, SD = 559.63), $t(14) = -2.01$, $p = .064$. However, as can be seen from the means in Table 6, the parents who were consciously aware of the DLP during the recording day engaged in a significantly greater amount of conversational turns per hour (M = 72.43, SD = 33.34) than parents who were not consciously aware of the DLP (M = 36.34, SD = 22.76), $t(14) = -2.18$, $p = 0.47$.

Table 6: Mean hourly counts for adult words and conversational turns (standard deviation in parentheses)

	Not consciously aware of recording device	Consciously aware of recording device	*p*
Adult words	1,301.79 (559.63)	1,914.52 (566.63)	.064
Conversational turns	36.34 (22.76)	72.43 (33.34)	.047

6.4 Using LENA across age ranges

An important part of the evaluation involved examining the practicality of using the recording device in infants at 6- and 12-months old, and toddlers at 18- and 24 months old.

6.4.1 Infants aged 5 – 12 months old

Feedback from parents indicated that the recording device was tolerated well among infants. Parents indicated that the device was able to be left in the front pocket of the babies clothing without the child generally noticing.

"LENA device didn't worry Sarah at all, although at times she did chew on it/play with the pouch. Excellent she couldn't get it out and leaving it in place all day meant she didn't know it could come out."

"Emily did touch her clothes where the device sat at 4-5 times during the day – I think she could tell her clothes were different."

- *Parents of 6-month olds*

Though, parents did indicate some concern regarding that the recording device being stored in the front pocket. One parent was concerned that the DLP might weigh the child down while he was crawling, whereas another parent suggested that this might inhibit or be a discomfort if the child lay on their stomach.

"The only thing I would say is that the device may be comfortable for babies when they roll onto their tummies. My baby seemed OK with it, though she didn't spend too much time on her tummy today."

- *Parent of 6-month old*

Although important to note, these issues did not arise for any participants for the current study.

Parental feedback also highlighted the importance of non-verbal interaction during the earliest ages. Unfortunately the device is limited to audio only and does not provide data regarding non-verbal communication.

"Unsure how successful the recording was with Johnny given his age. A lot of interaction from him is non-verbal (smiles, eye contact) and talking while feeding distracts him so this is a quick time."

- *Parent of 6-month old*

6.4.2 Toddlers aged 18 – 24 months old

There was an amount of overlap of concerns amongst 18- and 24- month parents prior to participation regarding whether their child will be happy to leave the DLP inside the clothing all day. The researcher made note to verbally check in with these parents after participation regarding whether the child left the device in all day. Often to the parents surprise, they would report that, apart from an occasional fidget with the front pocket, the parents reported that their child "was fine" to leave the device on them all day.

"It was unobtrusive and did not bother the child."

"Johnny did seem a bit bothered by the bulky rectangle on his chest, I was worried he would take it out or wet it."

- *Parents of 18-month olds*

7. Findings – Administrative considerations

7.1 Research Assistant considerations

7.1.1 Assumed knowledge

As discussed in Section 3.3, the ease of using the Digital Language Processors (DLP) by the Research Assistant (RA) supports the notion that LENA can be administered and used by the lay person. An individual with no formal qualifications could successfully administer the LENA device after basic training regarding the equipment. Though, individuals administering the device would also need to be aware of the ethical considerations involved with this research, as consistent with the National Statement on Ethical Conduct in Human Research (9).

7.1.2 Time to administer measures and enter data

Time durations for the Research Assistant (RA) to administer the LENA measures and complimentary questionnaires were considered. As itemised in Table 7, approximately one hour and forty minutes of the RAs time was taken to administer and enter data for each participant.

Table 7: Average time considerations for Research Assistant (RA) per participant (in minutes)

		Duration	Cumulative duration
Meeting with participant			
	Organising participant materials	3	3
	Explanation: how to use LENA	15	18
	Explanation[4]:Communicative Development Inventories (CDI)	10	28
Data scoring and entry			
	LENA measures	2	30
	Communicative Development Inventories (CDI)	30	60
Travel			
	Return trip to participant home	40	100

[4] The current study explained to parents how to complete the Communicative Development Inventories (CDI) so that the inventories could be completed independently by the parent at home. A greater duration should be allowed if the Research Assistant were to complete the Inventories with the parents.

7.2 Equipment and Peripheral Expenses

The study found that there were additional costings that may be considered for future large scale research in addition to the Research Assistant (RA) Full Time Equivalent (FTE) considerations and costs associated with the initial purchase of the LENA software, clothing items and Digital Language Processors (DLP). Estimated costs for the LENA equipment and other potential peripheral expenses are provided in Table 8.

Table 8: Possible monetary considerations for using LENA at scale (AU$)

		Estimated Cost	Frequency of cost
Equipment			
	LENA Pro software	$10,920[5]	Once-off
	Digital Language Processor (DLP)	$519 each[5]	Once-off
	Clothing item	$21 each[5]	Once-off
	Dual socket 10 core 2RU Server for processing audio files	$12,000	Once-off
	External hard drive for backup	$400	Once-off
	Digital Language Processor (DLP) repairs	$156 each[5]	6% of total DLPs per annum
	Shipping for DLP repairs <0.5kg (including insurance)	$131 + Custom duty (35% of value)	As required
	Standardised test forms	Dependent on test type and sample size	Once-off
	Lockable cabinets for Research Assistants (RA)	$600 per cabinet per 250 children	Once-off
Travel			
	Mobile phones for RAs	$300 per RA + $40 per month	As required
	RA petrol reimbursement	74c per km	As required
Other			
	Laundry expenses	$1.03 per item	As required
	Printing costs for questionnaire booklets	$2 per 10 pages	As required
	Vouchers and communication materials	Dependent on voucher amount and type of material	As required

7.2.1 Equipment

Although the LENA recording only required about two (2) minutes of the RAs time to upload from the Digital Language Processor (DLP), the recording required a further 3 and a half (3.5) hours to be processed by the LENA Pro Software (as mentioned in Section 3.3.5). The LENA software used to analyse the audio file output from the DLP relies heavily on CPU and Memory of the analysis machine. With a large cohort and a tight schedule of language assessments at specific ages, the

[5] Costs have been converted to Australian Dollar (AUD) estimates from United States Dollars (USD), based on conversion rate at time of publication; 1.0 USD = 1.3 AUD.

DLPs would need to be downloaded and processed in a timely manner to keep the study on track. In order to reduce the processing time of each audio file, additional CPU and Memory (RAM) resources are recommended beyond what a standard PC is able to deliver. IT experts from the Telethon Kids Institute have advised that the optimal method to scale CPU cores and Memory is to invest in server hardware. Server hardware can accept multiple sockets (2 or more) and multiple cores (8 and greater) CPUs as well support memory configuration well above 48GB (512Gb and higher). In our initial tests we have shown the analysis of a study file to be reduced to 1.5 hours with dedicated hardware. The following specifications have been recommended to achieve optimum processing time for DLP output when involving a large sample size: 1x Dual socket 10 Core 2RU server, 64GB RAM, 2x146GB SAS HDD, 3x1.2TB NLSAS HDD. An approximate cost for this equipment has been provided in Table 8.

The current study consistently found that each 16 hour LENA audio file is about 500MB, once compressed. Therefore, data storage requirements for backup of data can be predicted according to planned sample size and data collection frequency.

Repairs to the Digital Language Processors (DLP) over time have been estimated from information provided by the LENA developers. Any broken DLPs would need to be sent to Colorado in the USA to be repaired by the LENA Foundation. According to LENA staff, the national average DLP fail rate is 6% per annum, and repair costs are estimated at AU$140 each. No repairs were required for the current study.

7.2.2 Research Assistant (RA) Travel

For large studies it would be prudent to develop a protocol for data collection, where the RAs are required to call the Project Manager to confirm that they have arrived safely at the participant's home in the morning and that they have left at the end of the day. Therefore mobile phones and applicable phone credit should be incorporated into a budget.

As noted in the procedure, the majority of participants for the current study met at the Fraser Mustard Centre, however on four occasions the RA visited the participant at their home. These trips on average required a 16.45km return trip. Prospective studies should budget for petrol reimbursement at 74c per km. It is recommended that the data collection schedule be designed to drop the DLP off during the home visit and collect the DLP 1-3 days later, before travelling to a different participant's home to conduct their home visit. This will reduce travel time and expenses.

7.2.3 Other monetary considerations

Storage of participant materials for the current study was able to be borne through the RAs existing lockable cabinet. However, it is expected that additional storage for participant clothing items and completed questionnaires would be required for studies with large sample sizes and is indicated in Table 8. In addition to storage, infrastructure should also consider the cost of printing each participant questionnaire. It has been conservatively estimated that one single-sided, black and white A4 page costs 20 cents to print.

Laundering of clothes for the current study was achieved by the Research Assistant (RA). However, for larger studies the clothes to be laundered would be too great for a Research Assistant to cover

and a laundering service should be contracted. As indicated in Table 8, a local laundering service has quoted $1.03 per clothing item.

As mentioned in our procedure, the current study provided a $30 supermarket voucher to all participants as reimbursement for volunteering their time. It has been suggested that researchers offer vouchers and provide communication materials to support cohort retention for the duration of longitudinal studies. Examples of such retention strategies include biannual newsletters, a magnetic photo frame with contact information for the study and a height chart for children that shows the timing of the home visits.

8. Discussion

8.1 Audio environment

The primary advantage of LENA is that the software unobtrusively and objectively measures the language environment within the home for an entire waking day. Once uploaded, data is automatically sorted into meaningful speech, distant speech, noise, silence and background or TV and electronic sounds. The user, regardless of statistical knowledge, can easily examine the audio environment for the recording through the composite graphs provided within the software. Though, more sophisticated analysis was achievable by exporting the data from the software into the applicable statistical analysis software.

A limitation of the study is that parents may not remember to begin the LENA recording as soon as the child's day starts. Indeed, on two occasions parents did not remember until approximately an hour after the child woke up. Consequently, instructions in the future may include a suggestion that parents lay out the LENA clothing in the child's bedroom the night before.

The varied and often lengthy duration that children slept during the recording day exemplifies the importance of obtaining reliable bed times and nap estimates from each participant. The current study asked caregivers to specify when their child napped on a subsequent section of the questionnaire (Appendix C) rather than within the time-use diary that was completed during the recording day. This delayed contiguity may have compromised the accuracy of nap time estimations and consequently influenced hourly mean estimates of adult words and conversational turns. It is therefore recommended that future studies create items within the time-use diary that prompt the caregiver to specify the time that the child napped and was put to bed.

RECOMMENDATIONS:

1. **Include instructions for caregivers to lay out the LENA clothing the night before the recording day.**
2. **Amend time-use diary to request precise times that child was put down for naps and bed time.**

8.2 Factors that facilitated positive perceptions of the LENA recording device

Until recently, investigation into the early language environment has been limited due to requiring investigator presence or static recording devices, and transcribers to code all data. These methods have restricted sample sizes, as well as duration and frequency of recordings of research designs in the past. For example, the famous three-year longitudinal study by Hart and Risley (10) required an additional six years to enter, code and analyse thousands of pages of transcripts for 42 families. They explained that it took at least 8 hours to transcribe one hour of audio recording. Despite this dedication of time, results were based on 1 hour segments per month and thus problematic to make broad estimations of daily interactions from that data. A major advantage of the LENA software is that it uses complex algorithms to automatically collate the amount of adult words and adult-child interaction over a 16 hour period, without the need for investigator presence nor transcription.

The Digital Language Processor (DLP) used to collect audio environment data was well received by caregivers. This was due to the simplicity of the device as well as the complimentary clothing that stored the recording device for the duration of the day. Indeed, the fact that parents wished to be involved in a follow-up study was an encouraging sign for recruitment and retention in subsequent studies.

All children were able to wear the recording device comfortably during the recording day without impairing their movement. The LENA software and complimentary DLP was successfully used in a multiplicity of common activities for Australian families. The portability of the DLP meant that participant activities were not impeded during the recording day. Time-use diaries reflected a range of activities such as yoga classes, picnics at the park and meetings in highly populated cafes. Indeed, the varied range in audio environment across participants supports the diversity of activities between each participant. Crucially, allowing participants as much freedom in activities as possible meant that the representativeness of the data obtained was as representative of daily life as possible.

8.3 Perceived barriers of the LENA recording device

8.3.1 Requests for feedback and advice

The current study noted that many parents were interested in receiving development advice and individual feedback regarding their parental input. However, ethical approval was obtained under the condition that no feedback will be provided to participants. It was reasoned that providing feedback could be harmful if the results are not congruent with caregiver expectations. Though, it is not unreasonable for parents to request information regarding child development. It is therefore concluded that, where possible, future study should endeavour to provide caregivers useful advice regarding child development. Indeed, parent interest in longitudinal research could further be supported by providing such information.

RECOMMENDATIONS:

3. **When LENA feedback cannot be provided to participants (e.g., longitudinal studies), provide advice regarding an alternative topic that is non-consequential to language development (e.g., child nutrition).**

8.3.2 Ambiguity in Instructions

Although many participants commented on the simple instructions and ease of use, it was evident that instructions could be improved to elaborate on how to instruct other individuals during the recording session. Within instructions in the current study parents were asked to "let guests and other individuals around the child know that he/she is wearing a recording device". The instructions did not include a specific handout for individuals that may incidentally be recorded by the device. In most cases the instructions provided were sufficient; however, in one case the parent did not feel adequately equipped to answer the guest's questions regarding the recording. It is therefore advised that future research include a handout for participating parents to give to their guests for their reference.

Feedback from parents also indicated that specific explanation should be included in instructions when asking that the DLP be taken out of children's clothing for car rides. The purpose of this procedure is to avoid harm to the child if the car were to be involved in an accident. If this reasoning is made clear to parents, then it is likely that the procedure will always be followed.

Another consideration raised in this study relates to how the DLP will be used during usually private situations. If audio was being retained, one could suggest that the DLP is taken off the child when entering such places, e.g. public toilets. This protocol would not be necessary if the audio recording is deleted immediately upon upload to the computer. However, there would enviably be a trade-off between speech quality analysis (though retention of audio recording) and obtaining valuable parental input and interaction during a regular task.

One participant mentioned that the time-use diary could be improved to allow more detail within each hour of the day. Indeed, it would be useful for the time-use diary to be broken down into half-hourly or 15 minute increments, or an activity log where no time is specified and the parent indicates the time each activity begins. The current study asked for specific times for naps and television times, however there was no prompt for parents to note the precise time their child was put to bed at the end of the recording day. Parents would report the bed time within the activity log, but again the log did not allow enough accuracy in time reports. It is recommended that future research include an item that requests the precise time that the child was put to bed for the recording night.

RECOMMENDATIONS:

4. **Develop a hand-out for individuals who are incidentally recorded by the DLP and provide copies of this hand out within the instruction pack given to participating parents.**

5. **Develop protocol regarding use of recording device in private areas based on whether audio recording is obtained.**
6. **Within written instructions, include reasoning regarding why caregivers are instructed to remove DLP from child's clothing during car trips.**

7.4 Influence of LENA on perceived and actual communication

It is acknowledged that any observational study of the home environment may be likely to impact parent's behaviour. However the unobtrusive nature of the device and the fact that it is worn for over 16 hours means that the impact of the LENA instrument is likely to be far smaller than the influence of a researcher in the home recording/observing the families, or in a laboratory setting. This is one of the main points of differentiation between our study and others in the past, i.e. the collection of parent talk in a non-experimental natural home environment.

The current study indicated that parents who were consciously aware of the DLP engaged in a greater amount of conversational turns than parents who were not consciously aware of the DLP. This finding supports feedback from parents who perceived an increase to their elaboration and prompting of interaction while they were conscious of the DLP. These initial findings should be interpreted with caution, however, due to the study's very small sample size. Additional research is recommended to continue to check how participant awareness of the DLP during the recording day influences parental input. Additionally, for smaller studies, it may be feasible for researchers to obtain recordings from participating families on at least two recording days within the same week. By increasing the observations to two 16 hour recordings, it is expected that the parent would be less likely to keep up the abnormal behaviour due to their consciousness of the DLP.

RECOMMENDATIONS:

7. **Where possible, data collection to be taken on two occasions within the same week to reduce Hawthorn effect.**

7.5 Parent perceptions using LENA between ages

Research into the very early language environment is surprisingly sparse despite being a crucial period for brain development. Most research seeking to investigate the early language environment has focused on later ages (> 12 months). Identifying an efficient and comfortable means to measure parental input during the earliest of ages is likely to allow more detailed research to occur. Although the DLP recording device is made specifically to be worn by young children (and indeed has been used in research involving new born babies (11)), researchers were unclear whether the DLP would be practical for infants for a 16-hour uninterrupted recording. Feedback from parents indicated that the DLP was generally unnoticed by the infant during the recording. This finding supports the use of LENA during the earliest of ages.

Nonetheless, feedback from parents of infants at 6-months of age raised important considerations for very early ages. A great deal of parent-child communication is through gestures rather than vocalisations at 6-months since infants are not yet talking. The LENA device only collects data

regarding the acoustic properties of the day, therefore is only capturing a portion of the communication between parent and child.

Although the LENA device collects rich acoustic data, it in itself is not a sufficient measure of the early learning environment. The LENA software does not capture non-verbal gestures that the parent and child may be using to communicate nor does it derive the content of language. Standardised measures of parent-gesture coupled with a detailed understanding of the home environment would be recommended in future research using LENA. The current study did not include measures regarding immediate non-adult family members (e.g., siblings and birth order) or activities for the previous week (e.g., reading, child care attendance, or work outside of the home). This information may have been useful for interpretation of findings.

Parent feedback further indicated that the LENA device was tolerated well by older children. By 18-months of age it is common for children to be walking by themselves and becoming extremely active. This could have been a problem during the recording day because children may have been bothered or wished to play with the device. However, the results from this study suggest that participating in high levels of activity does not influence the practicality of the recording device nor restrict the child in play during toddlerhood.

RECOMMENDATIONS:

8. **Continue to administer a standardised measure of child gesture to complement the LENA acoustic measures.**
9. **Include measures regarding participant siblings, such as birth order, age and gender.**
10. **Include measures regarding activities for the previous week, such as reading time, child care attendance.**

7.6 Considerations for future research

The costs involved for purchase of equipment and research assistant time are notably efficient when considering the quantity and quality of the data obtained. Measures categorised and quantified by the LENA software enable a detailed snapshot of each child's audio environment for an entire waking day. For every hour and forty minutes of a Research Assistants time, the LENA equipment can capture information regarding a child's home environment for an uninterrupted 16 hour period.

Our findings indicate that the LENA technology could be administered and used with relative ease by both Research Assistant (RA) and caregiver. As noted previously, a key facilitator of the LENA equipment is its simple design. The Digital Language Processor (DLP), the recording device worn by the child and administered by the parent, only has two function buttons (on/off, record). This simplicity allowed parents to easily navigate the functions to begin the recording. The DLP automatically switches off after the 16 hour recording period, so there was no need for caregivers to touch any buttons once the recording had begun.

All Research Assistants should be aware of the ethical considerations regarding the study, particularly considering the sensitive data which may be collected (i.e., audio recordings within the

home). In line with the National Statement on Ethical Conduct in Human Research (9), a study protocol should be approved by a Human Research Ethics Committee (HREC) before any research is conducted. This protocol would identify how data will be obtained and retained by the research team.

RECOMMENDATIONS:

11. Research Assistants (RA) involved in LENA study should have existing knowledge regarding research ethics prior to contacting any participants.

7.7 Limitations

Our study sample consisted of mostly mothers with a bachelor degree or higher, and thus, their experiences in using the DLP may not be generalisable to other study populations. Additionally, the small sample size may further limit the representativeness of our findings. We should note, however, that our ability to successfully implement the use of the DLP with minimal training and instruction for all participants is encouraging. This preliminary data supports the use of the DLP in providing objective measures of parent input and interaction for infants and toddlers.

It is suggested that future recruitment strategy simply recruit participant families with children within an age range rather than specifically naming the age ranges the recording dates should occur. It is likely that the current trial would have had a quicker participant uptake if researchers sought families with children between 4 and 24 months old, and simply booked the recording day to occur on the applicable age increment.

RECOMMENDATIONS:

12. Continue to obtain caregiver feedback regarding the DLP recording device in future study.
13. Amend wording on study flyer to recruit families of children 5-24 months of age for data collection at 6-, 12-, 18- or 24 months of age.

7.8 Conclusion

This feasibility study using the LENA DLP within the homes of South Australian families is an important step in refining methods to objectively obtain parental input and audio environment. The findings of this study were tremendously positive toward the LENA recording device; however the trial also allowed us to recognise possible improvements for future study. Overall, we believe the rich parental input measures captured by LENA may provide critical insights into the benefits of interventions to ameliorate disadvantages in early language development.

9. References

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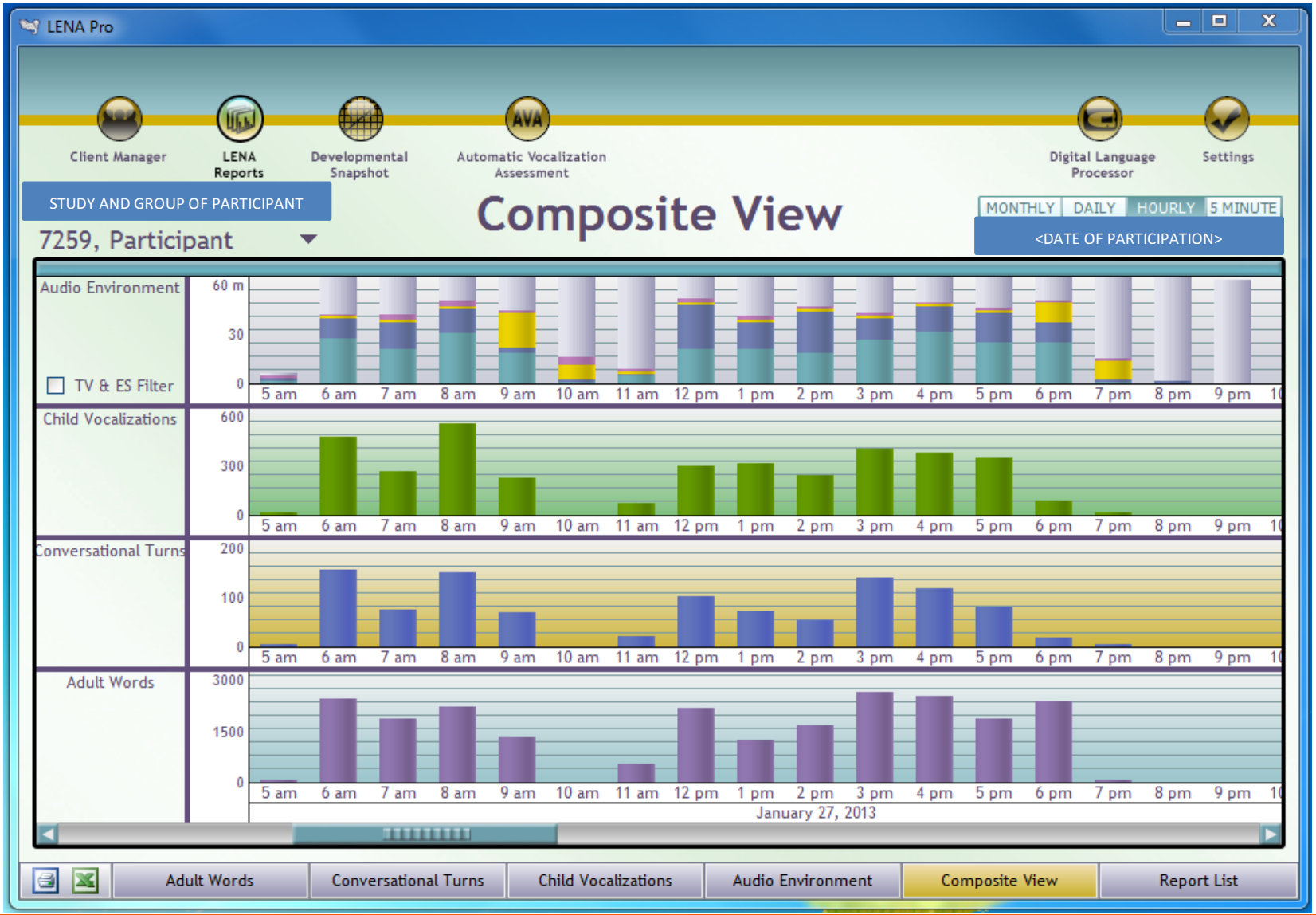
Power Button
Record/Pause Button
Screen
(States when “sleeping”,
“Recording” or “memory full”)
Microphone
LENA
REC

11. Appendix B – LENA software screenshot



12. Appendix C – Participant Questionnaire Booklet

Recording Date_____ Child ID #: _____

PARTICIPANT QUESTIONNAIRE BOOKLET

Please take your time when completing the questionnaire booklet. There are five parts to this booklet;

- Part 1 is to be completed prior to the recording session
- Part 2 is to be completed during the recording session
- Parts 3, 4 and 5 are to be completed immediately after the recording session

SESSION QUESTIONNAIRE: Part 1

Please complete the following questions prior to commencing the recording:

1. Child's age (in months):

   ……..

2. Child's gender

   ☐ Male ☐ Female

3. Are you the child's primary caregiver?

   ☐ Yes ☐ No

4. Are you the child's:

   ☐ Mother ☐ Father ☐ Other (please specify): ……..

5. Please indicate your age (in years): ……

6. Please indicate your highest level of education:

   ☐ Did not complete high school
   ☐ High school completion
   ☐ Certificate level I
   ☐ Certificate level II
   ☐ Certificate level III
   ☐ Certificate level IV
   ☐ Diploma
   ☐ Advanced Diploma
   ☐ Bachelor's degree
   ☐ Master's degree
   ☐ Postgraduate
   ☐ Other (please specify): ……..

7. How many adults live in your family home:

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4 or more (How many? ……..)

SESSION QUESTIONNAIRE: Part 2
Hourly Activity Log

Filling out this form will help the researcher compare your data with your recording day routine. Please complete this chart during your recording day, noting activities your child engaged in, such as:

Child care/preschool	Babysitter time	Play dates	Meal/snack times
TV/video time	Naps	Group gatherings	Errands (supermarket, etc)
Book reading	Car rides	Dressing times	Outings (zoo, library, etc)

Time	Activity	Main Caregiver	Other People Present	Notes
5 AM – 6 AM				
6 AM – 7 AM				
7 AM – 8 AM				
8 AM – 9 AM				
9 AM – 10 AM				
10 AM – 11 AM				
11 AM – 12 PM				
12 PM – 1 PM				

1 PM – 2 PM				
2 PM – 3 PM				
3 PM – 4 PM				
4 PM – 5 PM				
5 PM – 6 PM				
6 PM – 7 PM				
7 PM – 8 PM				
8 PM – 9 PM				
9 PM – 10 PM				
10 PM – 11 PM				
11 PM – 12 AM				

SESSION QUESTIONNAIRE: Part 3

Please complete the following questions immediately after recording:

1. Is your child babbling by using sounds like “bababa” or “mabega”?

   ☐ No ☐ Yes

2. Is your child speaking words (i.e., talking)?

   ☐ No ☐ Yes

3. a) Did your child take any naps during your recording session?

   ☐ No (please skip to question 4) ☐ Yes (please continue to question 3b)

   b) Please estimate the total amount of time your child spent napping (in minutes):

   ……

   c) Please indicate the time(s) of day your child napped? (e.g., 11am – 12pm and 1:30pm – 3:00pm)

   ……

4. a) Was the TV on while your child was present during your recording session?

   ☐ No (please skip to question 5) ☐ Yes (please continue to question 4b)

   b) Please estimate the total amount of time the TV was on while your child was present (in minutes):

   ……

   c) Please indicate the time(s) of day the TV was on while your child was present (e.g., 10am – 10:30am and 3pm – 6pm):

   ……

5. Is your child experiencing any health problems that might affect his/her speech?

   ☐ No ☐ Yes

   If so, please indicate the health issue below:

☐ Cold ☐ Sore throat ☐ Cough ☐ Teething

☐ Other, please specify: ……..

SESSION QUESTIONNAIRE: PART 4*

Please take your time when completing the following inventories in relation to your child. Every child will be different; there are no right or wrong answers.

*We do not have permission to reproduce the MacArthur-Bates CDIs and therefore cannot provide a copy of the standardised tests within this report.

Child ID #: _____

SESSION QUESTIONNAIRE: PART 5

1. a) Did you feel conscious/ aware of the recording device during the recording session?

   ☐ No (please skip to question 2) ☐ Yes (please continue to question 1b)

   b) If Yes, do you feel that you were more or less communicative with your child?

   ☐ More communicative ☐ Less communicative

   c) For how long do you think that you felt conscious or aware of the recording device in a way that influenced your normal behavior with your child?

_____
_____
_____
_____
_____
_____
_____
_____
_____

2. Did you have any concerns about the LENA Recording device?

_____
_____
_____
_____
_____
_____

_____

_____

3. Do you have any feedback to the research team?

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

4. Please write any additional comments or questions about your recording session.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Thank you for volunteering your time to participate in this study ☺

About the Fraser Mustard Centre

Working together to improve the development, education, health and wellbeing of young Australians, the Telethon Kids Institute and the South Australian Department for Education and Child Development have joined forces in a unique approach to research translation. The Fraser Mustard Centre collaboration aims to:

- Improve and promote the health and wellbeing of all children and young people in South Australia through the unique application of multidisciplinary research
- Help shift focus from the historical delineation between health and education services to an integrated approach with a focus on child development
- Build capacity amongst public sector staff and academic researchers to design, undertake and use research to improve the environments in which children live and the service systems which support families
- Attract funding for shared priorities for research that leads to improved developmental, education, health and wellbeing outcomes for children

The Fraser Mustard Centre brings forward-thinking policy makers and world class child health researchers. It reflects a shared view of policies and outcomes for children and young people. The Centre is a unique collaboration between two organisations passionate about making a difference.

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FRASER MUSTARD CENTRE

A COLLABORATION BETWEEN

Government of South Australia
Department for Education and Child Development

TELETHON KIDS INSTITUTE
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