South Australian Royal Commission into Early Childhood Education and Care.

Invited submission by Professor Sally Brinkman, with acknowledgements to my fellow Chief Investigators of the LiLO Study; Professors Sheena Reilly, Edward Melhuish and John Lynch, and PhD student Mary Brushe.

Background:

Language is a critical developmental accomplishment of early childhood, enabling later literacy, education, and employment. There are vast socioeconomic differences in vocabulary, sentence structure and communication styles. These social inequalities in language, have their origins in infancy and predict human capability formation over the life-course [1-3]. Many national birth cohorts have shown that, of the socioeconomic inequalities in child health and development, none are larger than those related to language [4, 5].

Children normally achieve three important language milestones in the first two years of life: (1) understanding words spoken by caregivers around 8 months; (2) saying their first words around 12 months and (3) combining 2-3 words in simple sentences at 24 months. While there are clear patterns in the order of emergence of language milestones, there is striking variability in the precise timing of the achievement of these milestones. In the Early Language in Victoria study (ELVS), 12 month old children spoke an average of 6 words but this ranged from 0 to 123 words. At 24-months, there was an average of 260 words spoken and ranged from 0 to 679 words [6-8]. This inherent variability of language onset often leads to developmental concern among caregivers, with 20% of Australian two-year-olds meeting criteria for expressive language delay [7, 9-12] and wait lists for speech therapy services a concern across the country [12].

Results of the 2021 Australian Early Development Census (AEDC) showed that 7.9% of 5 year old children were vulnerable in language and cognitive skills, and 8.6% developmentally vulnerable in communication skills and general knowledge in South Australia [13]. Of concern is that since the national AEDC data collection commenced in 2009, the triennial picture for South Australia has shown a progressive increase in developmental vulnerability on the Language and Cognitive domain, with that trend being in stark opposition to the other jurisdictions in Australia [13]. AEDC scores have also been shown to have good predictive validity for children's later NAPLAN (National Assessment Program - Literacy and Numeracy) results through primary and into high school [14]. Out of the five AEDC developmental domains, the Language and Cognitive domain is the strongest predictor of later NAPLAN scores [14].

There is little doubt that parents are the most important influence on language development and that language development trajectories are set early in life. Studies consistently show that children of parents who are more socioeconomically disadvantaged engage in fewer verbal interactions with their children compared to advantaged parents [15-18]. Socioeconomic inequalities in parental verbal input (parent talk) to their children are likely to be crucial to the intergenerational transmission of inequality [15, 16, 19]. As such, language is a potentially modifiable mechanism for mediating the large social inequalities in children's health and development [20, 21].

The most influential study of language spoken to the child in the home was conducted in 1995 by Hart and Risley [16]. This study involved a convenience sample of 42 families in Kansas, USA. From the age of 1-2 years children of parents from welfare, working-class and professional occupations heard 620, 1250, and 2150 words per hour, respectively. These figures were then linearly extrapolated to estimate that by 3 years of age the socioeconomic gap was 30 million words. This

"30-million-word gap" is popularly referred to by the media, researchers and policy makers (google hits = >91,000,000). Despite its popularity, the study has some serious flaws, mainly, that they did not used objectively measured language in the natural environment of the home and was based on a very small and highly selected convenience sample. Taken together, the generalisability of their study results to children in Australia is very weak.

Considering these flaws in the Hart and Risley study, we were successful in gaining National Health and Medical Research Council funding for the Language in Little Ones (LiLO) study. The study has collected objective measures of language exposure using speech recognition technology; Language Environment Analysis or LENA. Just as a Fitbit is a health and activity tracker, LENA tracks and measures parent-child talk. A digital language processor (DLP) is placed in specially designed clothing for the child to wear during the 16-hour recording. The LENA computer software is then used to automatically process the audio captured through the DLP. The three key LENA outputs are adult word count (AWC; the number of adult words spoken to the child), child vocalization count (CVC; the number of speech-related sounds made by the child) and conversational turn count (CT; the number of alternations between adult and child occurring within at least 5 seconds of each other).

The specific aims of the LiLO study are to:

1. Establish the temporal associations between trajectories of Parent Talk, Child Talk and Parent-Child Talk from 6 months to 5 years.
2. Determine how trajectories of Parent Talk, Child Talk and Parent-Child Talk differ by socioeconomic groups, parental language ability, and gender.
3. Examine the effects of trajectories of Parent Talk, Child Talk and Parent-Child Talk on child health and developmental outcomes at ages 3 years and 5 years, and differences by socioeconomic group, parent language ability and gender.
4. Simulate how interventions to close socioeconomic gaps in Parent Talk would reduce social inequality and improve overall levels of child health and development for Australian children.

Our study recruited families from birth and throughout the study period. We commenced recording parent-child talk when children were 6 months old, with repeated measures every 6 months until participants reach the age of 5 years. LiLO was explicitly designed to maximize contrasts across maternal education groups, by stratifying recruitment into a low educated group (mothers without any post-secondary school qualifications), and a high educated group (mothers with a bachelor's degree at minimum). At each wave of data collection, families undertook day-long (16-h) audio recordings. Our sample waivered throughout the study, but was in the order of 100 from the low maternal education grouping and 165 in the high education grouping. Families were recruited predominately from South Australia, with some from Western Australia and Queensland.

To date we have published two studies (appended) [22, 23]. Data are still being analysed and we expect further papers to be published over the next few years. Key findings from the papers conclude that:

- There is very large variability in "parent talk" within both of the education groupings,
- at both 6 months and 12 months there was no difference in the average number of words spoken between the two maternal education groupings, however
- at 18 months a gap emerges, and indeed this gap is found for the three LENA outcomes; adult words, child words/vocalisations and conversational turns.

Of particular interest is that for adult word count, children in the low maternal education grouping hear less words at 18 months than they do at 12 months, whereas the opposite is found for the high

educated grouping. It would seem that as the children's own language starts to emerge, adults in the two different education groupings start behaving differently. As such, the socioeconomic gap in parent language input would appear to emerge when the children start communicating themselves.

Our results are consistent with Hart and Risely in identifying a socio-economic "word gap", however they differ in that, we identify that this gap emerges between 12 and 18 months of age. Further Hart and Risely's proport that adult words increased over the children's first 3 years of life, but that the higher socioeconomic groups adult word count increases at a greater rate than the lower socioeconomic grouping. We found that the number of adult words in the low maternal education grouping decreases from 12 months of age.

As we continue to analyse the results of the LiLO study, we will determine if these trends continue as the children get older, and most importantly if these indicators of the home language environment actually predict the children's development outcomes. There is existing scientific literature that would suggest that children who experience more child-directed speech have positive language outcomes, although speech simply overheard by the child may be unrelated [24]. This literature would suggest that conversational turns, as measured by our LiLO study, may be the stronger predictor out of the three LENA word count measures. This would be consistent with the general literature behind early child development; those children raised in responsive and stimulating home environments will be more likely to thrive.

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RESEARCH ARTICLE Open Access

The education word gap emerges by 18 months: findings from an Australian prospective study

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Abstract

Background: The idea of the '30 million word gap' suggests families from more socioeconomically advantaged backgrounds engage in more verbal interactions with their child than disadvantaged families. Initial findings from the Language in Little Ones (LiLO) study up to 12 months showed no word gap between maternal education groups.

Methods: Families with either high or low maternal education were purposively recruited into a five-year prospective study. We report results from the first three waves of LiLO when children were 6, 12 and 18 months old. Day-long audio recordings, obtained using the Language Environment Analysis software, provided counts of adult words spoken to the child, child vocalizations and conversational turns.

Results: By the time children were 18 months old all three measures of talk were 0.5 to 0.7 SD higher among families with more education, but with large variation within education groups. Changes in talk from 6 to 18 months highlighted that families from low educated backgrounds were decreasing the amount they spoke to their children (− 4219.54, 95% CI -6054.13, − 2384.95), compared to families from high educated backgrounds who remained relatively stable across this age period (− 369.13, 95% CI − 2344.57, 1606.30).

Conclusions: The socioeconomic word gap emerges between 12 and 18 months of age. Interventions to enhance maternal communication, child vocalisations and vocabulary development should begin prior to 18 months.

Keywords: Word gap, Parent talk, Inequality, Early childhood development, Language

Background

The emergence of socioeconomic inequalities in many areas of children's health and development is evident early in life [1, 2]. Understanding when and how these inequalities develop is a key question for researchers and policymakers because preventive interventions should be in place before health and development gaps become entrenched [3]. Hart and Risley famously coined the term '30 million word gap' by estimating through linear extrapolation of data collected from 10 to 36 months, that by age four, parents in the United States (US) who were on welfare had spoken 30 million words less to their child than parents with professional occupations [4]. In a 10-year follow up, they found these socioeconomic differences predicted subsequent verbal ability, receptive and expressive vocabulary, and academic achievement in grade 3 [5].

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The term '30 million word gap' has garnered enormous attention, with over 113 million google hits. In response, new technology has been developed [6] and considerable resources expended on initiatives across the world aiming to reduce the word gap. The Hart and Risley findings were based on a convenience sample of 42 families in Kansas, with only 6 families in the welfare category, compared to 13 families in the professional category and 23 families in the working class category. Furthermore, data were collected through researchers videotaping 1 h in the family's home per month, which may not be representative of the natural home environment. Language data were collected from 10 months of age onwards, limiting the understanding of critical language experiences during the first year of life. The validity and generalizability of Hart and Risley's findings have been widely debated [7–10].

Gilkerson and colleagues [11] attempted to overcome some of the limitations of Hart and Risley's work through the use of newly developed speech recognition technology, Language Environment Analysis (LENA). Researchers were able to objectively measure a family's home language environment to capture the number of words children heard over a day. The study involved 329 English speaking families with children aged between 2 and 48 months, from Denver. Families completed LENA recording days once a month for 6 months and a subset of 59 families completed monthly recording days for an additional 32 months. Their results estimated a 4-million-word gap by age 4 between mothers with some high school vs. those with a college degree.

The Language in Little Ones (LiLO) study is a prospective study of Australian families aiming to understand maternal education differences in the number of words children hear and speak in the home environment during the first 5 years of life. The LiLO study started collecting language data in the home, involving day-long recordings, when the children were 6 months old with data collection occurring every 6 months, until their first year of schooling, around age 5. We previously reported that when children were 6 and 12 months old there were no meaningful differences in any measure of parent-child talk between maternal education groups [12]. There was large variability, with high and low talkers within both education groups.

The present study includes new data from the LiLO study when children were 18 months old. This is an important age in children's language development when they are beginning to expand their vocabularies. Here we report all data currently available from the LiLO study including the number of adult words spoken to the child, number of child vocalizations and number of conversations between adult and child over a day when the children are 6, 12, and 18 months old by levels of maternal education.

Methods

Study design

The LiLO study commenced recording parent-child talk when children were 6 months old, with repeated measures every 6 months until child age 5 years. LiLO was explicitly designed to maximize contrasts across maternal education groups, by stratifying recruitment into a low educated group (mothers without any post-secondary school qualifications), and a high educated group (mothers with a bachelor's degree at minimum). At each wave of data collection, families undertook day-long (16-h) audio recordings. A $10 supermarket voucher was provided to families as compensation after each wave.

Participants

Recruitment occurred within Adelaide and Port Pirie in South Australia, Bunbury in Western Australia and the Gold Coast in Queensland between April 1, 2017 and July 31, 2019. Expecting mothers were approached at public hospitals while waiting for their antenatal appointments. Additionally, postnatal recruitment occurred at Child and Family Health Services during early parenting groups and drop-in clinics in Adelaide, Port Pirie and Bunbury. Mothers were also approached at local shopping centres, council-run immunization clinics, community playgroups, children's centres and libraries across all locations. Families were excluded if they did not speak English in the home or if the mother's level of education did not fall within the low or high educated categories. They were also excluded if their child was part of a multiple birth, was born premature (< 37 weeks), had a diagnosed cause of language impairment (e.g. hearing impairment, Down Syndrome, Cerebral Palsy) or was born outside the date range of January 1, 2017 and December 31, 2017.

Figure 1 provides a detailed flow chart of participant numbers across the first three waves. As is common in prospective studies, there was difficulty in attempting to recruit socioeconomically disadvantaged groups [13]. At the first wave, only 65 low educated families were participating in the study despite extensive and exhaustive recruitment efforts. To boost sample size among the low educated, we extended the recruitment timelines and locations which meant families could join the longitudinal study even if they had missed the first or second wave of data collection. An additional 35 low educated families joined the study and only seven families (4 low educated; 3 high educated) had withdrawn since the study started. A home visit occurred with each family within 2 months of the child's 6, 12 and 18 month birthdates. Data collection procedures have been previously described, with processes remaining consistent at each wave for all families in the study [12].

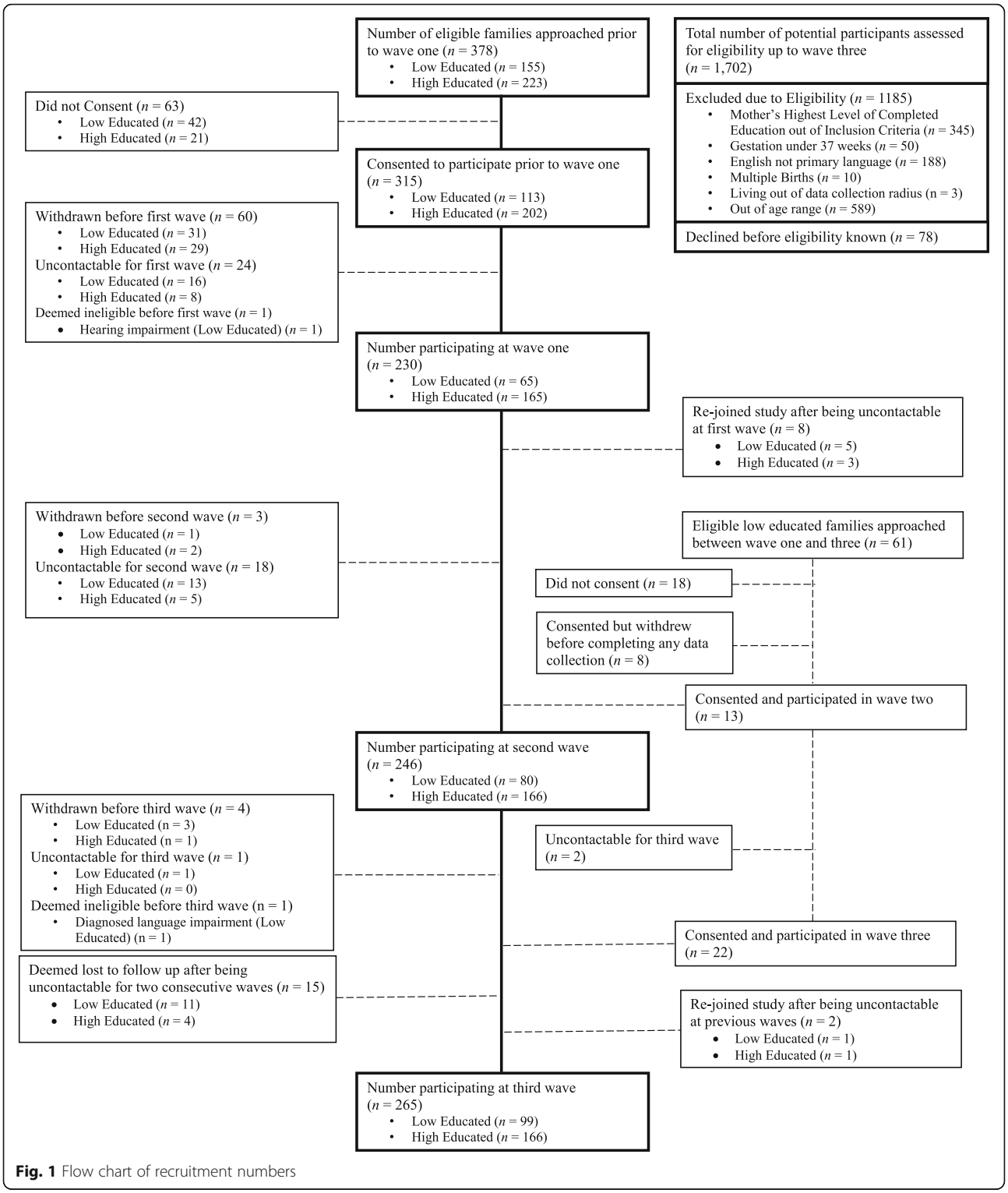

Fig. 1 Flow chart of recruitment numbers

Measures

The Language Environment Analysis (LENA) system was used to capture the child's home language environment. The LENA technology comprises a digital language processor (DLP) and LENA computer software to automatically process the audio captured through the DLP using algorithmic analysis of the acoustic properties in the speech signal [6, 14, 15]. Three key LENA measures were used in this study: adult word count (AWC; the number of adult words

spoken to the child), child vocalization count (CVC; the number of speech-related sounds made by the child) and conversational turn count (CT; the number of alternations between adult and child occurring within at least 5 s of each other). Home activity diaries were also completed by the parents outlining the activities of the child, by the hour, throughout the recording day. Total word counts, from the LENA software, were used in the analysis when the full 16-h recording was completed or the activity diaries confirmed that the LENA device was turned off when the child went to sleep. Adjusted word counts were calculated if the LENA device was turned off prior to child's bedtime, whereby average hourly counts were added to the total reported word count to take the total recording time up until the child fell asleep, as reported by the parents in the home activity diaries. Adjusted word counts were only used for one low educated family in wave 1 and one high educated family in wave 3. Reliability testing by the LENA Foundation has reported high levels of agreement between human transcribers and LENA system classification [15].

Statistical approach

Parent-child talk variables were modelled using random effects longitudinal models using the *xtmixed* command in Stata, to understand changes in adult word counts, child vocalizations count, and conversational turn counts according to maternal education, from child ages 6, 12 and 18 months old. The interaction of mother's education and wave of data collection was included as the only predictor in the model to identify how changes over time differ between education groups. The parameters were computed using the expectation maximisation (EM) algorithm. To identify differences between maternal education groups and their word counts across each wave, we used the *margins* command in Stata to calculate the predicted means for low and high educated families at each time point and plotted their mean word counts and 95% confidence intervals across waves in Fig. 2, 3 and 4. A comparison of means from the observed data and the computed model is provided in the supplementary appendices (See Additional file 1). Effect sizes were also calculated using Cohen's *d* [16].

To ensure the addition of the extra 35 low educated families at waves 2 and 3 did not affect the results, we undertook a sensitivity analysis that only included families who had participated since wave 1. Details of the sensitivity analyses are also provided in the supplementary appendices (See Additional file 2). All analyses and figures were conducted using Stata version 16 [17].

Results

Data for the first three waves were collected between August 1, 2017 and July 31, 2019. Of those families actively participating in the study, LENA data was not available for 11 families across the three waves. This was due to nine families at wave three skipping their visit due to personal reasons and for two families the LENA device malfunctioned (one at wave 1 and one at wave 3). One family was deemed ineligible due to a diagnosed cause of language impairment at the third wave, so their data was retrospectively removed.

The sample varied slightly across waves due to the increase in participant numbers, as shown in Table 1. The final analysis sample consisted of 163 families in the high

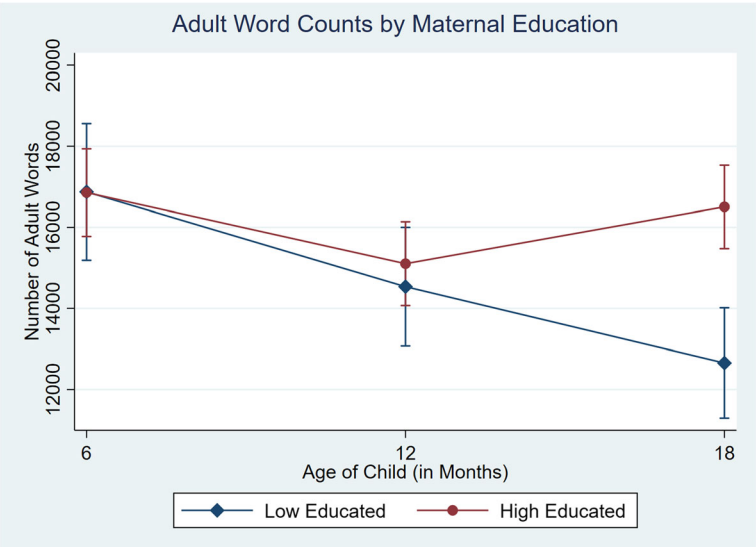

Fig. 2 Predicted mean adult word count and 95% CI by maternal education across 6 month, 12 month and 18 month wave of data collection

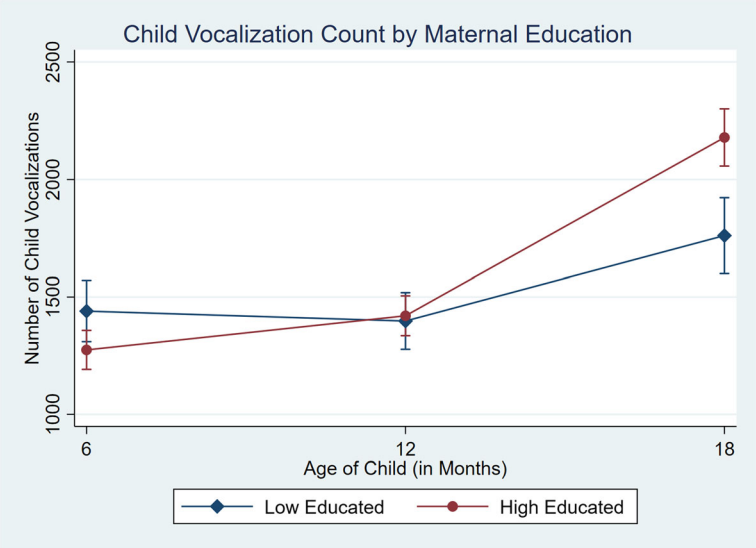

Fig. 3 Predicted mean child vocalizations count and 95% CI by maternal education across 6 month, 12 month and 18 month wave of data collection

educated group and 92 families in the low educated group. The average age of the mother at childbirth was 31.28 years and 85% of mother's were employed prior to their pregnancy. Just over half the children in the sample were first born and 54% were female.

Table 2 shows the results from the random effects model that estimates the interaction between mother's education and wave of data collection on the three LENA measures: adult word counts, child vocalization counts and conversational turn counts. The coefficient demonstrates the changes in growth for both low and high educated groups as compared to the 6 month baseline for the low educated group. As can be noted from the model, for adult word counts, families from low educated backgrounds were talking 4219.54 words less, 95% CI (– 6054.13, – 2384.95) to their children by 18 months, compared to high educated mothers who remained relatively stable across waves with only 369.13 fewer words 95% CI (– 2344.57, 1606.30) by 18 months. For child vocalization counts, the model demonstrates children

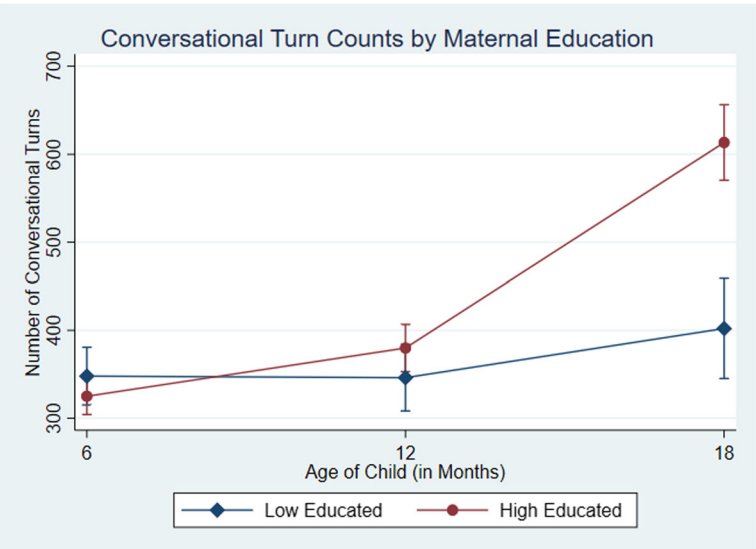

Fig. 4 Predicted mean conversational turns count and 95% CI by maternal education across 6 month, 12 month and 18 month wave of data collection

Table 1 Sociodemographic Characteristics of the Sample

	6 month Data Collection (*N* = 228)	12 month Data Collection (*N* = 245)	18 month Data Collection (*N* = 255)
Child			
Age, mo, mean (SD)	5.82 (0.58)	11.99 (0.51)	18.02 (0.56)
Girls, n (%)	122 (53)	130 (53)	136 (53)
Gestation, wk., mean (SD)	39.1 (1.35)	39.18 (1.50)	39.19 (1.49)
Firstborn, n (%)	128 (56)	131 (53)	136 (53)
Mother			
Highest level of completed education, University, n (%)	164 (72)	166 (68)	163 (64)
Age at childbirth, y, mean (SD)	31.36 (4.42)	31.22 (4.57)	31.28 (4.84)
Working up until pregnancy, yes, n (%)	199 (87)	211 (86)	217 (85)

from both the low (320.74, 95% CI 126.61, 514.88) and high (739.04, 95% CI 560.66, 917.53) educated groups increased their number of vocalizations by 18 months, but high educated children grew their vocalizations at a faster rate. For conversational turn counts, both high and low educated families had little growth between the first and second wave, however between the ages of 12 and 18 months, growth in turns between adult and child for the high educated group (265.62, 95% CI 211.52, 319.73) exceeded that of the low educated group (54.22, 95% CI -5.54, 113.98). The 95% confidence intervals in the models highlight large variability in growth across waves for both groups. However, on average low educated adults are talking less to their children by 18 months.

The graphs in Figs. 2, 3 and 4 depict the predicted mean and 95% confidence intervals for each measure of talk by maternal education groups at 6, 12 and 18 months of age. The figures show the emergence of the word gap for the number of adult words, child vocalizations and conversational turns by the time children were

Table 2 Random effects model estimates for LENA measures across maternal education groups

	Coef.	*p*	95% CI	
Adult Word Counts				
Number of adult words at 6 months among low educated = 16,872.86				
Low Educated at 12 months	-2336.90	0.016	-4243.32,	− 430.48
Low Educated at 18 months	−4219.54	0.000	−6054.13,	−2384.95
High Educated at 6 months	−16.64	0.987	−2019.84,	1986.55
High Educated at 12 months	− 1768.77	0.080	− 3746.90,	209.36
High Educated at 18 months	−369.13	0.714	−2344.57,	1606.30
Child Vocalisations Counts				
Number of child vocalizations at 6 months among low educated = 1440.28				
Low Educated at 12 months	−42.15	0.553	− 181.41,	97.11
Low Educated at 18 months	320.74	0.001	126.61,	514.88
High Educated at 6 months	− 165.36	0.036	−319.98,	−10.74
High Educated at 12 months	−19.97	0.801	− 175.49,	135.54
High Educated at 18 months	739.04	0.000	560.55,	917.53
Conversational Turn Counts				
Number of conversational turns at 6 months among low educated = 347.90				
Low Educated at 12 months	−1.79	0.935	−44.76,	41.16
Low Educated at 18 months	54.22	0.075	−5.54,	113.98
High Educated at 6 months	−22.92	0.248	−61.82,	15.98
High Educated at 12 months	31.99	0.139	−10.42,	74.41
High Educated at 18 months	265.62	0.000	211.52,	319.73

18 months old, in line with the results of the random effects model. For adult words spoken (Fig. 2) we found a difference of 17 words at 6 months, 568 words at 12 months and 3851 words at 18 months, with families in the high educated group talking more at wave two and three. For child vocalizations (Fig. 3) children from the low educated group were vocalizing slightly more, with a difference between groups of 166 vocalizations at 6 months. By 12 months, there were only 22 more vocalizations on average from children of high educated mothers and by 18 months, children in the high educated group had on average 418 more vocalizations. For conversational turns (Fig. 4), there were similar differences at 6 and 12 months with 24 and 34 turns between adult and child respectively. Families in the low educated group engaged in slightly more conversational turns at 6 months but families in the high educated group had more conversations at 12 months. Similarly, as with the adult words and child vocalizations, by 18 months the difference in conversational turns had grown to 212 turns with more in the highly educated group. Effects for mothers with higher education ranged from 0.5 SD for child vocalizations up to 0.7 SD for conversational turns. Sensitivity analysis that included only families who were observed at each time point did not change the results (See Additional file 1).

Discussion

These results demonstrate that the word gap between high and low educated mothers emerges between 12 and 18 months. The differences between high and low educated mothers were seen for adult words, child vocalizations and conversational turns with effects ranging from 0.5 for word counts to 0.7 SD for conversational turns. As well as understanding the emergence of mean differences in all measures of talk by 18 months, it is important to note the large variability within education groups. There are high and low talkers across the socioeconomic spectrum even though on average more educated mothers engaged in more talk. These results are generally consistent with Gilkerson et al. [11], who reported more talk among high educated mothers in the aggregated age band from 20 to 26 months.

When considering the implementation of interventions to support the home language environments of infants and toddlers, these results suggest a proportionate universalist approach [18] may be more appropriate, whereby services are universally available but designed with a scale and intensity that is proportionate to the nature of disadvantage. While there is a mean difference between education groups at 18 months, there is also large variability in parent-child talk in both education groups, hence targeting interventions only towards low educated families would miss a large proportion of children who are experiencing lower levels of language stimulation in the home among better educated mothers. Targeting of interventions to particular subpopulations presents challenges in reducing inequalities in early childhood development [2].

A limitation of the current study is the differences in sample size across the education groups, with fewer families participating in the low educated group than originally planned. Nonetheless, the low educated group is 10 times larger than Hart and Risley's welfare group and twice as large as Gilkerson's et al. some high school group. Numerous strategies were employed to encourage participation. However fewer mothers were identified as eligible in this group resulting in a lower recruitment rate. At later waves an additional 35 families were recruited to the low education group despite missing early waves of data collection and recruitment will continue until our target sample size is reached.

The findings provide support for the existence of a socioeconomic word gap and that this gap emerges between 12 and 18 months of age. However, longer term data are required to quantify the size of the word gap by age 4. Key strengths of the LiLO study are that data collection began when children were 6 months old and it captures day-long audio recordings, compared to Hart and Risley who only captured 1-h of data in the early evening and did not begin data collection until 10-months old. Each family in the LiLO study is also followed longitudinally, unlike only the small subset of families from the Gilkerson et al. study. Additionally, the larger sample, compared to both Hart and Risley and Gilkerson et al., and the use of the LENA technology means LiLO is well placed to continue quantifying the socioeconomic disparities in talk during the first 5 years of life. Importantly, data were from a population-based sample purposively designed to maximise education exposure contrasts as has been recommended by leading methodologists [19]. These results are likely to be generalizable to the English-speaking Australian population, and probably other English-speaking populations, although there may be ethnic and cultural differences that were not examined in this study. Future LiLO research will consider whether trajectories of talk influence later developmental outcomes and how this differs for maternal education groups. It will also be important to monitor the large variation within the two education groups to see if it is maintained as children age, and if an environment of high talking among low educated families is associated with better child development outcomes.

Conclusion

These results from the LiLO study suggest a socioeconomic word gap emerges between the ages of 12 and 18 months. Families from low educated backgrounds decreased the amount they spoke to their children between 6 and 18 months, compared to families from high educated backgrounds whose quantity of talk remained relatively stable across the same period. This is the first study to have used an objective measure of a child's home language environment and been able to provide insight into the timing of the divergence of parent-child talk between maternal education groups. This finding suggests the implementation of proportionate universal programs that encourage parents to talk more to their child should occur prior to 18 months of age.

Abbreviations

LENA: Language ENvironment Analysis; LiLO: Language in Little Ones; DLP: Digital Language Processer; AWC: Adult Word Count; CVC: Child Vocalization Count; CT: Conversational Turn

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12887-021-02712-1.

Additional file 1: Supplementary Appendix. Observed Means vs Computed Means. To compare the observed means in the raw data and the predicted means computed using the *margins* command.

Additional file 2: Supplementary Appendix. Sensitivity Analysis. To ensure the addition of the extra 35 low educated families at waves 2 and 3 did not affect the results, we undertook a sensitivity analysis which only included families who had participated since wave 1.

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Authors' contributions

SB, SR, JL, EM are chief investigators on the project and conceptualized the study. MB coordinated and supervised data collection for the study and wrote the first draft of the manuscript. JL, SB and MM conceptualized the analysis plan. MM and MB carried out the analysis. All authors contributed to the interpretation of findings and reviewed and revised the manuscript. Finally, all authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due to lack of informed consent for data sharing at the time of collection, but are available from the corresponding author on reasonable request. For further information on the data and materials used in this study, please contact the corresponding author.

Declarations

Ethics approval and consent to participate

The Women's and Children's Health Network (HREC/16/WCHN/190) and the University of Western Australia's (RA/4/1/8825) Human Research Ethics Committee approved this study, and written informed consent was provided by all participants and by the parent or guardian for participants under 16 years old. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

The authors declare they have no competing interests.

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How many words are Australian children hearing in the first year of life?

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Abstract

Background: There is evidence that parents from more socioeconomically disadvantaged backgrounds engage in fewer verbal interactions with their child than more advantaged parents. This leads to the so-called, '30 million-word gap'. This study aims to investigate the number of words children hear and the number of vocalizations children produce in their first year of life and examines whether these aspects of the early language home environment differ by maternal education.

Methods: Mothers were recruited into a five-year prospective cohort study and categorized into either high or low maternal education groups. Data was derived from the first two waves of the study, when the children were six and twelve months old. At both waves, children were involved in day-long audio recordings using the Language Environment Analysis software that provided automatic counts of adult words spoken to the child, child vocalizations and conversational turns. Descriptive results are presented by maternal education groups.

Results: There was large variation within each maternal education group, with the number of adult words spoken to the child ranging from 2958 to 39,583 at six months and 4389 to 45,849 at twelve months. There were no meaningful differences between adult words, child vocalizations or conversational turns across maternal education groups at either wave of data collection.

Conclusions: These results show that a word gap related to maternal education is not apparent up to twelve months of age. The large variability among both maternal education groups suggests that universal interventions that encourage all parents to talk more to their child may be more appropriate than interventions targeted towards disadvantaged families during the first year of life.

Keywords: Parent talk, Inequality, Early childhood development, Language

Background

The early years are fundamental in ensuring children grow up to be healthy, functioning adults [1–3]. By the time children start school there is a clear social gradient in most areas of child health and development [4]. The first five years of life, especially for children from disadvantaged backgrounds, are crucial in overcoming the intergenerational transmission of inequality, such that disadvantaged parents have disadvantaged children, who themselves go on to be disadvantaged adults [5].

Language ability is a critical developmental milestone that is directly related to later literacy, educational attainment and labor market experience. In the Australian context, results from the 2018 Australian Early Development Census, a triennial census of children's development at age 5, showed that 6.6% of children were developmentally vulnerable on the language and cognitive skills domain and 8.2% were vulnerable on the communication skills and general knowledge domain [6]. Both domains were socioeconomically patterned, with the highest levels of vulnerability amongst children from the most disadvantaged backgrounds. Poorer language skills have been shown to strongly predict poorer education outcomes in the mid and long term [3, 7].

Given socioeconomic inequalities in language development can be detected early and predict later outcomes,

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mechanisms for enhancing children's development require further investigation. Currently, some evidence suggests that the amount of maternal language heard during the early years may mediate the association between social disadvantage and child language ability [8].

Numerous studies indicate that parents from more socioeconomically disadvantaged backgrounds engage in fewer verbal interactions with their children, compared to those from advantaged backgrounds [9–13]. The most influential study of language spoken to the child in the home was that of Hart and Risley (1995) involving 42 families from Kansas, USA. From the age of 12 to 36 months, children of parents on welfare, working-class and professional backgrounds heard 620, 1250 and 2150 words per hour, respectively. Within group trends were linearly extrapolated to estimate that by the age of four, children from professional backgrounds heard over three times more than children from welfare families. Thus, the idea of the '30 million word gap' came into being.

Despite the enormous attention the study has received (google hits = 58,800,000), there are clear limitations. First, the study uses a small convenience sample ($n = 42$) and includes only six families on welfare. Second, the data collection method (researchers videotaping one hour per month in the home) is not likely to be representative of the natural home environment. For instance, while unbeknown to the authors at the time, it was later discovered that early evening, when videotaping usually occurred, is a period of extremely high talk for families [11]. Finally, the study began collecting data when children were 12 months of age, neglecting critical language experience under twelve months.

Since the Hart and Risley study, new speech recognition technology called Language ENvironment Analysis (LENA) has become available to allow researchers to objectively measure the amount of parent talk children hear in the home, without the need for videotaping or manual transcription. Gilkerson and colleagues [11] utilized LENA to replicate the work of Hart and Risley with 329 English-speaking families in Denver, USA with children aged 2 to 48 months. Their socioeconomic groups were based on mother's highest level of completed education, with education groups defined by completed some high school education, completed high school or general education diploma, completed some college and completed bachelor's degree or higher. Their cross-sectional findings estimated a 4 million word gap by age four between the highest and lowest socioeconomic group, significantly smaller than Hart and Risley's findings.

Another recent study involved 42 children aged 18 to 48 months from five communities across America with different levels of socioeconomic backgrounds (poor, working-class, middle-class) and like Hart and Risley, captured the number of words heard in the home through videotaping and transcription [14]. The authors main finding showed no meaningful differences between the poor, working-class and middle-class communities in the number of words spoken by the primary caregiver to the child, with some poor and working-class communities showing an advantage in words spoken, compared with middle-class communities. They posit that community variation in the amount of speech addressed to the child cannot be predicted by socioeconomic status alone [15]. This paper questioned the validity of the original Hart and Risley findings, provoking discussion around the importance of the original 30 million word gap hypothesis [15, 16].

The Language in Little Ones (LiLO) study is a prospective cohort study which aims to advance knowledge in this area by combining the use of the LENA software, recruiting a large socio-economically diverse sample, and beginning when children are six months old. The present study aims to quantify the number of adult words that are spoken to the child, number of child vocalizations, and number of times the adult and child engage in a conversational turn over a day, when children are aged six and twelve months. Furthermore, the study aims to examine whether these aspects of the early language home environment differ by maternal education.

Methods

Study design

The LiLO study follows two cohorts of children; *a baby cohort* that involves families with a child aged six months old at first data collection and *a toddler cohort* involving families with a child aged three years old at the beginning of data collection. Both cohorts are followed once every six months until the children turn 4 years old. The design includes purposive stratification by two levels of maternal education (only completed secondary school education or less and completed a bachelor's degree or higher) to explicitly maximize and adequately power contrasts across maternal education groups. At each six-month milestone, families undertake day-long (16-h) audio recordings and complete standardized questionnaires. Families were compensated with a $10 supermarket voucher after each wave of data collection. This paper reports on data from the first and second waves for the *baby cohort.*

Participants

Recruitment occurred between April 1, 2017 and January 31, 2019 both pre- and postnatally across Adelaide and Port Pirie in South Australia, Bunbury in Western Australia and Gold Coast, Queensland. Pregnant women were approached at Adelaide public hospitals while waiting for their antenatal appointments. Postnatally, mothers were asked to participate at Child and Family Health Service sites during drop-in clinics and at early parenting groups across Adelaide, Port

Pirie and Bunbury. Mothers were also approached at council-run immunization clinics, children centres, playgroups and shopping centres across all locations. Recruitment was limited to families whose home language was English. Mothers with a bachelor's degree or above were recruited into the high education group, and mothers with school only education were recruited into the lower education group. The study also excluded children with diagnosed causes of language impairment (e.g., hearing impairment, Down Syndrome, Cerebral Palsy) and was confined to singleton children and those born full term (37+ weeks) between January 1, 2017 and December 31, 2017.

A total of 230 families were involved in the first wave and 245 families in the second wave of data collection which included 60.84% of eligible mothers approached (See Fig. 1 for a flow chart of recruitment numbers). Our original power calculations required 120 children in each of the maternal education groups at wave one in order to detect a 0.3SD effect size. Due to the challenges in finding and engaging sufficient mothers with lower education levels we did not meet these initial sample size requirements and therefore extended original recruitment timelines and locations to boost numbers, which meant mothers were still able to join the longitudinal study even if they had missed the first wave of data collection.

Measures

Families' natural home language environments were captured using the Language Environment Analysis (LENA)

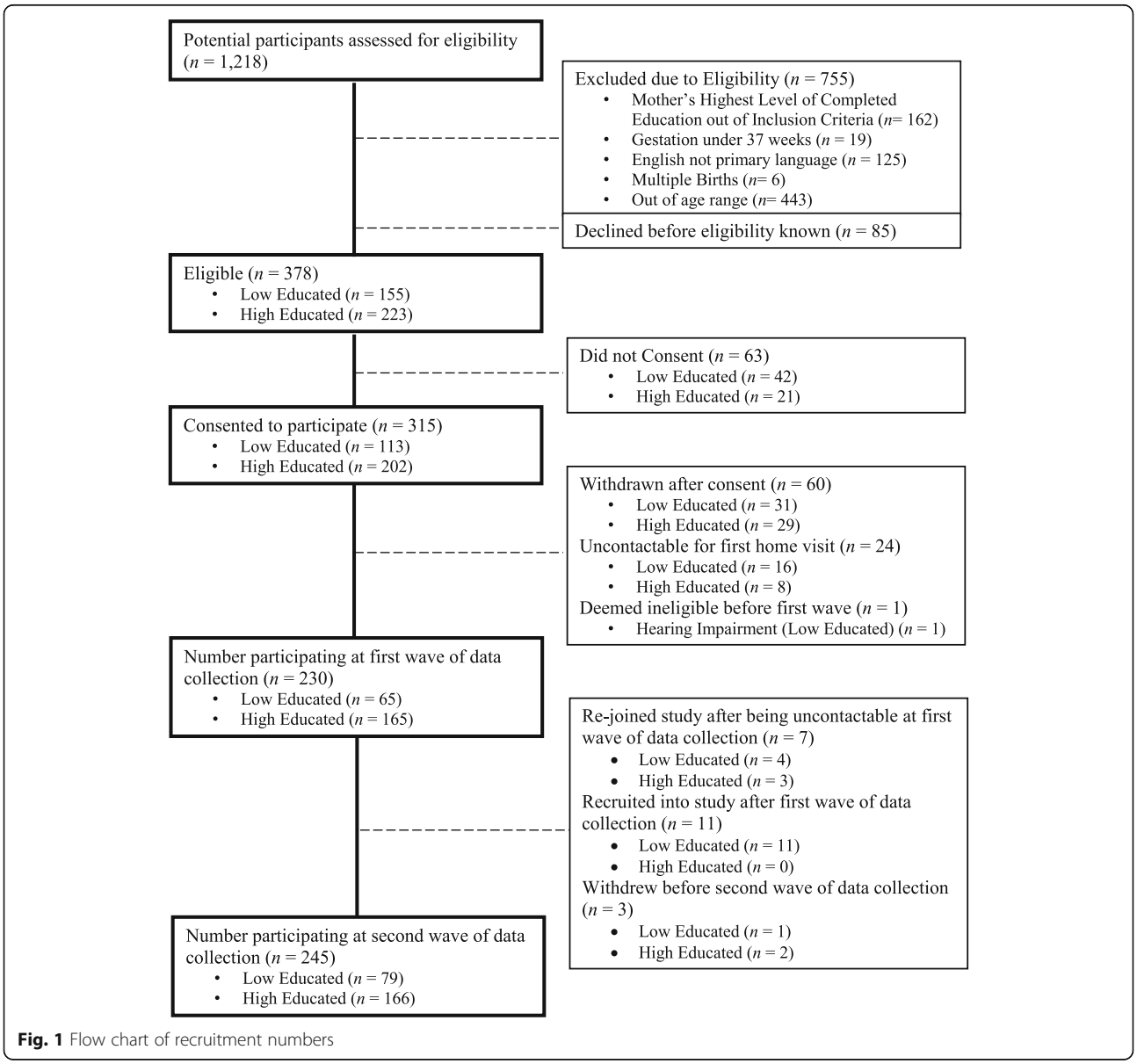

Fig. 1 Flow chart of recruitment numbers

system [11, 17, 18]. The LENA system comprises a specially designed age appropriate vest or t-shirt with a pocket in the front to hold a digital language processor (DLP) with LENA software, which automatically processes the audio captured in the DLP through algorithmic analysis of the speech signal [19]. LENA produces estimates of three key measures used in the current study: adult word counts (AWC), child vocalization counts (CVC) and conversational turn counts (CT). AWC's estimate the number of adult words spoken in approximately a 10-ft radius of the child wearing the recorder [11]. AWC's do not necessarily have to be child-directed speech but are loud enough to register on the LENA DLP. CVC's comprise the number of any speech-related sound made by the child wearing the DLP with each vocalization separated by 300 ms of silence. Finally, CT's are the number of alternations within a conversation between adult and child vocalizations as occurring within at least 5 s of each other. Either child or adult may initiate the conversation. Reliability testing conducted by the LENA Foundation found a high degree of agreement between human-transcribers and LENA system classification based on 70 h of recording data. For classification of adult words the two raters agreed 82% of the time and for child vocalizations they agreed 76% of the time [18]. It should be noted when overlapping speech occurs in the audio, the LENA software does not categorize this into either adult or child speech. While a trained human-transcriber may be able to identify the primary speaker, the LENA Foundation argues it is not known whether an infant or toddler would be able to distinguish during noisy language input. Therefore it is argued that the exclusion of these segments of audio by the LENA software may provide a more accurate representation of the child's meaningful language environment [18].

Additionally, during the home visit, the primary caregiver answered questions about family demographics, government payments received by the family, child care arrangements, services accessed by the child and family, and activities in the home with the focus child.

Procedure

Data collection

During data collection a researcher attended the family's home where they provided the LENA equipment, showed parents how to use it and then asked the standardized questionnaires. The family was given two weeks to complete one LENA recording day. The families were asked to pick a day (to undertake the recording) when the focus child was not in child care or sick, and not when the family had a big event (e.g., sporting match or birthday party). A researcher then returned to the family home after the recording day, picked up the LENA equipment and provided the family with their reimbursement. This procedure was consistent across all families and waves of data collection.

Statistical approach

Descriptive statistics are presented in Table 2 and box and whisker plots in Figs. 2, 3 and 4 to compare the distributions in talk by low and high education groups. The line in the middle of the box represents the median, the bottom of the box represents the 25th percentile and the top of the box represents the 75th percentile. The whiskers of the plot extend to 1.5 times the interquartile

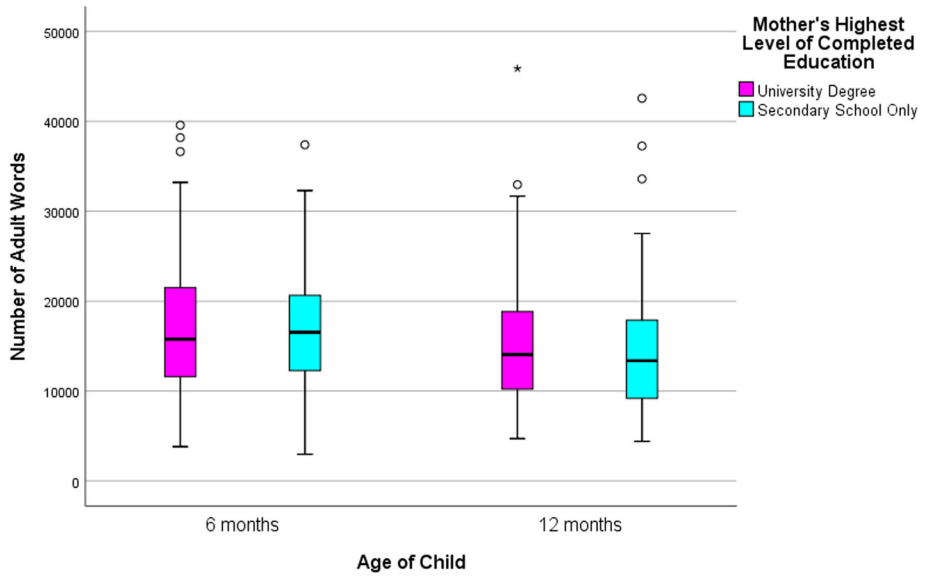

Fig. 2 Adult word count at 6 and 12 month wave of data collection by maternal education

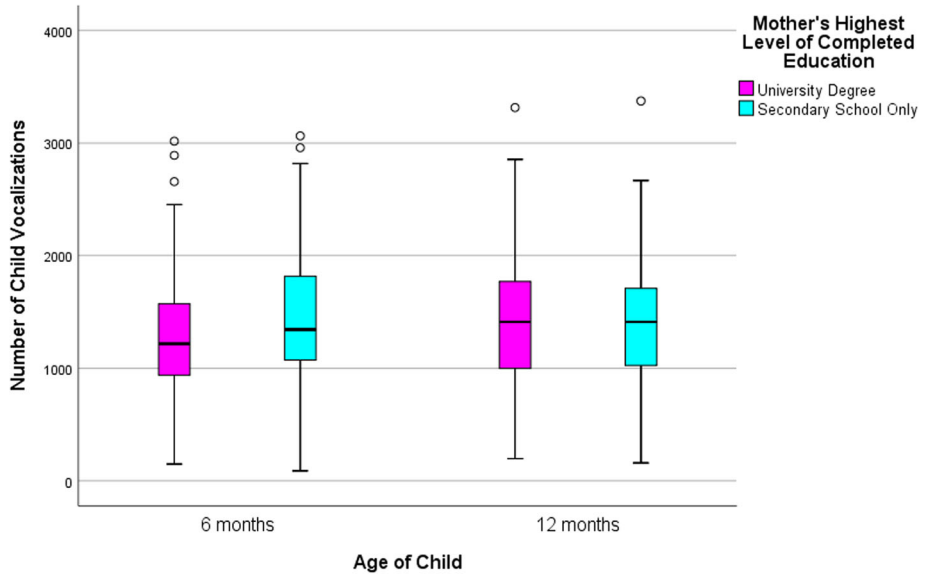

Fig. 3 Child vocalization count at 6 and 12 month wave of data collection by maternal education

range, with outliers falling outside this denoted by an asterisk, and fall at least 3 times outside the interquartile range. Independent sample t-tests were also conducted to compare the means between high and low educated groups. All analyses and graphs were conducted using IMB SPSS version 25.0 [20].

Results

LENA recordings for the first wave were completed between the August 1, 2017 and July 31, 2018 and recordings for the second wave were completed between February 1, 2018 and January 31, 2019. Each participant family undertook a LENA recording day within two months after turning 6 months and 12 months. Parents rarely used their ability to pause or stop the recording early, with 98.23% of families completing a full 16-h recording day during the first wave and 97.55% of families during the second wave. Of the ten families that stopped the recording across both waves, six completed at least 10 h of recording and noted the recording was stopped as the child went to sleep, therefore was included in the total sample. Three families in the first wave and one family in the second wave completed less than 10 h of recording due to either device malfunction or choosing

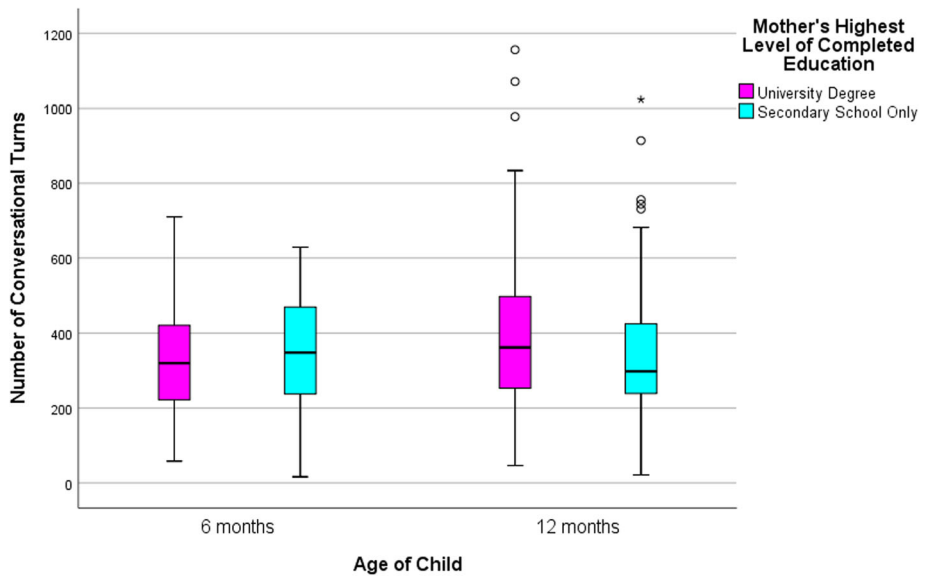

Fig. 4 Conversational turn count at 6 and 12 month wave of data collection by maternal education

to stop the recording early and were excluded from further analysis.

The final analysis sample involved 227 families, with 164 in the high education group and 63 in the low education group for the first wave, and 245 families, with 166 in the high education group and 79 in the low education group for the second wave (See Table 1). Note recruitment continued between wave 1 and 2, consequently the larger sample in wave 2. For the first wave, children were aged between 5 and 8 months of age (mean = 5.81) and 53.3% were female. Mother's average age at birth was 31.34, with 87.7% working until their pregnancy and 56.4% of children being first-born infants. In the second wave children were aged between 11 and 14 months (mean = 11.99) with the same percentage of females.

As shown in Table 2 there were small differences between the average number of adult words spoken, child vocalizations and conversational turns for the low and high education groups, at both waves. By standard criteria for 'statistical significance' children in the low education group vocalized more (approximately 160 vocalizations) than those in the high education group at the first wave (6 months). However, this difference was greatly reduced at the second wave (12 months).

The plots in Figs. 2, 3 and 4 depict the spread of the data demonstrating enormous variation within the two education groups across both waves. As an example, at the first wave the minimum AWC for the low educated group was 2958 words per day and the maximum count was 37,397 words (mean = 16,747.75; SD = 7228.62). The minimum AWC for the high educated group was 3795 words and the maximum were 39,583 words per day (mean = 16,883.58; SD = 7075.57). This highlights there is little difference between education groups but high variability within education groups and this is consistent for all three LENA measures, revealing high and low adult and child talkers within both education groups.

Table 1 Sociodemographic Characteristics of the Sample

	6 month Data Collection (*N* = 227)	12 month Data Collection (*N* = 245)
Child		
Age, mo, mean (SD)	5.81 (0.57)	11.99 (0.51)
Girls, n (%)	121 (53.3)	130 (53.06)
Gestation, wk., mean (SD)	39.2 (1.36)	39.14 (1.34)
Firstborn, *n* (%)	128 (56.4)	131 (53.47)
Mother		
Highest level of completed education, University, *n* (%)	164 (72.2)	166 (67.76)
Age at childbirth, y, mean (SD)	31.34 (4.42)	31.24 (4.57)
Working up until pregnancy, yes, *n* (%)	199 (87.7)	211 (86.12)

Discussion

The purpose of this study was to characterize, for the first time, the amount of talk/ vocalizing Australian children are hearing and uttering at home in the first 12 months of life. The study also examined differences linked to maternal education in adult words, child vocalizations and conversational turns. First, results showed high variability in the whole sample on all three measures of talk when children were six and twelve months of age. However, this did not substantively differ by maternal education. While there may be other factors in the home environment that are associated with this variability such as cultural or emotional characteristics, socioeconomic characteristics indexed in this case by maternal education did not differentiate the three measure of talk. Second, adults in the home of the low education group were talking, on average, just as much as adults in the high education group. In fact, within both education groups, the variability demonstrates some families speak over 35,000 words to their child in a day and others speak less than 4000 words. The similarities between the education groups are also reflected in the number of conversational turns between adults and children over the day, with no meaningful differences between education groups and again high variability in both groups.

The study by Gilkerson and colleagues, is most comparable to the current study and reports a 4 million word gap by age four [11]. Their observations began when children were two months old and they have reported their mean AWC's, CVC's and CT's at 6 months of age ($n = 50$). When they conducted their study, the LENA system only recorded 12-h days, compared to our 16-h recordings. Comparing average word counts for Gilkerson et al. and the LiLO study showed adult words were 1041 vs 1052, for child vocalizations 82.28 vs 82.46 and conversational turns 20.16 vs 20.62 respectively. While these average counts per hour are almost identical in the two studies, Gilkerson and colleagues did not report counts by socioeconomic groups at 6 or 12 months of age, so we are unable to compare [11]. The differing definitions of maternal education groups and different educational contexts in Australia and the United States may partially account for why the current study did not find the difference between education groups that other researchers have reported.

The Language in Little Ones (LiLO) study is the first study with a large sample using objective measures to characterize the verbal home environment by maternal education groups in the first year of life. These findings have important implications for interventions that aim to reduce the word gap, suggesting services with this specific aim may need to utilize a universal approach, rather than simply targeting families from low socioeconomic

Table 2 Daily LENA measures: distribution by the total sample and maternal education

	Adult Word Count				*p*-value*	Child Vocalization Count				*p*-value*	Conversational Turn Count				*p*-value*
	M	SD	Min	Max		M	SD	Min	Max		M	SD	Min	Max	
6 month Data Collection															
Total Sample ($n = 227$)	16,845.88	7102.57	2958	39,583		1319.48	551.74	87	3064		330.77	137.23	16	710	
Mother's Education															
Low Educated ($n = 63$)	16,747.75	7228.62	2958	37,397	0.90	1454.06	660.86	87	3064	0.05	347.90	152.39	16	629	0.28
High Educated ($n = 164$)	16,883.58	7075.57	3795	39,583		1267.78	496.24	147	3017		324.19	130.84	58	710	
12 month Data Collection															
Total Sample ($n = 245$)	14,888.66	6782.11	4389	45,849		1416.37	561.13	158	3373		369.26	178.34	21	1156	
Mother's Education															
Low Educated ($n = 79$)	14,407.25	7156.63	4389	42,545	0.44	1406.57	588.38	158	3373	0.85	345.71	188.99	21	1023	0.15
High Educated ($n = 166$)	15,117.76	6606.38	4701	45,849		1421.04	549.45	196	3316		380.46	172.51	46	1156	

*p-value is based on independent sample t-tests comparing the means between high and low educated groups

backgrounds, as it is clear from our data there are adults across both socioeconomic groups who would be considered low talkers. While our data cannot yet explain if the amount families talk to their children in the home will lead to differences in future development outcomes, previous research has suggested this is the case [8, 21, 22]. As the LiLO study progresses, it will describe the trajectories of AWC, CVC and CT's for low and high maternal education groups and consequences for child development outcomes over the first five years of life.

A shortcoming of the current work is the uneven sample across the education groups, with fewer low educated mothers participating than originally planned. This results from less mothers identified as eligible for the low educated group at recruitment sites and also the lower participation rate into the study for this group. As the LiLO study is longitudinal, attempts to overcome this flaw in future waves will continue by recruiting low educated mothers into our study as it progresses.

A further limitation is that the LENA data cannot effectively capture the quality of verbal interactions, beyond the use of conversational turns. While understanding the context of the words spoken to the child is not the focus of the study, the importance of the quality of early language input for child outcomes is recognized. Nonetheless, if the study can demonstrate the link between parents' talk and impacts on children's future development, this can inform the increasing number of interventions using the LENA technology to provide feedback to parents on their quantity of words [23, 24].

Conclusion

The results from the first two waves of the Language in Little One's study found large variability within maternal education groups and no meaningful differences between maternal education groups for the number of words spoken by adults to the child or the number of conversational turns between adult and child in the first year of life. This finding has implications for the 30 million word gap hypothesis, suggesting either a word gap does not emerge until after twelve months of age or for children living in Australia the gap does not exist. Implications of these findings suggest that interventions aiming to encourage parents to talk more to their child in the first year of life should be accessible for all parents, regardless of education level.

Abbreviations

AWC: Adult Word Count; CT: Conversational Turn; CVC: Child Vocalization Count; DLP: Digital Language Processer; LENA: Language ENvironment Analysis; LiLO: Language in Little Ones;

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Authors' contributions

SB, SR, JL, EM are chief investigators on the project and conceptualized the study. MB coordinated and supervised data collection for the study, carried out analysis and wrote the first draft of the manuscript. JL and SB conceptualized the analysis plan. All authors contributed to the interpretation of findings and reviewed and revised the manuscript. Finally, All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due to lack of informed consent for data sharing at the time of collection, but are available from the corresponding author on reasonable request. For further information on the data and materials used in this study, please contact the corresponding author.

Ethics approval and consent to participate

The Women's and Children's Health Network (HREC/16/WCHN/190) and the University of Western Australia's (RA/4/1/8825) Human Research Ethics Committee approved this study, and written informed consent was provided by all participants and by the parent or guardian for participants under 16 years old.

Consent for publication

Not applicable.

Competing interests

The authors declare they have no competing interests.

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