Article

FIRST LANGUAGE

Effects of feedback on parent–child language with infants and toddlers in Korea

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Abstract

The objective of this study was to investigate changes in the natural language environments of families with typically-developing infants receiving language feedback in South Korea. Volunteer parents of 99 children aged 4–16 months were randomly divided into experimental and control groups. During 6 months' intervention, the experimental group recorded weekly day-long automatically-analyzed LENA measures of language environment and viewed feedback, while the control group recorded only baseline, mid-period and post-test without feedback. LENA Adult Word Counts (AWC) and

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Conversational Turn (CT) counts correlated reasonably well with human transcripts. At baseline groups were not significantly different. At post-test there was no significant overall difference between experimental and control groups, but AWC and CT differences were significant for families below the 50th percentile at baseline. Korean parents whose linguistic environment was below average adapted their communicative interaction in response to linguistic feedback. The intervention has promise for use with at-risk families in many countries.

Keywords

Adult words, child words, cross-cultural, environment, feedback, infant, language, Korea, LENA (Language ENvironment Analysis), turns

Few carefully evaluated parental involvement initiatives have focused on developing child language in the early years of life, from 0 to 2 years of age. Even fewer of these studies have used an automatic computer-based method for analyzing full-day audio recordings of parent–child interactions, such as the LENA (Language ENvironment Analysis) technology. None of these studies in the English language literature has taken place in South Korea, a fascinating location for such investigations. The present study addresses these gaps. The article explores pre–post changes resulting from facilitating language development with feedback in a group of families randomly divided into experimental and control groups.

Context of the present study

In Korea, the single language Korean is used. While the Korean alphabet (*hangul*) may appear logographic, it is actually a phonemic alphabet organized into syllabic blocks. Each block consists of at least two of the 24 letters: at least one each of the 14 consonants and 10 vowels (Song, 2005). The language is thus more similar to English than say Chinese, so it was expected that English-based LENA algorithms might work for Korean.

Korean families are of various sizes, typically three to six people. Parental motivation for child success is very high. A. H. Kim (2008) studied parents' and adolescents' reports of parenting styles and found mothers were more aggressive/hostile, behaviorally controlling, and psychologically controlling than fathers. Parents tend to expect to express their support for their child's education by buying extra materials and tuition for the child, rather than actually doing something with the child themselves. Thus Korean parents with preschool children seem to have different parenting beliefs from parenting practices (Park & Kwon, 2009).

South Korea's science education, math, and literature are ranked highly in international comparisons. However, the education system is criticized for emphasizing passive learning and memorization, and being hierarchical (suppressing innovation) and competitive. Additionally, there are many private academies or cram schools (*hagwons*) which further emphasize passive memorization (Center on International Education Benchmarking, 2015; Janda, 2013).

Aim of the present study

The quantity and quality of adult–child interaction in developing the language of children in the early years using real-time day-long audio recordings and automatic analysis has never before been explored in such a highly education-oriented society as Korea, which nonetheless has issues of pedagogical style and high competition. The present study aimed to investigate the effect of feedback generated from the LENA technology on parent–child language interaction in such a society – with improvements on previous studies: a larger sample size, the use of experimental and control groups, and random allocation to conditions. (Further information on the LENA technology will be found under Measures and further information on the nature of the feedback will be found under Procedure below.) The study further explored differences between families who were given feedback from baseline recordings that their child's language environment was above or below average in relation to norms.

Adult interaction in early child language development

Evidence of the critical role of adult interaction in child language development strongly supports the capacity of very young children to respond to rich stimulation (Chapman, 2000; Hart & Risley, 1995; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Rowe, 2008). The properties of adult caregiver language are predictive of metrics of child language development.

We know that there is a relationship between adult language input to children and their subsequent development of vocabulary. For example, Boyce, Gillam, Innocenti, Cook, and Ortiz (2013) investigated 120 Latino dual language learners of low socioeconomic status. Language was assessed in both English and Spanish. The home language and literacy environments were significantly related to child language status at 24 and at 36 months, and indeed had predictive value. However, on average these socioeconomically disadvantaged children performed well below average age levels for the whole (non-disadvantaged) population. When performance in both English and Spanish was aggregated, scores were raised nearer to this criterion, but still below it.

We also know that there is a measurable quantitative relationship between parental language input and child acquisition of language over time. The acquisition of discourse connectives in relation to parental language input was studied by Van Veen, Evers-Vermeul, Sanders, and Van den Bergh (2009). Obviously, increasing child age and cognitive ability are factors which need to be taken into account. The researchers looked at the effects of parental input within one recording, but also at the effects of cumulative parental input over a longer period of time. They subsequently developed a growth curve incorporating all these variables which accounted for and predicted child language development over time in relation to parental input. Sample size for development of this growth curve was rather small, so replication of this study is needed.

Further, infant language behavior is shaped by parental language input but can also shape that input. Masur, Flynn, and Lloyd (2013) analyzed infant language behaviors before and after four categories of maternal utterance: responsive utterances, supportive behavioral directives, intrusive behavioral directives, and intrusive attentional directives. These were investigated longitudinally during dyadic free play at ages 13, 17, and 21 months. Children's positive social and object-directed behaviors increased both before and after maternal speech. When mothers engaged in language interaction with their child, this often resulted in disengagement with play and toys, but after the language interchange engagement with play and toys was resumed at a higher level. The researchers identified different patterns of interaction depending on the nature of the maternal utterance.

Beyond this, we also know that parental word choices tend to be reflected in preschoolers' phonological and vocabulary development. For example, Hohenstein (2013) focused on parent–child talk about motion while playing a board game. Spanish-speaking (21) and English-speaking (24) families were examined for lexical and syntactic differences in motion event expressions. English-speaking parents used more manner verbs and Spanish-speaking parents used more specific path verbs. English-speaking parents also used more general path verbs than did Spanish speakers. These differences mapped onto children's production of motion event language.

Taking a different slant, Reese, Robertson, Divers, and Schaughency (2015) investigated the development of preschool children's phonological awareness (an important predictor of later reading skill) as a function of parental talk. Parents who used more sound talk had children with more advanced phonological awareness, even after controlling for children's language skills and socio-demographic factors. Thus there are many reasons for the presumption that parental input increases child language, although this may be a reciprocal relationship. Parent word choices enhance vocabulary and parent sound talk enhances phonological awareness.

The responsiveness of parents to their child's vocalizations in conversational turns (Tamis-LeMonda, Bornstein, & Baumwell, 2001; Topping, Dekhinet, & Zeedyk, 2013) correlates particularly well with growth in child vocabulary. There is further evidence that turn taking impacts on early infant vocalizations. Bloom, Russell, and Wassenberg (1987) investigated very young (3-month-old) children, one group of 20 participants experiencing conversational turn-taking and another 20 random adult responsiveness. Infant vocalizations were categorized as speech-like (syllabic) or non-speech-like (vocalic). Turn-taking yielded higher quality of infant vocal sounds. When the adult maintained a give-and-take pattern, the infant produced a higher ratio of syllabic/vocalic sounds.

The frequency of turns does increase with age during the toddler years. Rutter and Durkin (1987) reported laboratory studies of vocal coordination and gaze in mother–infant play. They were interested in the use of gaze by children to signal that they had completed their vocalization and to indicate attention when the other person is speaking – highly related to turn-taking. Active structuring of vocal interaction was found by the end of the second year, and gaze began to approximate the typical adult pattern of signaling as early as 18 months. There were marked and consistent individual differences, however.

The converse has also been observed, in which deprivation in quality or quantity of language input leads to delayed language acquisition, lowered IQ, and reduced subsequent academic achievement (Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Landry, Smith, Swank, & Miller Loncar, 2000; Topping, Dekhinet, & Zeedyk, 2011). Thus, many aspects of language acquisition are driven by factors within caregiver intervention.

Automatic assessment of language

There are many different ways of assessing child language performance, although many studies only use one way. Gatt, Grech, and Dodd (2014) however examined expressive vocabulary development in children aged one to two and a half years through three methods: picture naming, caregiver report, and language sampling. Expressive vocabulary reported by caregivers was compared to word use elicited through picture naming and sampled naturalistically during play. Analyses revealed commonalities between pairs of measures which suggested their co-validity. However, commonalities between all three measures were fewer. Data collection methods did to some extent influence the nature of the data collected. The authors recommended the routine use of multiple measures in language assessment, but of course this is very time consuming and usually possible only with small participant numbers or short samples of language.

In the development of pre-term infants, the relationship between Adult Word Counts (AWC) and the frequency of child vocalizations has been noted (Caskey, Stephens, Tucker, & Vohr, 2011). Moreover, rates and durational properties of AWCs, child vocalizations, and Conversational Turns (CTs) have been shown to be useful in distinguishing the language environments of some clinical populations (Dykstra et al., 2013; Oller et al., 2010; Warlaumont et al., 2010; Warren et al., 2010; Wiggin, Gabbard, Thompson, Goberis, & Yoshinaga-Itano, 2012).

These interaction measures have recently become more easily studied through automatic means of assessing day-long audio samples of language. Such a means (e.g., the LENA technology) yields not only descriptive tools to characterize language environments, but also a potential source of intervention in the form of feedback to adult caregivers on their performance. A much longer sample of language is analyzed than is possible with human transcription (a minimum of 8 hours per day is specified for LENA analysis, but the whole recording of up to 16 hours is analyzed). The recording is then analyzed by computer, enabling distinction between adult speech, child vocalization, conversational turns (adult speech immediately followed by child vocalization or vice versa), television, noise, and other environmental factors. Elements of this analysis are then fed back to the caregivers.

Greenwood, Thiemann-Bourque, Walker, Buzhardt, and Gilkerson (2011) made LENA recordings with 30 middle to upper socio-economic status families with typically-developing children. There were vast differences in individual children's home language environments (adult word count, children's vocalizations, and conversational turns). Suskind et al. (2013) reported significant, positive results in utilizing automated linguistic analysis (and specifically AWC and CT) to measure the progress of non-familial caregivers of typically-developing children in setting and meeting goals to increase their speech in interactions with children.

Suskind et al. (2015) followed this up with a study of 23 low socio-economic status parents and their children (aged 18–36 months) with automated analysis, although there was a good deal of attrition. Twelve experimental and 11 control children allocated randomly to condition received eight weekly home visits. For the experimental group these were hour-long and focused on parent–child interactions to promote language development and included video modeling by the visitor and of the parent. For the control group they were much shorter (10 minutes) and focused on nutrition. In the experimental group parent knowledge of language development increased significantly 1 week and 4 months after the intervention, but not in the control group. For the experimental group, adult word counts (Cohen's $\delta = .34$), conversational turn counts ($\delta = .66$), and child vocalization counts ($\delta = .43$) from the LENA technology increased significantly during the intervention. At post-intervention the scores were still somewhat elevated, but not statistically significant. Thus the intervention showed effects, but not all of these were significantly maintained post-intervention.

In another continent, Zhang et al. (2015) used the LENA technology to investigate changes in the natural language environments of families receiving quantitative language feedback in Shanghai. Measures of adult word count and conversational turns with children were collected regularly over 6 months from volunteer parents of 22 children aged 5–30 months. Feedback reports to caregivers included individual family plus group counts. Overall, families increased word/turn counts significantly during the first 3 months then regressed to baseline levels during the summer months. However, parents whose word count output was below average at baseline significantly increased word count output to study conclusion. Increases in adult word and conversational turn counts were related to a subset of language development measures.

Although the majority of previous work has been with typically-developing children in American English-speaking (AE) households, one previous study reported on the validity of the LENA technology with a small number of Spanish-speaking families of young children aged up to 60 months (Weisleder & Fernald, 2013), finding a correlation between automated estimates and transcriber-based word counts of $r = .80$. A more recent study correlated automated estimates and transcriber-based counts for children aged up to 60 months in Mandarin and Shanghai Dialect (Gilkerson et al., 2015) with similar results ($r = .73$), although again the sample was small. Canault, Le Normand, Foudil, Loundon, and Thai-Van (2015) investigated the reliability of the LENA technology in French. Eighteen native French-speaking children were divided into six age groups ranging from 3 to 48 months old and recorded for three days per week. Six 10-minute chunks of recordings (a total of 324 samples) were transcribed and aligned to LENA Adult Word Count and Child Vocalization Count. AWC and CVC estimates were reasonably reliable ($r = .64$ and .71, respectively). These studies suggest that further research in other languages merits exploration.

Research questions

The present study is about the use of LENA technology as a primarily home-based intervention in a novel culture. It was with typically-developing children, had a fairly large sample, and experimental and control groups. The literature review suggests that parental language input is key to the development of preschoolers' own language, and that turn-taking is an important component of this. We sought to investigate whether Adult Word Count (AWC) and Conversational Turns (CT) generated by automated analysis were important in the development of language in a sample of children in an alternative culture.

Two research predictions were made. First, that receiving automated feedback would enable participant families to increase their adult word and conversational turn counts from baseline. Second, that such increases would be greater for the below-50th percentile group of the participant pool (who were expected to be more motivated on becoming aware of their 'below average' status, although it is accepted that this is purely speculative), as in the previous Chinese study (Zhang et al., 2015).

Method

Ethical approval was obtained from Hallym University prior to study participation.

Participants

The area chosen for this study was the capital city of Seoul and two coterminous provinces in the north of South Korea containing a total of 23.5 million people. To recruit participants, flyers and brochures were distributed to those pediatric clinics and baby daycare centers which agreed to inform families interested in the program. Initially 428 families expressed interest from 12 facilities. Of these, 132 gave informed consent. Subsequently 99 of these actually participated. These were self-selected volunteers. The majority were recruited from one pediatric clinic, one church, one workplace parent group, two baby centers, and three daycare centers.

All families spoke Korean at home (there are few local dialects in South Korea). Each had a baby aged between 4 months and 16 months. There were 45 boys (45%) and 54 girls (55%). Fourteen (14%) attended daycare centers. Most families were middle class: 36 (36%) made US$2000–3000 a month, 35 (35%) US$3000–5000 a month, and 24 (24%) more than US$5000 a month. These are average to above-average salaries for South Korea. With regard to maternal education levels, only one mother (1%) did not graduate from high school, 5% had graduated from high school, 74% were college graduates and 20% had a master's and/or doctoral degree. Almost half the mothers (43%) had a full-time job.

Participants were offered involvement in a longitudinal study using the LENA recording and feedback technology along with language development assessments. The 99 families were then randomly assigned either to experimental or control groups, yielding 49 in the experimental group and 50 in the control group. Each child in the experimental group was matched with a child of similar age in the control group, since language from a 5-month-old is very different to that of a 30-month-old, and each recording was thereby controlled for the child's age at baseline.

Results from experimental families were split into two groups depending on whether they were above or below the 50th percentile at baseline compared to the normative sample from the United States. It was assumed that families who saw they were 'below average' would be more motivated to change their behavior.

Some attrition ensued over the course of the study, reducing the experimental group to 40 and the control group to 44. Four out of nine withdrawing experimental families failed to show at the first meeting after baseline recordings. Others had difficulty recording regularly because some daycare centers did not allow recording in the center, some working mothers did not have time to record, and some had sick infants. There was no evidence of socio-economic bias in the pattern of withdrawal.

Measures

The main measures were language environment estimates obtained automatically using LENA technology (Ford, Baer, Xu, Yapanel, & Gray, 2008; Gilkerson & Richards, 2008), in which a small digital recorder is worn by the child in a front chest pocket of clothing designed to optimize microphone placement and minimize clothing friction noise. Data are collected in children's natural environments: homes, parks, playgrounds, and anywhere else children use or hear language. The recorder can hold 16 hours of audio, optimally recorded within a 6–10 foot radius at 16 kHz. Recordings were then computer analyzed with a digital sound analyzer that parses out the child's speech-related vocalizations and exposure to adult speech, the speech of other children, overlapping talk, silence, general noise, and television. Algorithms enable the discarding of crying or vegetative sounds (e.g., from respiratory or digestive systems) and automatically generate adult word, child vocalization, and conversational turn estimates. Further details of the LENA technology (e.g., on how words are estimated and turns identified) can be found in Richards, Gilkerson, Paul, and Xu (2008). LENA has previously been shown to be both valid and reliable when compared with trained human transcribers in American English (Xu, Yapanel, & Gray, 2009).

In addition, parents completed a Korean adaptation of the LENA Developmental Snapshot (KSNAP), a standardized measure of parent self-report of expressive and receptive language skills in children aged 2–36 months (Gilkerson & Richards, 2008). This 52-item inventory yields a total score, a developmental quotient, a developmental age, an expressive vocabulary raw score, and a percentile score. Gilkerson and Richards (2008) report a 3-month test-retest reliability of .93–.97 and an average correlation of .93 with various other language measures.

Parents also completed a locally normed Korean adaptation of the MacArthur–Bates Communication Development Inventories (K M-B CDI) (Pae & Kwak, 2011), which assess early language and communication. The K M-B CDI assesses expressive vocabulary for 8- to 36-month-old children, gesture and play for 8- to 17-month-old children, and expressive vocabulary and grammar for 18- to 36-month-old children. Heilmann, Weismer, Evans, and Hollar (2005) report concurrent validity of .63–.84 with mean length of utterance, .56–.82 with number of different words spoken, and .54–.77 with the Bayley Scales. The K M-B CDI appeared a valid and useful instrument to discriminate late-talking toddlers in the Korean population (S. Kim et al., 2014; Pae, 2003).

Procedure

At the outset, experimental and control children were assessed on the two language development measures. Four certified and experienced speech language pathologists administered the Korean versions of these instruments after receiving specific training in their administration. Then the experimental group made baseline LENA recordings and weekly recordings for 6 months. They also completed a daily activity log (especially regarding instances of book reading) on the same day as the recording. The control group made recordings only at baseline and months 3 and 6. Participants who completed recordings at baseline and months 3 and 6 were analyzed. (The control group was actually a wait list condition and received the intervention after the 6 months reported here.)

The experimental group received a single workshop the second month after starting. Thirty-one families participated; about 7–10 families in each of three parallel workshops. In the workshop, the group viewed six short (2-minute) video clips (which were displayed in the internet cafe after the workshop), participated in discussions of parental experiences, and received advice about enhancing the home language environment. The nine families who did not attend received in-depth individual phone guidance and were directed to the videos in the internet cafe.

Individualized LENA reports were explained in detail. Feedback centered on LENA reports, which displayed bar graphs of counts of AWC and CT (see Figure 1). The analysis showed the pattern of AWC and CT. Given their own individual AWC and CT for each recording, parents were encouraged to set an individual goal to do better at the next recording. However, details of parental goals were not analyzed. Parents could also see how their and their child's performance compared to the US norms for LENA in terms of percentiles, and consequently whether they and their child were below or above average and by how much. This feedback was delivered to the parent's home computers and was viewable after the LENA data had been analyzed.

Weekly recordings fed into the LENA technology were analyzed for the first 6 months for the experimental group. Every month the experimental group families were also telephoned by one of two research assistants in order to check whether they had any technical problems and to give encouragement. Experimental parents also had constant access to the internet cafe, to communicate with each other and discuss issues which they had in common. (However, parents preferred to talk over the phone and reported that they did not have time to access the cafe.) At the sixth month, the experimental participants were given five storybooks for babies and an online book-reading guide.

All experimental and control parents knew their child's language development status based on K M-B CDI percentile rank and Developmental Snapshot Development Quotients. The control group received no feedback, support, workshops, or storybooks. The control group recorded at the third month and at the end of the 6-month period to add to their baseline recording. At the end of 6-month period, all children were reassessed on language development.

Triangulation of implementation integrity

Although the LENA technology automatically yields data about implementation integrity in terms of parent and child behaviors, an additional check was made on this through an alternative procedure. Two research assistants in contact with the families made judgments of the experimental mother's attitude toward the LENA recordings on a 5-point Likert scale (1 = no interest or relatively very small number of recordings, 2 = very little interest or small number of recordings, 3 = average interest or average number of recordings, 4 = high interest or high number of recordings, 5 = very high interest or very high number of recordings). Of the 40 experimental mothers, there were 10 who were judged 5, four judged as 4.5, 16 judged as 4.0, four judged as 3.5, five judged as 3.0 and one mother as 2.5. Thirty mothers (75%) seemed to be participating sincerely. Six mothers (15%) seemed to have difficulties or less interest in study participation (judged 3.0 or less). Some parents reported that weekly recording was difficult and their babies refused to put on LENA vests.

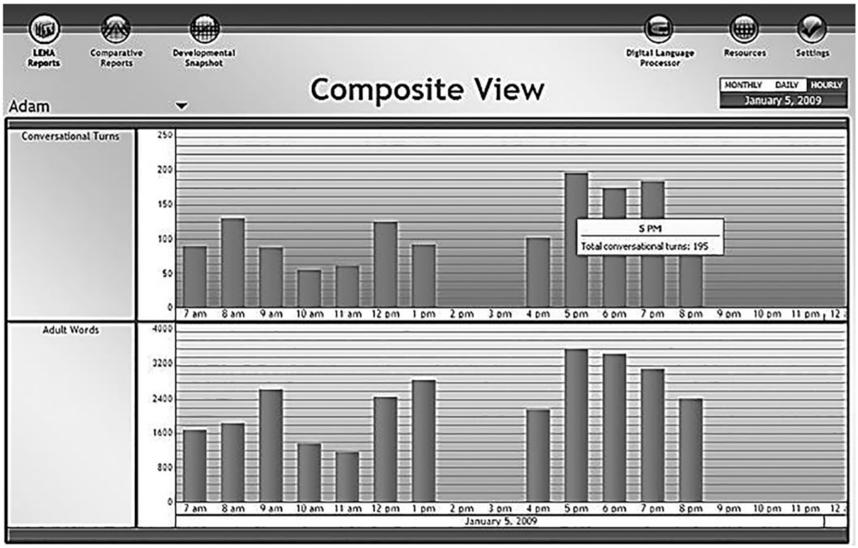

Figure 1. LENA feedback report.

Among the 10 mothers who were extremely interested in getting quantitative language feedback via LENA technology, there were three mothers who had babies at risk of language development at basal assessment (below 10th percentile on K M-B CDI on any of receptive, expressive vocabulary, gesture and play). After the 6-month intervention all these children were in the normal range of language development and above the 25th percentile on K M-B CDI. These families increased and sustained their language environment during the 6-month intervention period. However, there was no relationship between judgments of attitude and membership of above average or below average groups.

Statistical analyses

Firstly, the validity and reliability of LENA measures for Korean-speaking families were analyzed via comparisons with human transcription in correlation terms. Then LENA recording counts (AWC and CT) were analyzed in terms of raw scores and standardized scores. Chi-squared was used to test for significance with nominal variables. Two-way repeated-measures analyses of variance were conducted to evaluate groups' differences in LENA measures at baseline, 3 months, and 6 months. Post hoc tests were conducted where the analysis of variance yielded significant results, either independent or paired *t*-tests.

Results

Equivalence of LENA in Korean language

We had two sources of data to investigate the relationship of LENA counts to human transcripts in Korean language: 27 transcripts (about 10 minutes each) from infants aged

Table 1. Experimental and control equivalence at baseline on age, LENA, and language measures.

	Experimental			Control			*t*	*P*	*d*
	n	Mean	*SD*	*n*	Mean	*SD*			
Child age	49	10.29	2.85	50	10.10	2.97	.32	.75	.07
LENA AWC	45	14125	6313	54	13727	4827	.36	.72	.06
LENA CT	45	396	180	54	393	141	.08	.94	.02
KSNAP DQ	40	97.39	35.86	44	99.56	27.54	−.32	.75	−.06
K M-B CDI	40	4.34	7.00	44	6.45	8.76	−1.03	.31	−.30

Note: KSNAP DQ = Korean version of SNAP, Developmental Quotient. K M-B CDI = Korean MacArthur–Bates Communication Development Inventories. *d* = effect size (Cohen's δ). Only the last *d* is substantial.

3–15 months in home environments and 36 transcripts from infants aged 11–22 months in a clinic (in a 10-minute book reading and play context). Overall, human AWC counts were significantly correlated with LENA AWC counts ($r = .72$, $p < .001$). However, human CT counts were initially not significantly correlated with LENA CT counts ($r = –.03$, $p > .05$). When we excluded the data of five babies containing abundant overlaps or whining noises, there were significant correlations between human and LENA CT counts ($r = .67$, $p = .001$) (overlaps are human vocalizations confused with other sound sources). When a child is very young or has frequent whining sounds and/or overlapped speech, LENA CT counts might need to be interpreted cautiously. The data for 10 babies (28%) were assessed by two transcribers for inter-rater reliability. Agreement rate was 98.5% for AWC and 95% for CT. Overall it seemed that LENA AWC and CT counts could be applied to the Korean language context.

Experimental and control groups at baseline

There were no significant differences between the experimental and control groups at baseline on child chronological ages, gender (chi-squared = .01, $p = .912$), or the dependent measures of LENA counts on AWC or CT or language development measures (see Table 1). At baseline there was also no significant difference on the dependent measure of KSNAP between the above-50th percentile and below-50th percentile experimental subgroups (see below for analysis).

Experimental and control group differences over 3 and 6 months

For the dependent measure of AWC, a two-way repeated-measures ANOVA of treatment × time over 6 months showed that there was no significant interaction ($F(2,164) = .58$, $p = .56$, partial $\eta^2 = .007$) (Table 2) (partial η^2 effect sizes are categorized: $\geqslant .01$ small, $\geqslant .06$ medium, $\geqslant .14$ large). Nor was there any significant difference between the groups ($F(1, 82) = .153$, $p = .696$, partial $\eta^2 = .006$). There was a significant difference in the time factor ($F(2,164) = 3.62$, $p = .029$, partial $\eta^2 = .042$). Follow-up paired-samples *t*-tests showed that for both experimental and control groups, AWC increased in month 3

Table 2. Scores on AWC and CT at baseline and months 3 and 6 for experimental/control.

	Experimental			Control			Total		
	n	Mean	*SD*	*N*	Mean	*SD*	*n*	Mean	*SD*
AWC_0	40	14719.23	5536.25	44	13447.89	5916.08	84	14053.29	5739.55
AWC_3	40	15678.68	8098.66	44	15403.43	6758.99	84	15534.50	7382.77
AWC_6	40	13667.57	5754.51	44	13878.27	5975.61	84	13777.94	5836.97
CT_0	40	382.33	164.00	44	372.95	126.94	84	377.42	144.95
CT_3	40	476.56	207.16	44	459.86	185.77	84	467.81	195.23
CT_6	40	434.63	190.36	44	503.28	237.69	84	470.59	217.89

Note: 0 = baseline, 3 = the 3rd month, 6 = the 6th month.

but decreased in month 6. From month 3 to month 6, the experimental group AWC decreased significantly ($t(39) = -2.29$, $p = .027$), while the decrease of the control group was not significant.

For the dependent measure of CT, a two-way repeated-measures ANOVA of treatment × time over 6 months showed that there was a significant interaction ($F(2,164) = 3.14$, $p = .046$, partial $\eta^2 = .037$). As for AWC, there was no significant difference between groups ($F(1, 82) = .079$, $p = .779$, partial $\eta^2 = .001$). As for AWC, there was a significant difference in the time factor ($F(2,164) = 15.47$, $p < .001$, partial $\eta^2 = .159$). Follow-up paired-samples *t*-tests showed that for the experimental group the mean CT in months 3 and 6 was significantly higher than baseline CT ($t(39) = 3.828/2.467$, $p < .001$ or $= .018$). However, the CT in month 6 was significantly lower than in month 3 ($t(39) = -2.210$, $p = .033$). For the control group, the mean CT in months 3 and 6 was also significantly higher than the baseline ($t(43) = 3.164/4.065$, $p = .003$ or $< .001$).

Relative performance of above/below-50th percentile families overall

On the dependent measure of AWC, the below-50th percentile group numbered 36 and the above-50th percentile group 48, while on the dependent measure of CT the below-50th percentile group numbered 27 and the above-50th percentile group 57. Thus the total sample was in general above average compared to US norms. Two-way repeated-measures ANOVA showed that for AWC there was a significant interaction between time and above/below average group membership ($F(2,164) = 14.35$, $p < .001$, partial $\eta^2 = .149$). There was also a significant difference between the above average group and the below average group ($F(1,82) = 23.21$, $p < .001$, partial $\eta^2 = .221$). Additionally, there was a significant difference in the time factor ($F(2,164) = 4.75$, $p = .010$, partial $\eta^2 = .550$).

Similarly, two-way repeated-measures ANOVA showed that for CT there was a significant interaction between time and above/below average group membership ($F(2,164) = 6.33$, $p = .002$, partial $\eta^2 = .072$). There was also a significant difference between the above average group and the below average group ($F(1,82) = 15.05$, $p < .001$, partial $\eta^2 = .155$). Additionally, there was a significant difference in the time factor ($F(2,164) = 21.89$,

Table 3. Whole sample AWC/CT at baseline and months 3 and 6 in above/below average groups.

	Below AWC/CT50%			Above AWC/CT50%		
	n	Mean	*SD*	*N*	Mean	*SD*
AWC_0	36	9008.58	2276.61	48	17836.81	4494.74
AWC_3	36	13398.89	5466.05	48	17136.21	8239.62
AWC_6	36	12585.52	4836.54	48	14672.26	6390.70
CT_0	27	231.87	57.90	57	446.35	120.56
CT_3	27	400.57	160.86	57	499.67	203.14
CT_6	27	411.87	161.41	57	498.41	236.27

Note: 0 = baseline, 3 = the 3rd month, 6 = the 6th month.
Below AWC/CT50% = below average, Above AWC/CT50% = above average.

$p < .012$, partial $\eta^2 = .211$) (Table 3). Thus, the analyses showed that the AWC and CT trajectories of the above average and below average groups were different across 6 months.

Post paired *t*-tests indicated that for the below AWC or CT average groups, AWC and CT scores in both months 3 and 6 were significantly higher than the baseline scores (for AWC, $t(35) = 5.05/4.73$, $p < .001$; for CT, $t(26) = 6.77/6.97$, $p < .001$). However, for the above AWC average group, AWC scores in months 3 and 6 were lower or significantly lower than their baseline scores ($t(47) = -.77/-3.38$, $p = .51/.001$). For the above CT average group, CT scores in months 3 and 6 were significantly higher than the baseline scores ($t(56) = 2.31/2.08$, $p = .024/.042$). These results suggest that the below average group was more likely to increase their talk with children.

Relative performance of above/below average families in experimental group

The difference between the above/below AWC/CT average talk groups within the experimental group was then examined (Table 4). There was no significant difference between the groups at baseline on KSNAP raw score, although the effect size was quite large (AWC below average group $n = 13$, mean = 16.31, $SD = 5.12$; above average group $n = 27$, mean = 14.37, $SD = 4.62$; $t(38) = 1.20$, $p = .24$, Cohen's $\delta = .40$; CT below average group $n = 14$, mean = 14.50, $SD = 4.00$; above average group $n = 26$, mean = 15.27, $SD = 5.25$; $t(38) = .48$, $p = .64$, Cohen's $\delta = .17$). Once becoming aware of their position in the overall group, the below average group was considered likely to have higher motivation to perform.

Two-way repeated-measures ANOVA showed that for the above average and below average groups' AWC there was indeed a significant interaction between time and above/below average performance ($F(2,76) = 5.65$, $p = .005$, partial $\eta^2 = .129$). This was also true for CT ($F(2,76) = 3.20$, $p = .046$, partial $\eta^2 = .078$). Of course, sample size was small.

Post hoc paired-samples *t*-tests indicated that for the below average talk group, AWCs in months 3 and 6 were significantly higher than the baseline scores ($t(12) = 2.89/3.20$,

Table 4. Experimental group difference in AWC and CT between baseline and months 3/6 by above/below average group.

Group	AWC/CT	*n*	Difference 1 (Baseline – Month 3)					Difference 2 (Baseline – Month 6)				
			Value	*SD*	*t*	*p*	*d*	Value	*SD*	*t*	*p*	*d*
Below AWC50%	AWC	12	3689.62	4608.89	2.89	**.014**	.96	3049.98	3437.49	3.20	**.008**	.81
Above AWC50%	AWC	26	−355.06	6883.43	−0.27	.791	.05	−3026.51	4782.55	−3.29	**.003**	.58
Below CT50%	CT	13	155.10	120.97	4.80	**<.001**	1.31	117.39	95.86	4.58	**.001**	1.23
Above CT50%	CT	25	61.46	164.39	1.91	.068	.34	17.25	140.08	0.63	.536	.10

Note: Below AWC/CT50% = below average, Above AWC/CT50% = above average.
The figures emboldened are significant at $p < .05$.
d = effect size (Cohen's δ).

$p = .014/.008$). For the above average talk group, AWC in month 3 was lower than the baseline score (but not significantly), while AWC in month 6 was significantly lower than baseline scores ($t(26) = -3.29$, $p = .003$). For CT in the below average group, in both months 3 and 6 scores were significantly higher than baseline ($t(13) = 4.80/4.58$, $p \leqslant .001$). For the above average group, CT in both months 3 and 6 was slightly higher than the baseline score but not significantly. These results provided evidence that feedback worked better for the below average group than the above average group.

Developmental language measures

On the K M-B CDI, only the Expressive Vocabulary (EV) Scale was relevant to all the children. The small numbers for the other three scales were disregarded. As one would expect, within each treatment group, the scores on both the dependent measures of K M-B CDI EV and KSNAP increased significantly from baseline to month 3 and to month 6. However, there were no significant differences between the experimental and control groups at months 3 or 6 on either of these language development measures (Table 5).

Discussion

Summary of results

Human and LENA AWC counts correlated at $r = .72$, but human and LENA CT counts correlated only at .67 after exclusion of outlier cases. Overall it seemed LENA AWC and CT counts could be applied to the Korean language context, with caution in respect of the latter. There were no significant differences between experimental and control groups at baseline on child age, gender, LENA AWC and CT counts or language development measures. The experimental group was divided into those above average at baseline and

Table 5. Experimental/control groups at baseline and months 3 and 6 on snapshot and K M-B CDI EV.

		Experimental			Control			*t*	*p*	*d*
		n	Mean	*SD*	*N*	Mean	*SD*			
Baseline	KSNAP DQ	40	15.00	4.81	44	15.11	4.58	−.11	.91	−.02
	K M-B CDI (exp. words)	40	4.34	7.00	44	5.87	8.18	−.77	.45	−.21
Month 3	KSNAP DQ	40	22.75	6.75	44	21.98	5.68	.56	.58	.11
	K M-B CDI (exp. words)	40	23.47	33.39	44	26.82	36.65	−.42	.67	−.10
Month 6	KSNAP DQ	40	26.89	6.57	44	26.07	6.55	.55	.58	.12
	K M-B CDI	40	57.31	72.91	44	62.07	76.20	−.28	.78	−.06

Note: KSNAP DQ = Korean version of SNAP, Developmental Quotient.
K M-B CDI = Korean MacArthur–Bates Communication Development Inventories, Expressive Vocabulary.
d = effect size (Cohen's δ).

those below average (compared to US norms). There was no significant difference between these subgroups.

Overall over 6 months there was no significant effect of treatment over time between experimental and control groups in AWC. However, for CT there was evidence of an intervention effect. However, both AWC and CT showed a significant effect of treatment over time in relation to above/below average group membership. For the below average group, AWC at both months 3 and 6 was significantly higher than baseline scores, but for the above average group AWC was lower than baseline scores. The pattern was similar for CT.

Implications for the literature

Parental responsiveness is a key factor across a broad range of child development indices (Warren & Brady, 2007; Zimmerman et al., 2009). We know that very young children respond to rich language stimulation, particularly in terms of Adult Word Count and Conversational Turns (Rowe, 2008; Topping et al., 2013). Using American English, Suskind et al. (2013) and Suskind et al. (2015) reported significant positive results from automated linguistic feedback with non-parental caregivers of typically-developing children and the natural parents of socio-economically deprived children. Zhang et al. (2015) did the same with 22 families of typically-developing children using Shanghai Dialect and Mandarin. The present study extends the latter work to a new Asian language and culture (Korean), with a larger sample and random allocation to experimental or control groups. Zhang et al.'s (2015) 22 families came from two centers and enjoyed interaction with each other at regular workshops, while the present study recruited much more widely and had only one workshop. Consequently the present study did not have any impact of regular parental face-to-face meetings. However, both Zhang et al. (2015) and the present study only reported persistently enhanced language interaction for the below average section of the participant group (although in the case of Zhang et al. (2015) this was below the baseline average of the experimental group).

The increase in conversational turn counts is promising in that previous studies have shown this measure to be positively correlated with child receptive language (VanDam, Ambrose, & Moeller, 2012) and school readiness (Huttenlocher, Vasilyeva, Waterfall, Vevea, & Hedges, 2007; Zimmerman et al., 2009). In this typically-developing group, the experimental parents received feedback which always indicated their own family's status in relation to the average for the US. This gave a clear signal, and to parents who were notoriously highly competitive. However we accept that there may be other explanations for this.

One of the features of the LENA technology is its potential for application in studying variations across the various contexts of language use. For example, Hoff (2010) reported two studies. One was of 20 children aged 1;5–2;2 in conversation with their mothers: at mealtime, in toy play, and at book reading. The other was of 16 children aged 1;9–3;0 in dyadic toy play interaction with three different conversational partners: a 5-year-old sibling, an 8-year-old sibling, and their mother. In both studies the contextual effects had differential effects on children's vocabulary use and discourse cohesion. Book reading yielded the richest child vocabulary and produced more topic-continuing contributions. They used a richer vocabulary and produced more responses to questions in conversation with their mothers than in conversation with their older siblings. However, again there were persistent differences between children which endured over time.

Similarly, Leech and Rowe (2014) compared 5-year-old children's (N = 33) discussions with their parents during picture book and chapter book reading (chapter books tell the story primarily through the text, although they tend to be profusely illustrated). There was variation in the amount and type of discussion between contexts. Children needed more narrative skill to participate in chapter book reading. It seems there is much scope for micro-analyzing LENA data in relation to the social context in which it was used. For instance, research could compare language interactions of parents with those of other caregivers, such as grandparents or daycare staff. It could also directly compare language during book reading with language during other activities. It could also identify key times of the day which have high potential for language interaction.

Limitations of the research

Although the participant group was divided into experimental and control groups randomly, their initial selection was purely on the basis of self-selected volunteering. The participants were all of middle to high socio-economic status, so we do not know if the results would be true of other sections of the population. The participants were drawn principally from eight centers, the number of parents from each center was small, and the opportunities for face-to-face discussions between parents thereby limited. The broad span of child ages reflected very different normal language inputs at different ages. The study also somewhat confounded the effects of feedback and the effects of a parent workshop and telephone calls, although the point of the study was to test the intervention as a whole. Further, the rate of attrition was quite high. In addition, implementation fidelity of the intervention was not gathered by direct observation.

The control group performed at an unexpectedly high level, which we might attribute to the novelty for them of conducting a recording. Also, both experimental and control participants knew their child's language development status from the language assessment program at pre-test. Discovering their baby's initial language status was low could have triggered increased efforts to interact with their child. In future studies all these factors need to be remedied.

Despite these limitations, the results show benefits for below average families, in line with results of Zhang et al. (2015) in China, but using random allocation to conditions and a control group, in a different cultural and linguistic context. The participants were strenuously followed up by a vigorous and enthusiastic research team, but this follow-up was not so intense as to compromise sustainability of the program. These results have strong implications for onward research and practice.

Future research, practice and policy

In the future, a study which recruits participants from one locality or one center should be used coupled with face-to-face interaction to see if this makes any difference. This would also facilitate home visits by project staff if needed. The number of workshops could also be varied. We know from previous studies that parents greatly value the opportunity to discuss with other parents. Future studies could also vary the feedback with respect to nature, frequency, and content in an adaptive manner that better utilizes the information available from the automated system. Comparisons could be made of reports outlining a timeline of parent–child interactions during the course of the day with simpler and more complex forms of feedback. However, increasing the complexity of feedback may also have unwanted side-effects. As additional samples are obtained in this language and culture, representative normative standards can be derived to provide better estimates of individual family performance.

LENA technology seems to be able to decode Korean at an acceptable level of accuracy (with cautions about CT), and consequently it can be used in other studies in the future. This study was the third to extend automatic measurement of the language environment to a non-English language, and only the fourth to examine the effects of automatically generated feedback to parents on adult word counts and conversational turns with children. This positive result demonstrates the potential for further cross-linguistic extension of automatic assessment of child–caregiver interactions to a much broader range of populations.

It could be argued that more intensive and active coaching was needed. On the other hand, attendance at the workshop was markedly less than 100%, and there seems no guarantee that parents would attend more intensive coaching. A higher intensity of coaching would also be more difficult to sustain once the program was generalized to a larger population.

The intervention was effective, but only effective in the longer term with below average families. Of course, this is exactly the group who are most in need – those experiencing an impoverished language environment.

Conclusions

This study was conducted to determine whether adult–child interaction practices could be assessed in a novel culture and language using tools developed on American English in the US, and whether Korean-speaking parents would respond positively to language feedback concerning their interaction behavior. A family's relative ranking in the quality of participant home language environments was seen as a key principle. LENA measures were collected over 6 months with 40 experimental and 44 control families.

Results suggested that LENA can assess adult word counts and conversational turns fairly accurately in Korean, with some caution regarding CT. LENA technology performance in the Korean language was adequate to ensure reasonable language use estimates. Overall, experimental and control families showed few differences in AWC, but the experimental group performed better in CT. Receiving automated feedback resulted in participant parents raising their adult word counts from baseline to 3 months, although it then went down again. Likewise, conversational turns increased, then slipped back, but not as far as baseline levels.

Over the 6 months of the intervention, families below average at baseline responded significantly better to feedback than families above average. Increases in both AWC and CT were statistically significant for the below average half of the participant pool (who were expected to be more motivated on becoming aware of their 'below average' status on feedback reports). However, this study had several limitations, which should be addressed in the future.

Both China and Korea have now shown below average parents sustain improved language interaction over 6 months in response to LENA feedback. It could be argued that giving feedback in relation to the child's baseline status capitalizes on a degree of parental competitiveness which may be a feature in Asian countries but is less prominent in the West. Consequently a study exploring the comparative use of this kind of feedback with above and below average families in the West might be timely. However, this kind of research is increasingly focusing on families of low socio-economic status, a great many of whom could be construed as 'below average' in relation to the general population, so this question may be answered in a different way.

It seems that LENA feedback can have a positive effect on language interactions between parents and children in several different cultures with different language systems, and is particularly potent with families who are below average in language interactions – exactly the population who need it. Using LENA with families at risk of low language interaction seems likely to have the most profound effects on the future functioning of the children concerned.

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