2pSC15. Quality and quantity of infant-directed speech by maternal caregivers predicts later speech-language outcomes in children with cochlear implants

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Introduction

- Normal-hearing young children experience dramatically different quantities of speech input (Hart & Risley, 1995). Experiencing a higher quantity of input is related to better language outcomes (e.g., Cartmill et al., 2013). Experiencing greater diversity in lexical items is tied to better language development (Schwab, Rowe, Cabera, Lew-Williams, 2018).
- The **quality** of speech input also matters for normal-hearing children's language development. An infant-directed (ID) speech style involves more variable and/or higher F0; distinct statistical distributions of formants for vowels (Kuhl et al 1997; McMurray et al. 2013); slower rate; and structural changes (Christia & Seidl, 2014; Houston & Bergeson, 2014). Variability in ID speech has been tied to variability in language development outcomes (Liu et al., 2003; Weisleder & Fernald, 2013).
- Prelingually deaf children with cochlear implants (CIs) must learn language via a highly degraded speech signal. Many factors have been identified as influencing language outcomes in children with CIs (Aubuchon et al., 2015; Hay-McCutcheon et al., 2018). Variation in language input has not yet been examined as a source of variability in outcomes in children with CIs.

Question: How does variation in the quality and quantity of maternal language input to children with CIs predict variation in their clinical language outcomes?

Methods

- This study was based on 39 mother-child dyads consisting of a NH mother and an early-implanted child with a CI enrolled through Indiana University School of Medicine over a 10-year period.
- ***Predictor variables: maternal speech measures.*** Each mother completed lab recordings in an ID condition or an adult-directed (AD) condition consisting of spontaneous speech. Two minutes of each recording per condition were analyzed.
  - Multiple speech **quality** measures were obtained for each mother's speech:
    1) Difference in areas of the vowel triangles based on first (F1) and second (F2) formant values for /i, ɑ, u/ (ID – AD)
    2) Difference in vowel dispersion in F1, F2 for /i, ɑ, u/ (ID – AD)
    3) Ratio of fundamental frequency (F0) median for ID vs. AD
    4) F0 variability (inter-quartile range) in ID vs. AD, normalized by F0 median
    5) Rate of ID speech (syllables per second)
    7) Lexical diversity (i.e., type-token ratio in ID speech)
  - We also examined **quantity** of words spoken in two minutes of ID speech
- ***Predicted variables: child speech-language clinical outcomes.*** Each child who received a CI completed one or more of the following speech-language assessments at least two times between 6 months or ~7 years post-implantation:
  - Peabody Picture Vocabulary Test (**PPVT**)
  - Preschool Language Scales (**PLS**)
  - Reynell Developmental Language Scales (**RDLS-E**xpressive subtest)
  - Reynell Developmental Language Scales (**RDLS-R**eceptive subtest)
- ***Statistical approach.*** For each child and assessment specified above, a line of best fit over time was calculated, from which we determined (a) predicted outcomes at two years and (b) language growth over two years. Backward elimination of predictors was then used to determine which, if any, significantly predicted (a) and (b) for each assessment.

Results. Infant and adult directed speech showed significant group differences.

- All prosodic properties were significantly different between ID and AD speech.
- Segmental properties (vowel space and dispersion) didn't differ significantly between ID and AD speech due to high inter-individual variability in these properties.
- Lexical quantity and diversity differed significantly between ID and AD speech.

Table 1. Differences between ID and AD properties of speech

	ID		AD		Mean Difference		95% CI of the Mean Difference [Min, Max]		
Acoustic Predictors	*M*	*SE*	*M*	*SE*	*M*	*SE*		t(38)	*p*
Segmental									
Vowel triangle area (mels)	70254.21	5096.13	63850.39	4073.90	6403.82	6140.41	[-6026.79, 18834.43]	1.04	.304
Vowel token dispersion (mels)	342.44	5.33	328.96	5.19	13.48	7.06	[-.82, 27.78]	1.91	.064
Prosodic									
Speech Rate (Syllables / Sec)	3.79	0.11	4.29	0.09	-.49	.12	[-.73, -.26]	-4.28	<.001
Median F0 (Hz)	276.05	6.65	188.14	3.56	87.91	5.77	[76.23, 99.58]	15.23	<.001
IQR of F0 (Hz)	128.21	6.46	34.68	1.87	93.53	6.5	[80.24, 106.82]	14.24	<.001
Lexical									
Lexical Quantity	63.94	2.64	103.9	4.83	-39.96	3.94	[-47.93, -31.98]	-10.14	<.001
Lexical Diversity	.35	.03	.51	.01	-16	.03	[-.22, -.09]	-5.07	<.001

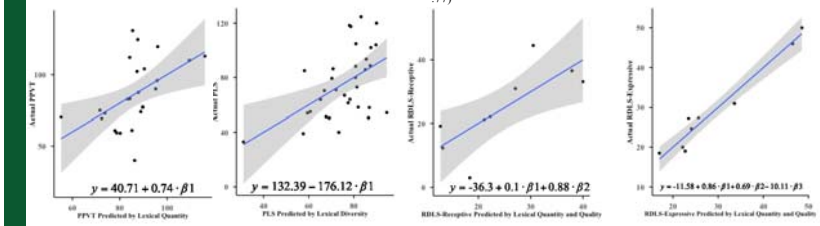
(a) Quality and quantity predicted outcomes in children with CIs.

PPVT
Lexical Quantity predicts PPVT ($p < .01$; $r = .509$)

PLS
Lexical Diversity predicts PLS ($p = .003$; $r = .507$)

RDLS-Receptive
Vowel triangle difference (β_1) and lexical diversity (β_2) predict RDLS-R ($p < .05$ for β_1, $p = .15$ for β_2, $p_{tot} = .07$, $r = .77$)

RDLS-Expressive
Vowel dispersion (β_1), normalized IQR F0 (β_2) and lexical quantity (β_3) predict RDLS-E ($p < .001$, $r = .97$)



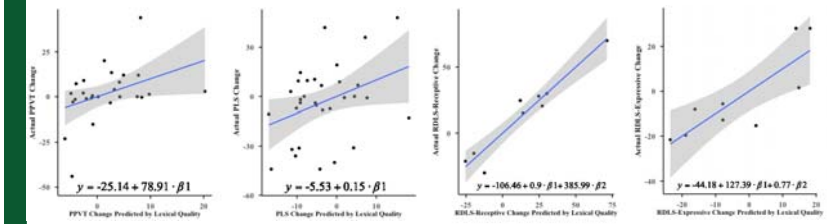
(b) Quality and quantity predicted language growth over 2 years.

PPVT
Lexical diversity predicts PPVT ($p = .042$, $r = .402$)

PLS
Vowel triangle area predicts PLS ($p = .042$; $r = .361$)

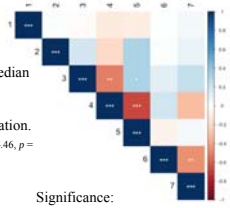
RDLS-Receptive
Lexical diversity (β_1) and vowel dispersion (β_2) predict RDLS-R ($p < .001$, $r = .963$)

RDLS-Expressive
Lexical Diversity (β_1), and Vowel dispersion (β_2) predict RDLS-E ($p = .03$, $r = .833$)



Individual differences among mothers in segmental and prosodic properties of ID speech.

- Prosodic properties were correlated with one another.
  - Normalized F0 variability and the ratio of ID to AD median F0 were strongly correlated ($r = -.666$, $p < .001$).
  - Speech rate was correlated with ratio of ID to AD median F0 ($r = .319$, $p = .048$) and F0 variability ($r = -.504$, $p = .001$).
- Prosodic variation was *not* correlated with segmental variation.
- Lexical diversity was correlated with lexical quantity ($r = -.46$, $p = .003$).



Predictors:

Segmental	Prosodic	Lexical	Significance:
1. Vowel space expansion	3. Median F0 ratio ID:AD	6. Lexical Quantity	*** p<=.001
2. Vowel space dispersion	4. Normalized IQR of F0	7. Lexical Diversity	** p<=.01
	5. Rate of ID speech		* p<= .05

Discussion

- These results showed that measures of the **quantity** and **quality** of speech taken from spontaneous speech of mothers recorded in the laboratory predicted clinical speech-language **outcomes** in children with CIs two years after implantation, as well as their clinical **change** over two years.
- This is the first evidence that the way mothers speak to their CI-implanted infants affects their children's speech-language development.
- These results support the notion that caregivers' **use of a high-quality, ID speech style** with children with CIs, as well as producing a **greater quantity and greater lexical diversity** in linguistic input, may foster enhanced clinical speech-language outcomes in children with CIs.

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