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**Mothers' Speech to Hearing-Impaired Infants with Cochlear Implants:
Some Preliminary Findings¹**

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Mothers' Speech to Hearing-Impaired Infants with Cochlear Implants: Some Preliminary Findings

Abstract. Caregivers typically speak to their normal-hearing (NH) infants using a distinct style known as infant-directed (ID) speech. With the recent expansion of cochlear implant (CI) criteria to include infants, it is critical to assess the changes in mothers' speech to infants as they acquire auditory skills via CIs, compared to mothers' speech to NH infants. To establish mothers' vocal style when speaking to their NH and implanted infants, we digitally recorded mothers speaking to their 4- to 10-month-old NH infants and mothers speaking to their 17- to 37-month-old hearing-impaired infants who use a CI. For the implanted infants, the average duration of implant use (i.e., "hearing age") was 11 months. We also recorded mothers' adult-directed (AD) speech. We analyzed the recordings in terms of the acoustic features known to characterize ID speech. The results were similar to those of previous studies. These preliminary findings suggest that mothers speak to NH and implanted infants in similar styles despite the chronological age difference in the two infant populations. That is, mothers' speech to infants is influenced by the child's "hearing age" rather than chronological age.

Introduction

Caregivers across cultures speak to their infants and children in a distinct style compared to how they speak to adults. Infant-directed (ID) speech is characterized by higher pitch, increased pitch range, shorter utterances, and longer pauses compared to adult-directed (AD) speech (Bergeson & Trehub, 2002; Fernald, 1991, 1992; Fernald & Simon, 1984; Papoušek, Papoušek, & Bornstein, 1985). Both mothers and fathers change their speaking style when talking to infants (Fernald, Taeschner, Dunn, Papoušek, de Boysson-Bardies & Fukui, 1989). Moreover, ID speech styles are similar across many languages such as French, Italian, German, Japanese, Mandarin, Swedish, and Russian (Fernald & Simon, 1984; Grieser & Kuhl, 1988; Jacobson, Boersma, Fields, & Olson, 1983; Kuhl, Andruski, Chistovich, Chistovich, Kozhevnikova, Ryskina, Stolyarova, Sundberg, & Lacerda, 1997).

Infants also show attentional and affective preferences for this style of speech. Very young infants will look longer at a visual stimulus in response to ID speech compared to AD speech (Cooper & Aslin, 1990, 1994; Fernald, 1985; Pegg, Werker, & McLeod, 1992). Infants also produce appropriate affective signals such as smiling in response to female ID speech rather than AD speech (Fernald, 1993; Werker & McLeod, 1989).

In turn, maternal speech is sensitive or responsive to several infant factors, including age (Kitamura & Burnham, 2003; Stern, Spieker, Barnett, & MacKain, 1983), linguistic skill (Burnham, Kitamura, & Vollmer-Conna, 2002; Fernald & Mazzie, 1991; Kuhl et al., 1997; Ratner, 1984), and affective or social context (Burnham, Kitamura, Vollmer-Conna, 2002; Trainor, Austin, & Desjardins, 2000). Caregivers' simulations of ID speech in the absence of their infants are easily differentiated from infant-present speech (Jacobson et al., 1983). Thus, the affective and cognitive characteristics of infants themselves contribute greatly to caregivers' communication style, even though the caregivers may not be consciously aware of fine-tuning their performances.

If we assume that infants' response to ID speech encourages caregivers' continued use of this vocal register, it would be important to determine if caregivers with hearing-impaired infants decrease their use of ID speech when they discover their infants are not responding to the auditory information.

Previous researchers have shown that when NH mothers first learn of their child's hearing loss they tend to increase their use of vocal exaggeration, but over time such vocal exaggeration decreases (Wedell-Monnig & Lumley, 1980). NH mothers who have hearing-impaired children tend to be more controlling and less responsive than NH mothers who have NH children (Cheskin, 1981; Goss, 1970; Henggeler & Cooper, 1983), and tend to repeat utterances rather than expand on them when speaking to hearing-impaired children compared to when speaking to NH children (Cross, Nienhuys, & Kirkman, 1985; Nienhuys, Cross, & Horsborough, 1984). Interestingly, mothers' speech to hearing-impaired children was also more similar to speech directed to NH children of the same linguistic age than to NH children of the same chronological age (Cross et al., 1985; Nienhuys et al., 1984). Finally, NH mothers tend to produce fewer and less complex verbal utterances but more nonverbal attention-getting behaviors in interactions with hearing-impaired infants and children compared to interactions with NH infants and children (Goldin-Meadow & Saltzman, 2000; Koester, Brooks, & Karkowski, 1998; Koester, Karkowski, & Traci, 1998).

It also appears that hearing-impaired infants and children behave differently than NH infants and children when interacting with their NH mothers. Koester (1995) found that 9-month-old infants with hearing loss did not actively elicit their mothers' attention by means of smiling, greeting, or reaching, in contrast to NH 9-month-olds. Instead, the hearing-impaired infants displayed more self-comforting and repetitious motor behaviors than NH infants. Other studies have found that hearing-impaired children are more passive and less responsive than NH children when interacting with their NH mothers (Henggeler & Cooper, 1983; Wedell-Monnig & Lumley, 1980). These studies suggest that hearing loss does have an effect on infants' and children's interactions with their caregivers.

The findings from these studies are both clinically and theoretically important because maternal responsiveness and sensitivity to their infants and children, particularly those with hearing loss, has been linked to the development of cognitive and linguistic skills (Hart & Risley, 1995; Kaplan, Bachorowski, Smoski, & Hudenko, 2002; Liu, Kuhl, & Tsao, 2003; Meadow-Orlans & Spencer, 1996; Pressman, Pipp-Siegel, Yoshinaga-Itano, & Deas, 1999; Spencer & Meadow-Orlans, 1996). For example, NH children who heard more parental utterances between the ages of 11 and 18 months were more likely to have much better language skills at ages 3 and 8 years than those children who heard fewer parental utterances during infancy (Hart & Risley, 1995). Moreover, Liu and colleagues (2003) found that maternal vowel clarity was positively correlated with 6- to 8-month old and 10- to 12-month old NH infants' speech discrimination abilities. NH 4-month-old infants display better learning skills in response to ID speech of nondepressed mothers compared to the much less exaggerated ID speech of depressed mothers (Kaplan et al., 2002). Finally, maternal sensitivity and responsiveness predicts language gain and representational play in hearing-impaired children (Pressman et al., 1999; Spencer & Meadow-Orlans, 1996).

With the recent FDA expansion of CI criteria to include profoundly deaf infants, it is critical to assess the changes in mothers' speech and singing to infants as they acquire auditory skills via CIs, compared to mothers' speech and singing to NH infants. Despite the growing support for effects of early experience on the speech perception skills in hearing-impaired infants and children with CIs (e.g., Houston, Ying, Pisoni, & Kirk, 2003; Miyamoto, Kirk, Robbins, Todd, Riley, & Pisoni, 1997; Svirsky, Robbins, Kirk, Pisoni, & Miyamoto, 2000), there has been very little research on the nature of the input these infants and children receive on a daily basis from their caregivers. Detailed investigation of caregivers' communicative interactions with their hearing-impaired infants who use CIs is needed to determine the optimal input for the development of language and other complex cognitive abilities.

To our knowledge, there has been only one published study on the early linguistic experience of hearing-impaired children with CIs. In a recent study from our laboratory, Stallings, Kirk, Chin, and Gao

(2000) found that parents' familiarity with uncommon words was positively correlated with the vocabulary and language skills of their hearing-impaired children with CIs. However, no research has assessed the acoustic characteristics, such as pitch level, in caregivers' speech and singing to hearing-impaired infants and children with CIs. The purpose of the current study was to determine whether NH mothers of NH infants and mothers of hearing-impaired infants with CIs use similar ID vocal styles.

Method

Participant Characteristics

NH mothers of implanted infants (N=6) were recruited from the clinical population at the Indiana University School of Medicine, Department of Otolaryngology – Head and Neck Surgery, and NH mothers of NH infants (N=6) were recruited from the local community. Table 1 shows demographic data across individual infants. The mean age of the CI infants was 26.9 months, the mean age at stimulation was 15.6 months, and the mean duration of CI use (i.e., “hearing age”) was 11.4 months. Mean age of the NH infants was 7.6 months. All mothers were reimbursed \$10 per visit.

Hearing Status	Gender	Chronological Age (months)	“Hearing Age” (months)
NH116	F	10.30	10.30
NH141	F	8.45	8.45
NH147	F	8.49	8.49
NH151	F	9.90	9.90
NH170	M	4.05	4.05
NH171	F	4.51	4.51
CI03	F	23.85	11.64
CI08	F	37.07	17.99
CI10	M	23.00	12.63
CI12	M	23.16	6.18
CI16	M	17.5	3.51
CI21	F	37.04	16.12

Table 1. Infant demographic information. Note that chronological age of normal-hearing infants is the same as their “hearing age.”

Procedure

We digitally recorded mothers speaking to their infants or an experimenter in a double-walled copper-shielded sound booth (IAC). In the ID speech condition, we asked mothers to sit with their child on a blanket or a chair, whichever option was most comfortable for them. We also provided the same group of quiet toys for all mother-child dyads. Mothers were instructed to speak to their child as they normally would at home. In the AD speech condition, an experimenter conducted a short interview with each mother. The order of ID and AD performances was counterbalanced across mothers. Mothers' speech was recorded by a hypercardioid microphone (Audio-Technica ES933/H), powered by a phantom

power source. The microphone was linked to an amplifier (DSC 240) and a digital/audio tape recorder (Sony DTC-690). We also videotaped the recording sessions using a digital camera (Sony DCR-TRV 120/TRV 320).

Acoustic features known to characterize maternal ID speech were analyzed using Praat speech analysis software (Boersma & Weenink, 1996): average fundamental frequency (Hz), minimum fundamental frequency (Hz), maximum fundamental frequency (Hz), utterance duration (s), and duration of pauses between utterances (s). All features were measured for each utterance in a two-minute speech sample in both ID and AD conditions and then averaged across utterances. An utterance was defined in this study as a complete sentence or a complete thought.

Results

Figure 1 shows the average pitch results in NH mothers' speech to NH infants, hearing-impaired infants with CIs, and a NH adult. In terms of average pitch level, a 2 (speech type: ID vs. AD) \times 2 (NH infant vs. hearing-impaired infant with CI) repeated measures ANOVA revealed a significant main effect of speech type ($F(1, 10) = 65.19, p < .0001$). There was no effect of hearing status, and no interaction between speech type and hearing status. Pitch was higher in mothers' speech to infants than to an adult experimenter, regardless of their infant's hearing status.

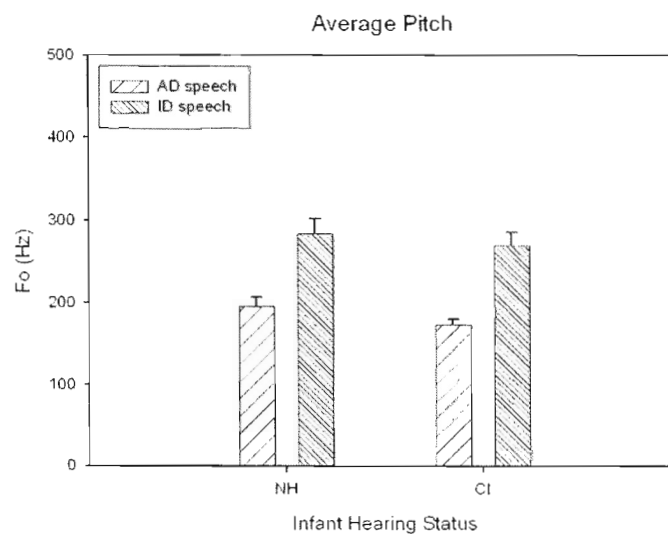


Figure 1. Average pitch in normal-hearing mothers' speech to normal-hearing infants, hearing-impaired infants with cochlear implants, and a normal-hearing adult. Error bars represent standard error.

Figures 2 and 3 show the minimum and maximum pitch results in NH mothers' speech to NH infants, hearing-impaired infants with CIs, and a NH adult. We found a significant main effect of speech type (minimum pitch: $F(1, 10) = 67.12, p < .0001$; maximum pitch: $F(1, 10) = 37.67, p < .0001$). Again we found no effect of hearing status and no interaction between speech type and hearing status. Both minimum and maximum pitch levels were higher in mothers' ID speech compared to mothers' AD speech, regardless of infant hearing status.

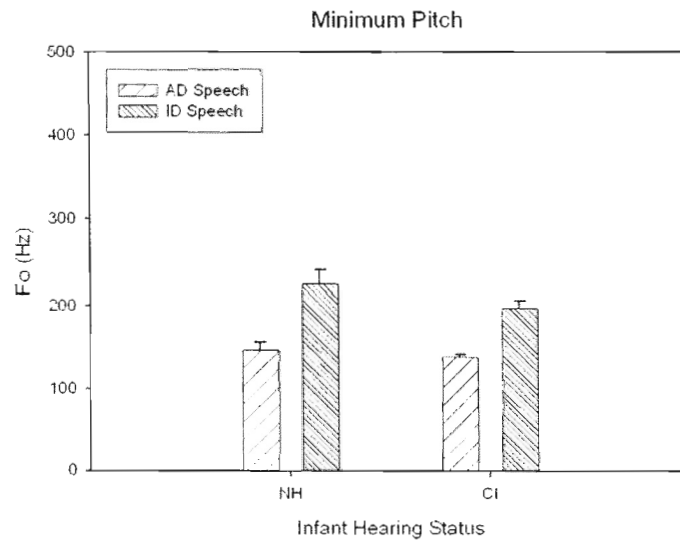


Figure 2. Minimum pitch averaged across normal-hearing mothers' speech to normal-hearing infants, hearing-impaired infants with cochlear implants, and a normal-hearing adult. Error bars represent standard error.

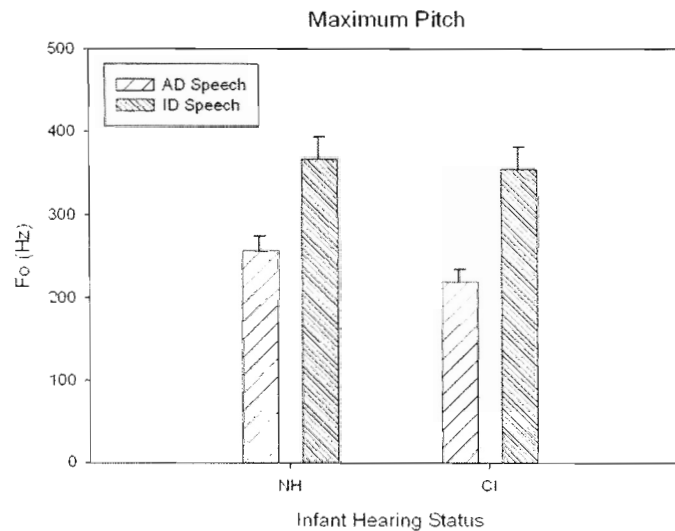


Figure 3. Maximum pitch averaged across normal-hearing mothers' speech to normal-hearing infants, hearing-impaired infants with cochlear implants, and a normal-hearing adult. Error bars represent standard error.

Figures 4 and 5 show the average utterance durations and the average duration of pauses between utterances in NH mothers' speech to NH infants, hearing-impaired infants with CIs, and a NH adult. We performed 2 (speech type: ID vs. AD) x 2 (NH infant vs. hearing-impaired infant with CI) repeated measures ANOVAs on the measures of utterance duration and pause duration. One NH mother/NH infant dyad was excluded from this analysis due to experimenter error. We found a significant main effect of speech type for both utterance duration ($F(1, 10) = 39.90, p < .0001$) and pause duration ($F(1, 9) = 9.76,$

$p = .01$). There was no main effect of hearing status for either duration measure. Although there was no significant interaction between speech type and hearing status for utterance duration, this interaction approached significance for the measure of pause duration ($F(1, 9) = 4.20, p = .07$). Mothers' utterances were shorter in duration when speaking to their infant than to an adult experimenter, regardless of infant hearing status. On the other hand, pauses between utterances were longer when directed to infants than adults, and this difference was much more pronounced in mothers of NH infants compared to mothers of hearing-impaired infants with CIs.

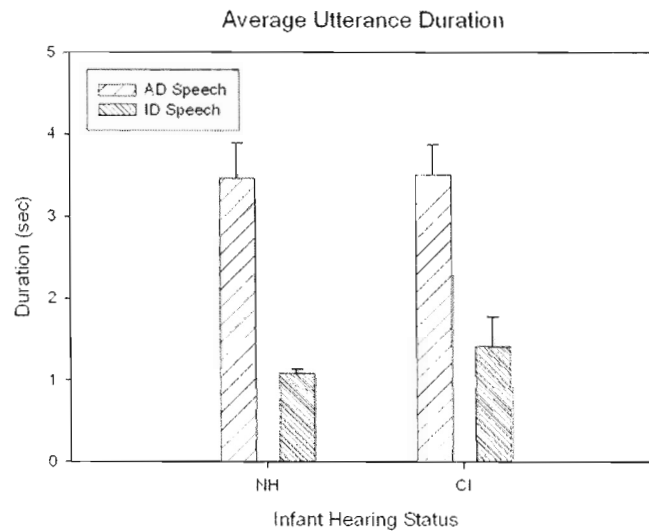


Figure 4. Utterance duration averaged across normal-hearing mothers' speech to normal-hearing infants, hearing-impaired infants with cochlear implants, and a normal-hearing adult. Error bars represent standard error.

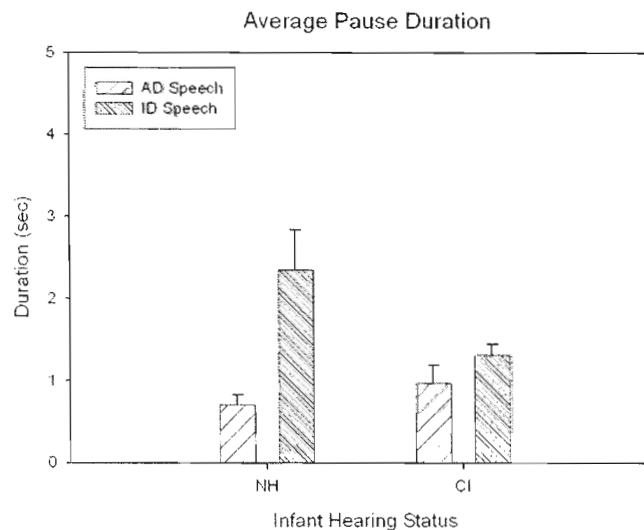


Figure 5. Pause duration averaged across normal-hearing mothers' speech to normal-hearing infants, hearing-impaired infants with cochlear implants, and a normal-hearing adult. Error bars represent standard error.

Discussion

As expected from previous literature, the results of the present study revealed that the average, minimum, and maximum pitch levels were higher in ID speech than AD speech, and utterances were shorter in duration in ID speech than AD speech, regardless of infant hearing status. Average pause duration was longer in ID speech compared to AD speech when directed to NH infants, but not when directed to CI infants. These preliminary findings suggest that mothers speak to NH and CI infants in similar styles despite the chronological age difference in the two infant populations. That is, mothers' speech to infants is influenced by "hearing age" rather than chronological age.

These results are both clinically and theoretically significant. Not only has ID speech quality been linked to infants' development of language and other cognitive skills (Kaplan et al., 2002; Liu et al., 2003; Pressman et al., 1999; Spencer & Meadow-Orlans, 1996), but recent studies have also shown that very early auditory and audiovisual experiences and activities have significant effects on hearing-impaired children's development of speech perception and language skills (e.g., Bergeson, Pisoni, & Davis, 2003; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). These studies simply group hearing-impaired children with CIs into broad categories such as Oral Communication (i.e., auditory/verbal communication) versus Total Communication (i.e., simultaneously signed and spoken English) and Early-implanted versus Late-implanted. Although differences in speech and language performance across these groups are informative and clinically useful, there is still a great deal of variability within these broad categories and it is unclear exactly what types of specific experiences and activities children in each group are receiving. Thus, it is extremely important to investigate other factors that may underlie this variability. Further studies of mothers' vocal communication styles while interacting with their hearing-impaired infants and children with CIs should contribute greatly to understanding the large variability in speech and language outcome measures. Our findings could also be used to develop the optimal speech therapy tools to increase speech perception and language performance in hearing-impaired infants and children who receive CIs.

References

- Bergeson, T.R., Pisoni, D.B., & Davis, R.A.O. (2003). A longitudinal study of audiovisual speech perception by children with hearing loss who have cochlear implants. *The Volta Review, 103*, 347-370.
- Bergeson, T.R., & Trehub, S.E. (2002). Absolute pitch and tempo in mothers' songs to infants. *Psychological Science, 13*, 72-75.
- Boersma, P. & Weenink, D. (1996). *PRAAT, a system for doing phonetics by computer* (Rep. No. 132). Amsterdam, The Netherlands: University of Amsterdam, Institute of Phonetic Sciences.
- Burnham, D., Kitamura, C., & Vollmer-Conna, U. (2002). What's new, pussycat? On talking to babies and animals. *Science, 296*, 1435.
- Cheskin, A. (1981). The verbal environment provided by hearing mothers for their young deaf children. *Journal of Communication Disorders, 14*, 485-496.
- Cooper, R.P., & Aslin, R.N. (1990). Preference for infant-directed speech in the first month after birth. *Child Development, 61*, 1584-1595.
- Cooper, R.P., & Aslin, R.N. (1994). Developmental differences in infant attention to the spectral properties of infant-directed speech. *Child Development, 65*, 1663-1667.
- Cross, T.G., Nienhuys, T.G., Kirkman, M. (1985). Parent-child interaction with receptively disabled children: Some determinants of maternal speech style. In K. E. Nelson (Ed.), *Child Language: Volume 5* (pp. 247-290). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

- Fernald, A. (1985). Four-month-old infants prefer to listen to motherese. *Infant Behavior and Development, 8*, 181-195.
- Fernald, A. (1991). Prosody in speech to children: Prelinguistic and linguistic functions. *Annals of Child Development, 8*, 43-80.
- Fernald, A. (1992). Meaningful melodies in mothers' speech to infants. In H. Papoušek, U. Jürgens, & M. Papoušek (Eds.), *Nonverbal vocal communication: Comparative and developmental approaches* (pp. 262-282). Cambridge: Cambridge University Press.
- Fernald, A. (1993). Approval and disapproval: Infants' responsiveness to vocal affect in familiar and unfamiliar languages. *Child Development, 64*, 657-674.
- Fernald, A., & Mazzie, C. (1991). Prosody and focus in speech to infants and adults. *Developmental Psychology, 27*, 209-221.
- Fernald, A., & Simon, T. (1984). Expanded intonation contours in mothers' speech to newborns. *Developmental Psychology, 20*, 104-113.
- Fernald, A., Taeschner, T., Dunn, J., Papoušek, M., de Boysson-Bardies, B., & Fukui, I. (1989). A cross-language study of prosodic modifications in mothers' and fathers' speech to preverbal infants. *Journal of Child Language, 16*, 477-501.
- Goldin-Meadow, S., & Saltzman, J. (2000). The cultural bounds of maternal accommodation: How Chinese and American mothers communicate with deaf and hearing children. *Psychological Science, 11*, 307-314.
- Goss, R. (1970). Language used by mothers of deaf children and mothers of hearing children. *American Annals of the Deaf, 115*, 93-96.
- Grieser, D.L., & Kuhl, P.K. (1988). Maternal speech to infants in a tonal language: Support for universal prosodic features in motherese. *Developmental Psychology, 24*, 14-20.
- Hart, B., & Risley, T.R. (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore, MD: Paul H. Brookes.
- Henggeler, S.W., & Cooper, P.F. (1983). Deaf child-hearing mother interaction: Extensiveness and reciprocity. *Journal of Pediatric Psychology, 8*, 83-95.
- Houston, D.M., Ying, E.A., Pisoni, D.B., & Kirk, K.I. (2003). Development of pre-word-learning skills in infants with cochlear implants. *The Volta Review, 103*, 303-326.
- Jacobson, J.L., Boersma, D.C., Fields, R.B., & Olson, K.L. (1983). Paralinguistic features of adult speech to infants and small children. *Child Development, 54*, 436-442.
- Kaplan, P.S., Bachorowski, J.-A., Smoski, M.J., & Hudenko, W.J. (2002). Infants of depressed mothers, although competent learners, fail to learn in response to their own mothers' infant-directed speech. *Psychological Science, 13*, 268-271.
- Kitamura, C., & Burnham, D. (2003). Pitch and communicative intent in mother's speech: Adjustments for age and sex in the first year. *Infancy, 4*, 85-110.
- Koester, L.S. (1995). Face-to-face interactions between hearing mothers and their deaf or hearing infants. *Infant Behavior and Development, 18*, 145-153.
- Koester, L.S., Brooks, L.R., & Karkowski, A.M. (1998). A comparison of the vocal patterns of deaf and hearing mother-infant dyads during face-to-face interactions. *Journal of Deaf Studies and Deaf Education, 3*, 290-301.
- Koester, L.S., Karkowski, A.M., & Traci, M.A. (1998). How do deaf and hearing mothers regain eye contact when their infants look away? *American Annals of the Deaf, 143*, 5-13.
- Kuhl, P.K., Andruski, J.E., Chistovich, I.A., Chistovich, L.A., Kozhevnikova, E.V., Ryskina, V.L., Stolyarova, E.I., Sundberg, U., & Lacerda, F. (1997). Cross-language analysis of phonetic units in language addressed to infants. *Science, 277*, 684-686.
- Liu, H.-M., Kuhl, P.K., & Tsao, F.-M. (2003). An association between mothers' speech clarity and infants' speech discrimination skills. *Developmental Science, 6*, F1-F10.

- Meadow-Orlans, K.P., & Spencer, P.E. (1996). Maternal sensitivity and the visual attentiveness of children who are deaf. *Early Development and Parenting, 5*, 213-223.
- Miyamoto, R.T., Kirk, K.I., Robbins, A.M., Todd, S., Riley, A., & Pisoni, D.B. (1997). Speech perception and speech intelligibility in children with multichannel cochlear implants. In I. Honjo & H. Takahashi (Eds.), *Cochlear implant and related sciences update. Advances in otorhinolaryngology* (pp. 198-203). Basel, Switzerland: Karger.
- Nienhuys, T.G., Cross, T.G., & Horsborough, K.M. (1984). Child variables influencing maternal speech style: Deaf and hearing children. *Journal of Communication Disorders, 17*, 189-207.
- Papoušek, M., Papoušek, H., & Bornstein, M.H. (1985). The naturalistic vocal environment of young infants: On the significance of homogeneity and variability in parental speech. In T.M. Field & N.A. Fox (Eds.), *Social perception in infants* (pp. 269-297). Norwood, NJ: Ablex.
- Pegg, J.E., Werker, J.F., & McLeod, P.J. (1992). Preference for infant-directed over adult-directed speech: Evidence from 7-week-old infants. *Infant Behavior and Development, 15*, 325-345.
- Pressman, L.J., Pipp-Siegel, S., Yoshinaga-Itano, C., & Deas, A. (1999). Maternal sensitivity predicts language gain in preschool children who are deaf and hard of hearing. *Journal of Deaf Studies and Deaf Education, 4*, 294-304.
- Ratner, N. B. (1984). Patterns of vowel modification in mother-child speech. *Journal of Child Language, 11*, 557-578.
- Spencer, P.E., & Meadow-Orlans, K.P. (1996). Play, language, and maternal responsiveness: A longitudinal study of deaf and hearing-impaired infants. *Child Development, 67*, 3176-3191.
- Stallings, L.M., Kirk, K.I., Chin, S.B., Gao, S. (2000). Parent word familiarity and the language development of pediatric cochlear implant users. *The Volta Review, 102*, 237-258.
- Stern, D. N., Spieker, S., Barnett, R. K., & MacKain, K. (1983). The prosody of maternal speech: Infant age and context related changes. *Journal of Child Language, 10*, 1-15.
- Svirsky, M.A., Robbins, A.M., Kirk, K.I., Pisoni, D.B., & Miyamoto, R.T. (2000). Language development in profoundly deaf children with cochlear implants. *Psychological Science, 11*, 153-158.
- Trainor, L.J., Austin, C., & Desjardins, R. (2000). Is infant-directed speech prosody a result of the vocal expression of emotion? *Psychological Science, 11*, 188-195.
- Wedell-Monnig, J., & Lumley, J.M. (1980). Child deafness and mother-child interaction. *Child Development, 51*, 766-774.
- Werker, J.F., & McLeod, P.J. (1989). Infant preference for both male and female infant-directed talk: A developmental study of attentional and affective responsiveness. *Canadian Journal of Psychology, 43*, 230-246.
- Yoshinaga-Itano, C., Sedey, A.L., Coulter, K.D., & Mehl, A.L. (1998). Language of early- and later-identified children with hearing loss. *Pediatrics, 102*, 1161-1171.