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Research Article

Affective Properties of Mothers' Speech to Infants With Hearing Impairment and Cochlear Implants

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Purpose: The affective properties of infant-directed speech influence the attention of infants with normal hearing to speech sounds. This study explored the affective quality of maternal speech to infants with hearing impairment (HI) during the 1st year after cochlear implantation as compared to speech to infants with normal hearing.
Method: Mothers of infants with HI and mothers of infants with normal hearing matched by age (NH-AM) or hearing experience (NH-EM) were recorded playing with their infants during 3 sessions over a 12-month period. Speech samples of 25 s were low-pass filtered, leaving intonation but not speech information intact. Sixty adults rated the stimuli along 5 scales: positive/negative affect and intention to express affection, to encourage attention, to comfort/soothe, and to direct behavior.
Results: Low-pass filtered speech to HI and NH-EM groups was rated as more positive, affective, and comforting compared with the such speech to the NH-AM group. Speech to infants with HI and with NH-AM was rated as more directive than speech to the NH-EM group. Mothers decreased affective qualities in speech to all infants but increased directive qualities in speech to infants with NH-EM over time.
Conclusions: Mothers fine-tune communicative intent in speech to their infant's developmental stage. They adjust affective qualities to infants' hearing experience rather than to chronological age but adjust directive qualities of speech to the chronological age of their infants.

Previous research suggests that the affective quality of infant-directed speech (IDS) provides a foundation for developing infant language skills and establishing successful mother–infant social–emotional communication (Fernald, 1989, 1992; Fernald & Mazzie, 1991; Kitamura & Burnham, 1998; Papoušek, Bornstein, Nuzzo, Papoušek, & Symmes, 1990; Singh, Morgan, & Best, 2002; Singh, Morgan, & White, 2004; Snow, 1977, 1989; Trainor, Austin, & Desjardins, 2000; Werker & McLeod, 1989). Still, little is known about the affective characteristics of maternal speech to infants and children with severe-to-profound hearing loss who receive cochlear implants (CIs). Cochlear implantation has become a standard medical treatment, which allows infants with prelingual deafness to communicate via spoken language (American Speech-Language-Hearing Association, 2004). The aim of the current study was to examine the affective properties of speech directed to infants with CIs in order to identify variables that can maximize the likelihood of successful verbal communication in children with hearing impairment.

The affective quality in both IDS and adult-directed speech is transmitted by prosodic characteristics, such as changes in pitch, duration, and timing; loudness; and voice quality (Laukka, Justin, & Bresin, 2005; Scherer, 1986, 2003; Williams & Stevens, 1972). It is especially important in early infancy because it draws infants' attention to speech sounds (Singh et al., 2002, 2004; Trainor et al., 2000), conveys mothers' communicative intentions, and encourages social interaction (e.g., turn taking) in caregiver–infant dyads (Fernald, 1992; Fernald & Simon, 1984; Katz, Cohn, & Moore, 1996; Kitamura & Burnham, 2003; Papoušek, Papoušek, & Symmes, 1991; Stern, Spieker, & MacKain, 1982). It has been shown that infants respond differently to melodic contours that transmit meaningful caregivers' messages (Fernald, 1993; Kitamura & Lam, 2009; Papoušek et al., 1990). Thus, affective communication is suggested to promote and facilitate infant socialization and language development (Fernald, 1989, 1992; Locke, 1993; Papoušek et al., 1990; Snow, 1977, 1989; Stern et al., 1982).

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Several affective intent types have been identified in IDS to infants with normal hearing (NH) (Fernald, 1989, 1992, 1993; Katz et al., 1996; Kitamura & Burnham, 2003; Papoušek et al., 1990, 1991; Stern, Spieker, Barnett, & MacKain, 1983). The most often cited types are comfort and soothe, approval/reward and disapproval/prohibition, engagement of infant attention, and direction of infant's behavior (Fernald, 1989, 1992, 1993; Katz et al., 1996; Kitamura & Burnham, 2003; Kitamura & Lam, 2009; Papoušek et al., 1990, 1991; Stern et al., 1982).

Researchers also suggest that affective behavior expressed in caregivers' speech changes over time, presumably reflecting changes in infant development (Kitamura & Burnham, 2003; Kitamura & Lam, 2009; Stern et al., 1982). In early infancy (0–3 months), a mother's voice to an infant with NH is characterized by comforting and soothing properties that regulate the infant's arousal level, accommodate limitations of the newborn's perceptual abilities, and introduce the infant to his or her first social interactions (Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2002). From 3 to 6 months, there is a marked increase in affective features of IDS that may be in response to infants' increased social responsiveness (Kitamura et al., 2002). Around 9 months of age, affective features of IDS start to decline, and at the same time, there is an increase in directive behavior (Kitamura et al., 2002), which may reflect the significant reorganization of the infant's linguistic, social, and cognitive abilities that occurs around this age (Bretherton, 1992; Burnham, 1987; Burnham, Kitamura, & Lancuba, 1999; Feinman, Roberts, Hsieh, Sawyer, & Swanson, 1992; Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993; Kuhl et al., 2008; Murphy & Messer, 1977; Piaget, 1963; Polka & Werker, 1994; Werker & Tees, 1984). At 12 months of age, a reemergence of affective qualities of IDS is observed that possibly offers encouragement to infants whose communicative, social, and emotional interactions have become more mature (Kitamura et al., 2002; Polka & Werker, 1994; Werker & Tees, 1984). Although there is little recent research examining affective qualities of IDS after 12 months of age, it is possible that they diminish over time as their influence on infant language acquisition will likely decrease (Kitamura et al., 2002; Liu, Tsao, & Kuhl, 2009; Stern et al., 1983).

Despite the accumulated evidence on the affective characteristics of IDS to infants and children with NH (Katz et al., 1996; Kitamura & Burnham, 2003; Lam & Kitamura, 2010; Papoušek et al., 1991; Stern et al., 1983), little is known about the affective properties of speech to infants with hearing loss. Observational studies of children with hearing impairment (HI) have identified their mothers with NH as more directive, hostile (frustrated), and intrusive; less responsive; and displaying less positive affect compared with mothers of children with NH (Brinich, 1980; Goss, 1970; Henggeler & Cooper, 1983; Lam & Kitamura, 2010; Meadow-Orlans & Steinberg, 1993; Pipp-Siegel, Blair, Deas, Pressman, & Yoshinaga-Itano, 1998; Quittner et al., 2010, 2013; Spence & Gutfreund, 1990; Spencer & Meadow-Orlans, 1996; Wedell-Monning & Lumley, 1980). Furthermore, there is growing evidence that the development of social cognition (e.g., theory of mind and emotion understanding), which is delayed in children who are deaf (Schick, de Villiers, de Villiers, & Hoffmeister, 2007), is constructed within early social interactions (Carpendale & Lewis, 2004). Indeed, mothers with NH include fewer references to emotions and mental states when talking to their deaf children than when talking to their children with NH, and these differences correlate with children's performance on theory-of-mind tasks (Moeller & Schick, 2006). It is possible that the consequences of such atypical dyadic interactions could result in less secure attachment, difficulty sustaining attention, and slower development of linguistic competence (Barker et al., 2009; Quittner et al., 2013).

Pediatric CI users are shown to perform more poorly on both perception and production of vocal emotions than their peers with NH (Chin, Bergeson, & Phan, 2012; Hopyan-Misakyan, Gordon, Dennis, & Papsin, 2009; Most & Aviner, 2009; Nakata, Trehub, & Kanda, 2012; Volkova, Trehub, Schellenberg, Papsin, & Gordon, 2013). The poorer level of performance by pediatric CI users may be explained by the limitations of CI devices that relay inaccurate and/or degraded prosodic information, for example, pitch and spectral cues (Geurts & Wouters, 2001; Green, Faulkner, & Rosen, 2004) that transmit vocal affect (Laukka et al., 2005; Scherer, 1986, 2003; Williams & Stevens, 1972). However, despite CI device limitations, pediatric CI users are able to perceive and produce vocal emotions (e.g., happy vs. sad) with some children performing as well as children with NH (Chin et al., 2012; Nakata et al., 2012; Volkova et al., 2013). Because affective quality of IDS is a core factor for the development of language and communication skills (Fernald, 1989, 1992; Fernald & Mazzie, 1991; Papoušek et al., 1990; Singh et al., 2002; Snow, 1977, 1989; Werker & McLeod, 1989) and children with CIs can perceive and produce many prosodic characteristics associated with vocal emotion (Chin et al., 2012; Nakata et al., 2012; Volkova et al., 2013), it is critical to understand the role of maternal affect in spoken language development of children who use CIs.

The aim of the current study was to quantify the affective quality of speech to infants with NH and infants with HI over the first year of cochlear implantation to elucidate how hearing status affects mothers' expression of vocal affect. Research on communicative intent/affect in IDS to infants with NH has shown a decrease in positive features, such as expression of affect and approval, positive affect, and comfort, and an increase in attention-getting and directive properties of mothers' speech across the first 12 months (Kitamura & Burnham, 2003; Kitamura & Lam, 2009; Kitamura et al., 2002). In this study, it is predicted that the expression of affective intention in maternal speech to infants with NH will follow a similar pattern.

Several studies in our laboratory comparing mothers' production of prosodic characteristics in IDS to infants with NH and infants with prelingual deafness who received CIs have suggested that mothers adjust the prosodic properties of their speech to hearing experience rather than to the chronological age of their infants (Bergeson, Miller, & McCune, 2006; Kondaurova & Bergeson, 2011; Kondaurova, Bergeson, & Xu, 2013). Because the affective properties in speech are transmitted by prosodic characteristics (Bachorowski, 1999; Kitamura et al., 2002; Laukka et al., 2005; Papoušek et al., 1991; Scherer, 1986, 2003; Stern et al., 1983; Williams & Stevens, 1972), it is possible that the affective quality of IDS would be more similar in speech to infants with HI and infants with NH who have equal hearing experience but not chronological age. However, it is also possible that IDS to infants with HI will be less positive and more directive in comparison to that to infants with NH regardless of the match in either chronological age or the amount of hearing experience due to atypical interactions between mothers with NH and infants and children with deafness that have been reported in earlier studies (Brinich, 1980; Goss, 1970; Henggeler & Cooper, 1983; Lam & Kitamura, 2010; Meadow-Orlans & Steinberg, 1993; Pipp-Siegel et al., 1998; Quittner et al., 2010, 2013; Spence & Gutfreund, 1990; Spencer & Meadow-Orlans, 1996; Wedell-Monning & Lumley, 1980).

Method

Participants

Sixty participants (mean age = 28.3 years, *SD* = 11, women = 42, men = 18) were recruited at the Indiana University–Purdue University Indianapolis (IUPUI) campus and from the local Indianapolis community to rate the maternal speech. Participants were native American English speakers who grew up in the Midwest and had no self-reported history of speech and hearing disability. All participants were paid $10 for their participation under a protocol approved by the IUPUI Institutional Review Board.

Perceptual Rating Experiment

Recording Procedure

Previous recordings of IDS to infants with NH and infants with HI who received CIs were used to prepare stimuli for the current perceptual rating experiment (Bergeson et al., 2006; Kondaurova & Bergeson, 2011; Kondaurova, Bergeson, & Dilley, 2012; Kondaurova et al., 2013). A brief summary of recording methods is provided below.

Mother–infant participants. Mothers of infants with HI and infants with NH (n = 33) were recruited from the clinical population at the Indiana University School of Medicine, Department of Otolaryngology—Head and Neck Surgery and from the local community and were reimbursed $10 per visit. All mothers had NH, and the experimental groups were created on the basis of the hearing status of their infants. The HI group (n = 12, infant age 13.3–25.5 months) included mother–infant dyads with infants with HI who received CIs (infant age at CI stimulation 10.3–22.7 months). Due to the severe-to-profound degree of hearing loss, infants with HI were considered to have no hearing experience prior to CI. The NH age-matched (NH-AM) group (n = 12, infant age 13.5–25.7 months) included mother–infant dyads with infants with NH who were of the same chronological age as the infants with HI. The NH experience-matched (NH-EM) group (n = 9, infant age 2.3–3.6 months) included mother–infant dyads with infants with NH who had approximately 3 months of hearing experience at the time of the first visit. All mother–infant dyads were invited for three visits. The HI group came to three sessions at 3, 6, and 12 months post-CI. The NH-AM group came to three sessions so that they were approximately the same chronological ages as the infants with HI when they were 3, 6, and 12 months post-CI. The NH-EM group came to three sessions when infants were approximately 3, 6, and 12 months of age. Table 1 shows the number of mother–infant dyads, infant mean age, and gender. Table 2 provides information on communication method, deafness etiology, and the type of CI device for each infant in HI group.

Maternal speech recordings. The 33 mothers were digitally recorded speaking to their infants as they normally would do at home while playing with quiet toys and to an adult experimenter in a semistructured interview. For a detailed description of recording procedures, see previous studies (e.g., Kondaurova & Bergeson, 2011). Recordings were made at a sampling rate of 44.1 kHz with 16-bit amplitude resolution.

Syntactic coding. Utterances were coded and segmented using the Systematic Analysis of Language Transcripts, Research V8 software (Miller & Iglesias, 1984). For a detailed description of coding procedures, see previous studies (e.g., Kondaurova & Bergeson, 2011).

Stimuli Preparation

Auditory stimuli. Speech samples of 25 s taken after the first 60 s of each mother's recording were selected using MATLAB Version 2009a (The Mathworks Inc.). Following the protocol developed by Kitamura and Burnham (2003), any infant vocalization or noise that occurred between the mothers' utterances was removed and replaced with 300–600 ms of silence. Thus, if the pause between mothers' utterances after removing infant vocalizations and/or noise was less than 300 ms, it was increased to 300 ms; if the pause between mothers' utterances after removing infant

Table 1. Number of mother–infant dyads, infant mean age (in months, standard deviation) and gender at each testing session.

Group	Session	Age	Dyads	Gender
HI	3 months post-CI stim	18.1 (4)	12	M 10, F 2
	6 months post-CI stim	20.6 (5.5)		
	12 months post-CI stim	27.4 (4.3)		
NH-AM	1 session	18.2 (4)	12	M 7, F 5
	2 session	21.4 (4)		
	3 session	27.4 (4.3)		
NH-EM	1 session	2.9 (0.4)	9	M 5, F 4
	2 session	5.8 (0.4)		
	3 session	12 (0.4)		

Note. HI = hearing impairment; CI stim = cochlear implant stimulation; NH-AM = normal hearing, age-matched; NH-EM = normal hearing, experience-matched.

Table 2. Communication method, deafness etiology, and the type of cochlear implant device.

Participant	Device (L = left ear; R = right ear)	Communication method	Etiology
2528	Nucleus 24 Contour, R	OC, TC	Unknown
2529	Med El C 40+, R	OC	Brachio-oto-renal syndrome
2813	Nucleus Freedom—Contour Advance, R	Unavailable	Unknown
3098	Nucleus Freedom—Contour Advance, R	Unavailable	Unknown
3374	Nucleus Freedom—Contour Advance, R, L	OC	Unknown
2518	Nucleus 24 Contour, R	OC	Connexin 26-DFNB/35delG allele variant/GJB2/DFNB1
2514	Nucleus 24K, L	OC	Connexin 26-DFNB/35delG homozygote/ossification
2535	Nucleus Freedom—Contour Advance, L	OC	Mild Mondini
2540	Nucleus Freedom—Contour Advance, L	OC	Mondini/genetic
2515	Nucleus 24 Contour, L	OC	Auditory neuropathy
2543	Nucleus Freedom—Contour Advance, L	OC	Unknown
2536	HiRes 90K, R	TC	Unknown

Note. OC = oral communication, TC = total communication.

vocalizations and/or noise was more than 600 ms, it was decreased to 600 ms. If the pause between mothers' utterances after removing infant vocalizations and/or noise was between 300 and 600 ms, it was left intact. If an infant vocalization or noise occurred within a mother's utterance, this utterance was removed, and a 300- to 600-ms pause between the preceding and the following utterances was inserted following the algorithm described above.

After removing infant vocalizations and/or noise from all 25-s speech samples, they were amplitude normalized and low-pass filtered (LPF) at 400 Hz (6 dB/octave roll off) using AUDACITY Version 2.02 (Audacity Team). LPF removed all segmental information, rendering speech samples unintelligible while leaving the pitch information intact (see online supplemental materials: Audio Recording CI_3m, Audio Recording NH-AM_3m, and Audio Recording NH-EM_3m).

In total, there were 99 LPF speech samples (HI group = 12 mothers × 3 sessions, NH-AM group = 12 mothers × 3 sessions, NH-EM group = 9 mothers × 3 sessions). Table 3 presents the number of utterances and LPF speech sample durations for each session and group. The differences in the duration of LPF speech samples were due to the inclusion of the whole utterances rather than having to cut off the final utterance at a 25-s LPF speech sample end point. All stimuli were played to 12 adult native American English speakers, volunteers from the IUPUI campus, who confirmed that they were unintelligible.

Table 3. Number of utterances and low-pass filtered speech sample duration in infant-directed speech to infants with hearing impairment and infants with normal hearing, age-matched, and infants with normal hearing, experience-matched.

Session/raters	HI group	NH-AM group	NH-EM group
	Mean number of utterances (*SD*)		
Session 1	16.5 (2.6)	18.4 (3)	18 (2.7)
Session 2	17.4 (2.7)	18.8 (3)	16.7 (3)
Session 3	16.7 (3.4)	17.2 (2.4)	17.6 (3)
	Low-pass filtered speech sample duration (s)		
Session 1	26.5 (1)	25.8 (0.6)	26.8 (0.8)
Session 2	26.2 (0.5)	26 (0.6)	25.8 (0.7)
Session 3	26.6 (1.4)	26.6 (1)	27.1 (1.3)
	Total number of utterances played		
Raters Group 1	198	214	151
Raters Group 2	205	223	164
Raters Group 3	204	216	155

Note. HI = hearing impairment; NH-AM = normal hearing, age-matched; NH-EM = normal hearing, experience-matched.

Rating Procedure

Rating scales. Five rating scales measuring the perception of affective intent in IDS were used (Kitamura & Burnham, 2003). The five scales were (a) positive and negative affect, a measure of the degree of perceived positive or negative affect (e.g., "It's the fish! Oh, we are so excited!" or "Look at these feet, they stink, they stink, they stink."); (b) intention to express affection, a measure of such categories as approval and reward (e.g., "Yay! You did it!"); (c) intention to encourage attention, a measure of vocal quality that engages and maintains attention (e.g., "Look. It's a ball."); (d) intention to comfort or soothe, a measure of maternal vocal quality that serves to soothe and comfort an infant (e.g., "Did you fall down? Here is your milk."); and (e) intention to direct behavior, a measure of mothers' intention to direct infants' attention (e.g., "Put it on your head.").

Procedure. Using PsyScript Version 5.1d3 software (retrieved from http://www.subjectpool.com/psyscript), participants rated the communicative intent/affect in LPF speech along the five rating scales. Raters were presented with written instructions (see Appendix) followed by oral explanation of the experimental procedure and examples of mothers' speech behavior if any of the scales were unclear. They were informed that they would listen to LPF speech samples of IDS. However, raters were not informed that children varied in hearing status. After they heard the first stimulus (after pressing a button on the computer screen), they could either proceed with providing responses on rating scales that appeared on the computer screen or they could listen to the same stimulus the second time by pressing a replay button in the lower right-hand corner of the screen. If a participant chose to press it with a computer mouse, the stimulus was played the second time and the button faded out.

After the stimulus was played for the first time, participants saw three rating scales, positive and negative affect, intention to express affection, and intention to encourage attention, on the first computer screen. After these scales were completed, the next two scales, intention to comfort or soothe and intention to direct behavior, appeared on the second computer screen. Pilot results demonstrated that due to the short duration of each LPF speech sample and the absence of any segmental/semantic information, participants preferred seeing as many scales on one computer screen as possible in order to remember and evaluate speech affect/communicative intent in a given LPF sample.

The first scale, positive and negative affect, was numbered from −4 (*very high negative affect*) to +4 (*very high positive affect*). The other four scales were numbered from 1 (*not at all*) to 5 (*extremely*). All scales were 9-point scales, on which the step size was 1 for positive and negative affect and 0.5 for the other four scales. Each rating scale had instructions and corresponding response boxes next to it. After raters heard an LPF speech stimulus and saw scales with instructions and response boxes next to them, they clicked a response box for a given scale with a computer mouse. Participants could respond only once for each scale.

Each new trial was initiated after the rater provided the response for the last scale on the second screen. Each trial was self-paced with no response time limit. Before the experiment began, there was a practice session consisting of four trials. The structure of the practice session was identical to the actual experiment with responses recorded.

To avoid fatigue and retain all participants, 60 adult raters were randomly assigned to three groups with 20 participants in each group. Each group rated one third of all LPF speech samples, with each participant rating 33 samples (HI = 12 samples, NH-AM = 12 samples, NH-EM = 9 samples). The 33 maternal LPF speech samples for each group were presented once in a random order. This rating procedure resulted in 20 ratings for each LPF speech sample on each rating scale. The averages of the 20 ratings from 60 raters for 99 LPF speech samples were used in the analyses. The rating procedure took about 40–45 min to complete.

Results

Factor Analysis

The five rating scales at each testing session (positive/negative affect, intention to express affection, intention to encourage attention, intention to comfort or soothe, intention to direct behavior) from all groups (HI, NH-AM, NH-EM) were first subjected to factor analysis using SPSS 20 in order to identify factors that could potentially underlie these ratings. Prior to performing factor analysis, the suitability of data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of many coefficients of .3 and above. The Kaiser-Meyer-Oklin value for all three sessions was .7, exceeding the recommended value of .6 (Kaiser, 1970, 1974). Also, Bartlett's (1954) test of sphericity reached statistical significance at $p < .001$, which supports the factorability of the correlation matrix. Factor loadings are presented in Table 4.

For each testing session, factor analysis revealed the presence of two components with eigenvalues exceeding 1 that were labeled Affective and Directive factors. An inspection of the scree plot revealed a clear break after the second component for each of the testing sessions. Using Cattell's (1966) scree test, it was decided to retain two components, affective and directive, for further investigation. The Affective factor explained 50.8% (Session 1), 47.9% (Session 2), and 49.7% (Session 3) of the variance. The directive factor explained 26.2% (Session 1), 27.2% (Session 2), and 26.2% (Session 3) of the variance. To aid in the interpretation of these components, varimax rotation was performed. The rotated solution revealed that the Affective factor showed strong loadings from the positive/negative affect, intention to express affection, and intention to comfort or soothe rating scales, which encompass qualities associated with regulating infant emotions and encouraging social interaction (see Table 4). The Directive factor showed strong loadings from the intention to direct behavior rating scale, which is related to features that gain, maintain, and direct infants' attention (see Table 4). The intention to encourage attention rating scale contributed to both factors but to different degrees: It loaded strongly on the Directive factor and to a lesser degree on the Affective factor (see Table 4).

Latent Factor Linear Mixed Model Analysis

On the basis of the factor analysis that demonstrated two underlying factors (Affective and Directive), a latent factor linear mixed model analysis was conducted (An, Yang, & Bentler, 2013) in order to examine (a) whether the perception of affective and directive qualities of IDS depended on the hearing status of the infant and (b) whether the perception of affective and directive qualities of IDS changed over the period of the three testing sessions in LPF speech in each (HI, NH-AM, NH-EM) group.

In the latent factor linear mixed model, the five rating scales determine two underlying processes that reflect the affective and directive quality of mothers' LPF speech. These two underlying processes are simultaneously modeled as a function of group (HI, NH-AM, NH-EM) and session (Sessions 1, 2, 3).

The differences in the Affective and Directive factors across the three groups at each testing session and across time were estimated based on the model and compared using Wald t tests. Cohen's d effect size was again obtained by dividing the predicted difference by the standard deviation of the factor, both of which were estimated by the model. Figure 1 presents the estimated Affective and Directive factors at the three testing sessions in the HI, NH-AM, and NH-EM groups.

Affective factor. The results demonstrated a significant effect of Group, $F(2, 31) = 4.92$, $p = .01$. T tests showed a significant difference between HI ($M = 1.56$, $SE = 0.1$) and

Table 4. Factor loadings for five scales of communicative intent/affect.

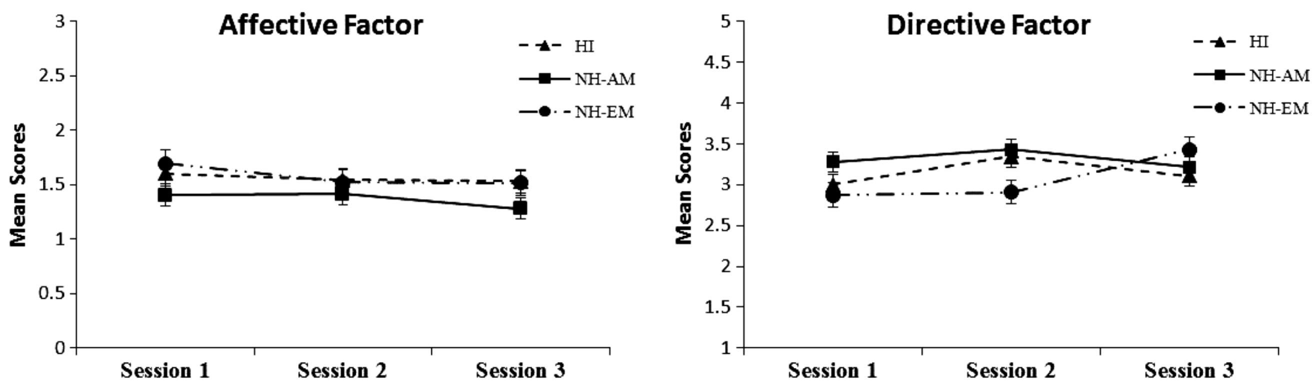
	Affective			Directive		
Scale	**Session 1**	**Session 2**	**Session 3**	**Session 1**	**Session 2**	**Session 3**
Positive/negative affect	0.90	0.86	0.90			
Intention to express affection	0.88	0.89	0.88			
Intention to encourage attention	0.46	0.37	0.46	0.74	0.79	0.74
Intention to comfort and soothe	0.81	0.80	0.81			
Intention to direct behavior				0.89	0.87	0.89

NH-AM groups (M = 1.37, SE = 0.09), t(31) = 2.67, p = .01, d = 1.19; between NH-EM (M = 1.58, SE = 0.11) and NH-AM groups, t(31) = 2.72, p = .01, d = 1.31; but no difference between HI and NH-EM groups (p = .8). These findings suggest that mothers' LPF speech to infants with HI and infants with NH-EM was perceived as more affective compared with speech to infants with NH-AM with no difference between HI and NH-EM groups. There was also a significant effect of Session, F(2, 31) = 6.71, p = .004. Follow-up t tests showed a significant difference between Session 1 (M = 1.57, SE = 0.1) and Session 2 (M = 1.49, SE = 0.09), t(31) = 2.23, p = .033, d = 0.5, and between Session 1 and Session 3 (M = 1.44, SE = 0.09), t(31) = 3.64, p = .001, d = 0.81, indicating that, overall, the affective quality of LPF IDS decreased over the course of three testing sessions. The Group × Session interaction was not significant (p = .18).

Directive factor. The results demonstrated a significant Group × Session interaction, F(4, 31) = 4.74, p = .004, suggesting that the difference in directive quality of LPF IDS among the groups varied across the three testing sessions. As a consequence, the groups were compared at each testing session using F tests and Wald t tests. At the time of the first session, there was no significant difference in the perception of directive quality among the HI (M = 3.01, SE = 0.13), NH-EM (M = 2.87, SE = 0.15), and NH-AM (M = 3.28, SE = 0.13) groups, p = .11. At the time of the second session, there was a significant difference across the three groups, F(2, 31) = 3.94, p = .03. The directive quality was significantly different between the NH-EM (M = 2.91, SE = 0.15) and NH-AM (M = 3.43, SE = 0.13) groups, t(31) = 2.67, p = .01, d = 1.79, and between the NH-EM and HI groups (M = 3.34, SE = 0.13), t(31) = 2.24, p = .03, d = 1.48, but not between the NH-AM and HI groups (p = .62), suggesting that the perception of directive quality of LPF IDS was lower in the NH-EM compared with the NH-AM and HI groups at the second session. At the time of the third session, there was no significant difference between any of the groups (NH-EM [M = 3.43, SE = 0.15], NH-AM [M = 3.21, SE = 0.13], HI [M = 3.11, SE = 0.13]), p = 0.26, suggesting that the perception of directive quality of LPF speech was the same in all three groups.

The session effect was examined using F tests and Wald t tests for each group. For the NH-AM group, there was no significant difference in ratings between any of the sessions (Session 1 [M = 3.28, SE = 0.13], Session 2 [M = 3.43, SE = 0.13], Session 3 [M = 3.21, SE = 0.13]), p = .27. For the HI group, no significant difference in rating between any of the sessions was identified (Session 1 [M = 3, SE = 0.13], Session 2 [M = 3.34, SE = 0.13], Session 3 [M = 3.11, SE = 0.13]), p = .05. For the NH-EM group, the F test demonstrated a significant difference in directive quality across the testing sessions, F(2, 31) = 8.07, p = .002. Additional t tests demonstrated a significant difference between Session 1 (M = 2.87, SE = 0.15) and Session 3 (M = 3.43, SE = 0.15), t(31) = 3.6, p = .001, d = 1.93, and between Session 2 (M = 2.91, SE = 0.15) and Session 3, t(31) = 3.4, p = .002, d = 1.79. Session 1 and Session 2 were not significantly different (p = .81). This suggests that raters' perception of

Figure 1. The estimated mean scores for affective and directive factors at the three testing sessions (Sessions 1, 2, 3) in low-pass filtered infant-directed speech to HI, NH-AM, and NH-EM groups. HI = hearing impairment; NH-AM = normal hearing, age-matched; NH-EM = normal hearing, experience-matched.



directive features of LPF IDS to the NH-EM group increased by the time of the third session.

In summary, the results of the latent factor linear mixed model analysis demonstrated that LPF speech to infants with HI and infants with NH-EM was perceived as more affective compared with speech to infants with NH-AM with no difference between HI and NH-EM groups. The affective quality of the LPF speech also decreased for all groups over the course of three testing sessions. The results also suggested that LPF speech to infants with HI and infants with NH-AM was perceived as more directive compared with speech to infants with NH-EM at the time of the second session. There was also an increase in the perception of directive quality of LPF IDS to infants with NH-EM by the time of the third session.

Discussion

The current study quantified the affective characteristics of LPF IDS to infants with NH and infants with HI who received CIs to understand how infant hearing status affects mothers' vocal expression of affect. The results provided evidence of two independent dimensions in mothers' speech, affective and directive, derived from the five categories of communicative intent in LPF speech to infants. The perception of the affective quality (Affective factor) was found to depend on the amount of infant hearing experience. The perception of the directive quality (Directive factor) depended on the chronological age of an infant.

The results demonstrated that the perception of the Affective factor (the positive/negative affect, intention to express affection, intention to comfort or soothe, and, to some degree, the intention to encourage attention scales) was higher in speech to infants with HI and infants with NH-EM than in speech to infants with NH-AM. We also found a decrease in the perceived affective quality of speech to all infant groups over the course of three testing sessions. However, the perception of features associated with the Directive factor (the intention to direct behavior and intention to encourage attention scales) was higher in LPF speech to infants with HI and infants with NH-AM than to younger infants with NH-EM at the time of the second session. An increase in the perception of directive characteristics of LPF speech to infants with NH-EM was also identified at the time of the third relative to the first or second sessions. Overall, these results suggest that infant hearing status and infant age determine the adjustment of communicative intent in mothers' speech that serves several pragmatic functions, such as the communication of affect and approval and the engagement and maintenance of infants' attention (Fernald, 1989; Katz et al., 1996; Kitamura & Burnham, 2003; Papoušek et al., 1990, 1991; Stern et al., 1982).

Mothers' adjustment of the affective properties of their speech to the amount of hearing experience of infants with HI is in agreement with studies showing that infant hearing status predicts mothers' vocal behavior (Bergeson et al., 2006; Cross, Nienhuys, & Kirkman, 1985; Kondaurova & Bergeson, 2011; Kondaurova et al., 2013; Nienhuys, Cross, & Horsborough, 1984). To be specific, mothers adjust the prosodic characteristics of their speech according to the amount of linguistic experience infants with HI have rather than infants' chronological age (Bergeson et al., 2006; Kondaurova & Bergeson, 2011; Kondaurova et al., 2013). Because the affective properties of speech are transmitted via prosodic cues, it is reasonable to expect that adjustments to the affective intent in IDS would be determined by infant hearing status.

Previous research suggests that the affective properties of IDS play an important role in infants' attention to speech sounds (Singh et al., 2002, 2004; Trainor & Desgardins, 2002). Infants show a preference for speech with positive affect over sad or neutral speech irrespective of whether it is in IDS or adult-directed speech (Singh et al., 2002). In addition, studies examining infants of depressed mothers have demonstrated that general learning mechanisms in infancy depend on the affective salience of mothers' speech (Bettes, 1988; Kaplan, Bachorowski, Smoski, & Hudenko, 2002; Kaplan, Bachorowski, & Zarlengo-Strouse, 1999). As a consequence, it is possible that in the current study mothers were instinctively trying to enhance the perceptual learning of infants with HI by exaggerating the affective characteristics of IDS (Kaplan et al., 2002; Singh et al., 2002; Trainor & Desgardins, 2002).

The decline over time in the ratings of the affective quality of LPF speech to infants is supported by previous results demonstrating a decrease in the perception of the affective component of IDS over time (Kitamura & Burnham, 2003; Stern et al., 1983). Research with the NH population suggested that the general decrease in the affective characteristics of mother's speech is in accord with an increase in its linguistic function that facilitates infants' ability to segment speech stream into linguistically relevant units, such as clauses, phrases, and words (Fernald, 1992; Gleitman, Gleitman, Landau, & Wanner, 1988; Peters, 1983; Seidl, 2007; Soderstrom, 2007).

Research also suggests that the expression of positive affect peaks at 6 and 12 months of age (Kitamura & Burnham, 2003). The peak at 6 months of age serves to promote reciprocity between mother and infant, facilitating socialization and infant development (Kitamura & Burnham, 1998, 2003). By 12 months, when infants begin to master their own language productions (Polka & Werker, 1994; Werker & Tees, 1984) and social–emotional interactions become more mature, an increase in affective quality of IDS offers encouragement, stimulating mother–infant interaction (Kitamura & Burnham, 2003). However, unlike previous findings (Kitamura & Burnham, 2003), the current study demonstrated no increase in the ratings of affective characteristics of LPF IDS from 3- to 6- and 12-month-old infants in the NH-EM group. These results could be explained by the use of a different dialect, Midwest American English, compared with the Australian English examined previously (Kitamura & Burnham, 2003); by a large intersubject variability of mothers' speech; or by the different recording methodology. Future studies with a larger number of mothers would help to understand the longitudinal trends in the perception and function of affective qualities of IDS during the first 2 years of infant development.

Our results also suggested that the perception of the directive quality of LPF IDS was affected by infant chronological age. Thus, the perceptual ratings of the directive quality were higher at the time of the second session in speech to older infants with HI and infants with NH-AM than the younger NH-EM group. In addition, an increase in the perception of directive characteristics by the time of the third sessions was identified in speech to only the infants with NH-EM.

Previous research indicated that the directive quality of IDS might depend on outward signs of infant sociocognitive stage of development (Kitamura & Burnham, 2003; Kitamura & Lam, 2009). By 6 months of age, infants have better motor control and coordination (Peiper, 1963; White, Castle, & Held, 1964), and there are increases in the infant's expressions of interest and joy (Malatesta, Grigoryev, Lamb, Albin, & Culver, 1986). At 9 months, infants begin to treat the mother as a social referent for interpreting discrepancies in the environment (Feinman et al., 1992). The appearance of social referencing converges with other functionally similar behaviors, such as the ability to follow pointing gestures (Murphy & Messer, 1977) and to understand simple instructions (Hubley & Trevarthen, 1979). Because in the current study infants with HI and infants with NH-AM were, on average, 15 months older than the NH-EM group at the time of the first session, it is possible that mothers produced more directive affect in response to the child's socioemotional behavior regardless of his or her hearing status.

However, studies also suggest a reorganization of NH perception and production abilities reflecting the acquisition of a native language structure (Kuhl et al., 2008; Stern et al., 1983) that can affect mother–infant interactions. Thus, a higher incidence of directive utterances in mothers' speech appears around 9–12 months of infant age (Kitamura & Burnham, 2003), which coincides with infant perceptual preferences to utterances with directive affect type (Kitamura & Lam, 2009). An increase in the perception of directive quality in speech to infants with NH-EM identified in the current study supports and extends results of earlier research (Kitamura & Burnham, 2003) but as applied to the communicative intent in IDS.

A model of mother–infant interaction proposed by Kitamura and Lam (2009) suggests that infant feedback modifies mothers' production, although there are forces acting on both the mother and infant that shape the feedback loop. Infants' responses are determined by their level of development, whereas mothers' specific expression of IDS is modified by her cultural and language background (Kitamura & Burnham, 2003; Kitamura et al., 2002). The current study extends the application of this model to interactional behavior in hearing mother–infant with HI dyads, suggesting that infant hearing status (stage of linguistic development) determines the expression of affective properties of IDS, but his or her chronological age (stage of socioemotional, motor, and cognitive development) determines the expression of directive characteristics of IDS. One limitation of the current study is its focus on the unimodal perception of affective intent in IDS. Future research that investigates both vocal and nonvocal behavior of infants with HI and their caregivers is needed to overcome this limitation and provide a more ecologically valid method for assessing variables that contribute to the affective communication in hearing mother–infant with HI dyads.

Overall, the results of the study support the more general proposal that human communication is specifically adapted to allow the transmission of generic knowledge between individuals, a major principle underlying a natural pedagogy theory (Csibra & Gergely, 2009). Thus, the natural pedagogy theory argues that human communication is ostensible: It communicates not only the message but also the fact that the message is being intentionally communicated to the recipient (Sperber & Wilson, 1986). Newborn infants are prepared to be on the receptive side of natural pedagogy because they are sensitive to ostensible signals that indicate that they are being addressed by developing referential expectations in ostensive contexts and by being biased to interpret ostensive-referential communication as conveying information that is child-relevant and generalized (Csibra & Gergely, 2009).

Ostensive signals in human communication are thought to exist in both nonauditory (e.g., a direct gaze toward the addressee) and auditory (e.g., IDS vs. adult-directed speech register) modalities, both of which suggest that a child is being addressed (Csibra & Gergely, 2009). The results of the current study extend the application of the natural pedagogy theory to affective messages transmitted in IDS. Thus, the adaptation of affective quality of IDS to infant hearing status suggests that the mother instinctively enhances the notion that the subsequent action (e.g., the speech act) is intended to be communicative and that the infant is the intended recipient. However, because infants with HI and infants with NH-AM are of the same chronological age with presumably similar levels of development, no enhancement of directive quality of IDS was required because it possibly reflects nonauditory modalities of communication (e.g., the infant's ability to follow a gesture).

Earlier studies with infants with HI and children suggested that infant hearing loss causes more controlling, directive, and less positive maternal behavior that possibly reflects an appropriate adjustment to children's behavioral problems (e.g., noncompliance, inattention) as a result of language delay (Barker et al., 2009; Lederberg & Everhart, 2000; Quittner et al., 2010). However, previous research examined parent–child interactions with children who were either identified with hearing loss at an older age and/or had hearing aids (Goss, 1970; Henggeler & Cooper, 1983; Lam & Kitamura, 2010; Meadow-Orlans, 1997; Pipp-Siegel et al., 1998; Quittner et al., 2010; Spencer & Meadow-Orlans, 1996; Wedell-Monning & Lumley, 1980). It is possible that the less positive and more directive behavior of mothers reported in prior studies emerges later when language delays become more apparent and interfere in parent–child interactions (Lederberg & Mobley, 1990; Meadow-Orlans, 1997). Future research needs to collect more evidence on hearing mother–infant with HI interactions in order to understand mechanisms underlying human communication and learning.

In summary, the results of the current study suggest that the affective component of mothers' speech to infants with NH and infants with HI with CIs includes two independent categories, affective and directive factors, reflecting different functions of IDS (Fernald, 1989, 1992). Although the perception of the affective characteristics of the LPF IDS was influenced by the amount of infant hearing experience, the perception of the directive quality depended on the chronological age of an infant. Previous research has documented that infants with NH show a strong perceptual bias toward speech with positive emotions, which is critical for mother–child socialization and infants' acquisition of language skills (Fernald, 1989, 1992; Fernald & Mazzie, 1991; Papoušek et al., 1990; Singh et al., 2002, 2004; Trainor et al., 2000). Future research needs to pinpoint variables that influence the affective communication in hearing parent–infant with HI dyads and examine the correlation between the affective quality of IDS and language outcome measures of infants with HI to provide the basis for novel clinical interventions to be used by speech-language therapists and parents of infants with HI.

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Appendix

Screen Instructions

You will be asked to rate a large number of speech samples on five rating scales. These scales measure the emotions and intentions mothers convey to their infants. The speech has been filtered, meaning that the intonation contour is left intact but the speech is unintelligible, as though you are listening to someone speaking in the next room. Your ratings of speech samples should be based on qualities expressed in the intonation patterns in the speakers' voice. Try to focus on the implicit message or tone of voice in each speech sample, as the speech samples can convey more than one message.

The five rating scales are: *Positive and Negative Affect, Intention to Express Affection, Intention to Encourage Attention, Intention to Comfort or Sooth* and *Intention to Direct Behavior*. Most of these scales are self explanatory but *Intention to Encourage Attention* is intended to measure vocal qualities that engage and maintain infant attention while *Intention to Direct Behavior* includes directive utterances, e.g. 'look at the doggie' and prohibitive utterances, e.g. 'don't do that.'

You will hear a 25-second speech sample and will be presented with 5 rating scales afterwards. Please press the button (with your mouse) on each scale that corresponds to ratings with your judgment of the speech sample. If you need to listen to the speech sample again, you can press a "Play Speech Sample Again" button in the lower right-hand corner of the computer screen. You will be able to hear each speech sample only twice: once before the rating scales are presented, and then any time after you press the "Replay" button. If you do not want to hear the stimuli a second time, simply do not press the "Replay" button on the computer screen. You will have 4 practice trials. After the practice trials are completed you can start the experiment.