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Exploring Cascading Effects of Multimodal Communication Skills in Infants With Hearing Loss

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Abstract

Infants and toddlers with hearing loss (HL) are at risk for developing communicative delays that can have a substantial lasting effect. Understanding child characteristics that may be targeted in early intervention is essential to maximizing communicative outcomes in children with HL. Among the most malleable predictors of communication skills include maternal responsivity, gestures, and vocalizations. The purpose of this study was to examine the relationship among maternal responsivity, prelinguistic communication skills and expressive vocabulary in children with HL. Based upon the results we propose a theoretical cascading model of communicative outcomes for children with HL such that gesture use may be associated with future vocalizations which may in turn be related to long-term spoken language outcomes. This exploratory model may be supported by the underlying transactional model of bidirectional language development that occurs through maternal sensitivity in the first two years of life. Additionally, parents of children with HL may be less likely to respond to a single mode of communication than to a combination of modes. This exploratory study provides a theoretical framework by which multimodal communication development in infants and toddlers with HL may be better understood, and suggests hypotheses for future research and implications for intervention practice.

Although advances in hearing aid and cochlear implant technology have improved language outcomes for children with hearing loss, they continue to have poorer language skills than their hearing peers (Belzner & Seal, 2009). Compared to hearing children, children with hearing loss produce significantly fewer communicative acts (Nicholas & Geers, 2003), take longer to acquire their first 50 words (Nott, Cowan, Brown, & Wigglesworth, 2009), have lower vocabulary knowledge (Lund, 2016), have difficulty using grammatical structures in writing and spoken language (Inscoe, Odell, Archbold, & Nikolopoulos, 2009; Spencer, Barker, & Tomblin, 2003), have poorer narrative skills (Crosson & Geers, 2000), and fail to achieve age-appropriate reading levels in high school (Geers, Tobey, Moog, & Brenner, 2008). Understanding malleable factors that may be targeted in early intervention is essential to maximizing communication outcomes in children with hearing loss.

Child Characteristics

While children with hearing loss are experiencing greater gains in spoken language than ever before, considerable variability exists (Koehlinger, Van Horne, & Moeller, 2013; Niparko et al., 2010; Tomblin, Oleson, Ambrose, Walker, & Moeller, 2014; Vohr et al., 2008). For example, some children who receive cochlear implants fail to achieve age-appropriate receptive and expressive language skills (Niparko et al., 2010). These persistent language difficulties extend beyond those children with severe to profound hearing loss. Children with mild to severe levels of hearing loss may also experience greater difficulties with language and literacy skills than children with typical hearing (Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007c; Tomblin, Harrison, Ambrose, Oleson, & Moeller, 2015). The majority of studies examining predictors of language outcomes for children with hearing loss have focused on child-level

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factors that are not easily addressed in early intervention. For example, younger age of implantation, more residual hearing, and shorter duration of auditory deprivation are associated with more rapid growth in receptive and expressive spoken language (Niparko et al., 2010). While these factors are important factors related to cochlear implants or hearing aids, these child factors are not easily targeted by early intervention providers.

Considering the skills children use before spoken words may reveal child-level factors that are not only associated with spoken language outcomes, but also may be targeted in early intervention (Vohr et al., 2011). Before children learn to talk, they use prelinguistic communication skills such as gestures and vocalizations to participate in social interactions. Not only are vocalizations and gestures associated with spoken language skills in hearing children but they are also potentially malleable (Wu & Gros-Louis, 2016).

Gestures

Gestures are an important part of early communication for infants. Waving, reaching, and pointing are a primary means of interacting with others. All children, regardless of hearing level, use gestures to communicate before they are able to say words (Iverson & Goldin-Meadow, 2005). In fact, deaf children, who are not exposed to a spoken or visual language, point at the same number of objects as hearing children (Feldman, Goldin-Meadow, & Gleitman, 1978).

Early gesture use is particularly important because it predicts spoken language skills in hearing infants (Rowe & Goldin-Meadow, 2009). Gestures may have a cascading effect on language learning in several ways. Gestures allow children to communicate during a period in which they are unable to communicate using speech. Furthermore, gestures used by the child may elicit more responses from communication partners and this increased parental linguistic input may subsequently result in increased child language skills (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007).

Despite the strong relationship between gesture use and later language skills in hearing infants, it is unclear how prelinguistic gesture use is related to spoken language skills in children with hearing loss. To date, only four studies have directly examined the relationship between gesture use and spoken language skills in children with hearing loss (Ambrose, 2016; Dromi, 2003; Vohr et al., 2011; Zaidman-Zait & Dromi, 2007). All studies with exception of Vohr and colleagues (2011) failed to find a relationship between gesture use and spoken language skills. These conflicting findings may be the result of how gesture use was measured. For example, Vohr et al. (2011) used a categorical measure of gesture use (i.e., above and below the 10% percentile on a parent report of symbolic gestures), while in the other three studies, gesture use included all gestures types and was treated as a continuous variable. It is important to note that only one study included an observational measure of gesture use (Ambrose, 2016). Furthermore, in all four studies, gesture use and spoken language skills were measured concurrently. Given that gesture use often precedes spoken language development, these findings are not surprising.

Vocalizations

Vocalizations are an important precursor to spoken language for all children regardless of hearing ability (Moeller et al., 2007a). In hearing infants, infant vocal development progresses from crying (reflexive), to cooing (non-distress vocalizations), to babbling, and then finally to words. This progression is largely influenced by the infant's articulatory control (Stark, 1978) and by parental social shaping (Gros-Louis, West, & King, 2014).

For children with hearing loss, lack of access to sound disrupts vocal development by altering the quality and quantity of vocalizations. Infants and toddlers with hearing loss have a smaller variety of consonants (Stoel-Gammon & Otomo, 1986) and produce consonant–vowel syllables at a later age than hearing infants (Oller & Eilers, 1988). Amount of hearing loss is also associated with canonical syllable use and vocalization types (von Hapsburg & Davis, 2006).

While the quality of vocalizations depends on auditory-perceptual skills, the effect of hearing loss on vocalization quantity is less clear. Several studies report that infants with hearing loss vocalize as frequently as hearing infants (Iyer & Oller, 2008; Koester, Brooks, & Karkowski, 1998; Moeller et al., 2007a; Nathani, Oller, & Neal, 2007). However, methodological limitations such as varying degrees of hearing loss and variations in the sampling of vocalizations hinder our understanding as to the extent to which hearing loss influences the amount of vocalizations. Recent research comparing vocalizations of infants before and after receiving a cochlear implant suggests that auditory feedback is critical to frequency of vocalizations (Fagan, 2014). Nine-month-old infants with profound hearing loss vocalized less frequently than hearing infants, but these differences did not maintain following cochlear implantation, suggesting that auditory access is critical to infant vocalizations (Fagan, 2014). Furthermore, infants with hearing loss use fewer adult-directed vocalizations than hearing infants (Moeller et al., 2007b). These new findings suggest that auditory feedback may play an important role in frequency of vocalizations. However, the relative contribution of caregiver response to vocalizations in infants with hearing loss remains unknown.

Dyadic Influences

As early as the first few weeks of life, parents and infants develop nuanced patterns of interaction. These early social experiences provide the foundation for the context in which children learn language. Two broad classes of parent behaviors (sensitivity and stimulation) are related to language development for hearing children and children with hearing loss (Szagun & Stumper, 2012; Vallotton, Mastergeorge, Foster, Decker, & Ayoub, 2016). These behaviors are not mutually exclusive and there is often overlap in sensitivity and stimulation as parents who are sensitive also tend to be more stimulating (Holden & Miller, 1999).

Sensitivity

Sensitivity refers to temporally contingent behaviors in response to a child's affective, gestural, or vocal cues (Shin, Park, Ryu, & Seomun, 2008). There is strong evidence that sensitivity has indirect and direct effects on language development. Maternal sensitivity is related to the amount and quality of coordinated joint attention interactions in which hearing children learn new words (Farrant & Zubrick, 2012; Tomasello & Farrar, 1986). Furthermore, maternal responsiveness to child vocalizations at 13 months predicts the timing of spoken language milestones, such acquisition of first 50 words (Tamis-LeMonda, Bornstein, & Baumwell, 2001). This strong relationship between sensitivity and word learning is present across toddlerhood. Two-year-olds learn new words in the context of contingent responses but not in non-contingent responses (Roseberry, Hirsh-Pasek, & Golinkoff, 2014). Even

3-year-old learn words more easily when they are related to their interests (Kucirkova, Messer, Sheehy, & Flewitt, 2013). While sensitivity is likely to support early word learning during the first three years of life, there is increasing evidence suggesting that its effect may decrease after 12 months (Vallotton et al., 2016).

Stimulation

Similar to sensitivity, stimulation also has a positive effect for spoken language skills in children with hearing loss. For example, number of word types used by caregivers and their utterance lengths are positively associated with child language skills (DesJardin & Eisenberg, 2007). In addition, expansions and recasts have a significant impact on language development in children with hearing loss (Cruz, Quittner, Marker, & DesJardin, 2013). As children's skills for imitation and social referencing improve, children are better able to learn new words from stimulating contexts that extend beyond their own focus of attention (Vallotton et al., 2016). Unlike sensitivity in which the focus is on the child, stimulation includes behaviors designed to promote a child's language or cognitive development independent of the child's focus of attention. The seminal work of Hart and Risley (1995) illustrates the importance of language stimulation for children. Enriched home environments in which parents use more words and use complex referential language are positively related to language development during and beyond early childhood (Farah et al., 2008; Weizman & Snow, 2001). As toddlers grow, it becomes easier for them to take advantage of this extended discourse to expand their own vocabulary (Vallotton et al., 2016). Taken together, these findings suggest that both sensitivity and stimulation support language development yet the relative effects may vary by developmental level (Landry, Smith, Swank, & Guttentag, 2008).

Mismatch

When infants are born with hearing loss, they experience reduced access to parental input for two reasons. First, hearing loss limits their amount of access to spoken language (stimulation). Second, the hearing status mismatch between the parent and the infant may result in communication difficulties within the parent–child dyad (sensitivity). These communication difficulties may arise from difficulty tailoring interactions to meet the infant's learning strategies. While parents attempt to adapt to their infant's communication needs, they are limited by their own communicative experiences. For example, a parent who learned language primarily through auditory information, may use fewer non-auditory (visual, tactile) communicative strategies (Loots, 2003), while a Deaf parent is more likely to use visual attention strategies than hearing parents (Waxman & Spencer, 1997). Perhaps to compensate for this mismatch, hearing parents are more directive (i.e., directing the child to do something) (Ambrose, Walker, Unflat-Berry, Oleson, & Moeller, 2015; Fagan, Bergeson, & Morris, 2014; Vaccari & Marschark, 1997). This increased directive behavior may result in reduced engagement in sustained interactions between children with hearing loss and their hearing parents (Gale & Schick, 2009; Lederberg & Mobley, 1990). Given that 95% of children with hearing loss have at least one hearing parent (Albertini, 2010), providing strategies to overcome the mismatch is essential to maximizing long-term spoken language outcomes for children with hearing loss.

Despite this mismatch, maternal sensitivity and stimulation are positively associated with language development in children with hearing loss (Ambrose et al., 2015; Niparko et al., 2010; Pressman, Pipp-Siegel, Yoshinaga-Itano, & Deas, 1999). Not only does maternal sensitivity at the time of cochlear implantation have a positive effect on spoken language 4 years afterward, but the magnitude of these effects are similar to those found for age at implantation (Quittner et al., 2013). This striking finding indicates that maternal sensitivity should be a critical target of early intervention.

Purpose of the Present Study

Given the variability in language outcomes in children with hearing loss, it is essential to understand child and parent factors that are associated with increased language skills in children with hearing loss. To date, no study has examined the relationship among multimodal prelinguistic communication skills and maternal sensitivity/stimulation on spoken vocabulary in infants and toddlers with hearing loss. Specifically, the following research questions guided the current study:

1. Are multimodal prelinguistic communication skills (gestures, vocalizations) associated with later spoken words in infants and toddlers with hearing loss?
2. What is the relationship among early communication skills in children with hearing loss (gestures, vocalizations, early words) and maternal supports (sensitivity, stimulation) concurrently and over 6-months of development?
3. Does maternal sensitivity vary by communication mode (single mode vs. multimodal)? And does relative responsiveness to communication mode differ for children with and without hearing loss?

Methods

Participants

Infants and toddlers (6–18 months) with hearing loss and their mothers were recruited to participate in this longitudinal observational study through medical centers and pediatrician offices in the mid- and southwest regions of the United States. Population estimates for these regions include 40–55% representation from under-represented races (Black, American Indian, or Asian) and Hispanic ethnicity according to the 2010 United States Census (U.S. Census Bureau, 2010). Sixteen mother–child dyads participated in the current study (Table 1), and all children were diagnosed with a bilateral congenital hearing loss (Table 2). Degree of hearing loss for children with hearing loss was extracted from the child's audiology medical record. Not all children are represented at each time point due to missing data or late study entry. The majority of child participants were male, 25% from minority groups, and at entry into the study were on average 10 months old (SD = 4 months). All mothers had normal hearing and no dyads used sign language as the primary mode of communication. Participants were observed over 4 time points at 6-month intervals. The timing of the observations varied by participant and, as such, children were grouped according to 6-month age bands as illustrated in Table 1. In addition, an 18-month-old age-matched sample of hearing infants was also included. Hearings status was confirmed by parent report of a passed newborn hearing test or recent hearing test. Hearing children were only observed on one occasion. Participant numbers and demographic data are presented by age group in Table 1.

Measures

During each time point, parents and children participated in home assessments. Assessments were conducted by a master's level deaf educator or speech-language pathologist or were completed by the

Table 1 Demographics

Mean (SD) [range]	Hearing loss	Typical hearing
N		
Full sample	16	16
By age group	12	16
0;6	15	
1;0	14	
1;6	15	
2;0		
Chronological age in months		
Full sample	17.63 (3.36)	17.5 (3.27)
By age group	8.91 [6–11]	
0;6	14.51 [12–17]	
1;0	19.86 [18–23]	
1;6	27.65 [24–30]	
2;0		
Gender	44% female	50% female
Race	25% minority	25% minority
Average family income	99,860 (66,966) [28,000–300,000]	98,154 (49,749) [40,000–600,000]
Developmental quotient: (Mullen, 1997)		
Full sample	53.75 (13.29)	49.50 (8.94)
By age group	56.42 (17.54)	
0;6	47.07 (14.68)	
1;0	52.21 (11.59)	
1;6	49.07 (11.97)	
2;0		
Communication (CSBS)		
Full sample	14.62 (4.58)	14.96 (2.47)

Note. Developmental Quotient measured by the Mullen Scales of Early Learning (MSEL) with a mean of 50 SD = 10. []= range, ()=standard deviation.

Table 2 Participants with hearing loss characteristics by age group

	6 months $n = 12$	12 months $n = 15$	18 months $n = 14$	24 months $n = 15$
Number of participants with				
Bilateral hearing aids	11 [92%]	12 [80%]	9 [64%]	11 [73%]
One cochlear implant and one hearing aid	1 [8%]	1 [7%]	1 [7%]	1 [7%]
Bilateral cochlear implants	0 [0%]	2 [13%]	4 [29%]	3 [20%]
Degree of hearing loss in better ear				
Mild (25–40 dB HL)	2 [17%]	2 [13%]	3 [21%]	3 [20%]
Moderate (41–70 dB HL)	4 [33%]	6 [40%]	6 [43%]	7 [47%]
Severe (71–90 dB HL)	4 [33%]	4 [27%]	3 [21%]	1 [7%]
Profound (91+ dB HL)	2 [17%]	3 [20%]	2 [14%]	4 [27%]
Early intervention hours per month M (SD)	7.00 (4.96)	7.69 (4.47)	11.54 (4.63)	11.60 (6.72)

Note. Early intervention hours include speech therapy, special education services, deaf education, and parent training.

mother and returned by mail. Reliability and fidelity of administration were completed for 20% of observational measures, balanced across time points. Fidelity was measured by an observer watching a video of the assessment and completing a fidelity checklist to ensure all items were presented in a similar manner. Fidelity averaged 95% [range = 81–100%].

Gesture use

Gesture diversity and use were measured using the behavior sample from the Communication and Symbolic Behavior Scale which was administered in each participants' home (CSBS, Wetherby & Prizant, 2003). This was selected to allow for a measure of diversity and fluency and provided the greatest variability and stability due to the direct observation. The weighted raw score for total number of gestures (including pointing, showing, and giving) was used as the measure of gesture use. Raw scores on the CSBS gesture scale can range from 0 to 22. Raw scores were used to retain maximum variability, and standard scores were unnecessary due to the constraint on age. Two independent raters achieved point-by-point agreement on scoring the CSBS for greater than 80% of occurrences prior to the start of the study. They both independently rated 20% of CSBS sessions during the study and average point-by-point reliability exceeded 90%.

Child vocalizations

The child's vocalizations were captured using naturalistic daylong recordings using the Language ENvironment Analysis (LENA™, Ford, Baer, Xu, Yapanel, & Gray, 2008). Children wore audio recorders for an average of 14 hr a day in their natural environment. A total of 157,986 utterances were captured in the 75 recordings used in this study. The processing software segments recordings into identified key child, other child, adult female, and adult male utterances. Then the software removes vegetative sounds and cries, and reports total child vocalizations. Due to the varying length of recordings, a total rate of vocalizations per hour was calculated. The LENA™ pro software automated child vocalization variable has been found to be 76% reliable with human transcription (Ford et al., 2008).

Spoken words

Parents reported the total number words said by their child using the MacArthur-Bates Communication Development Inventories: Words and Gestures (MCDI, Fenson et al., 2007). The MCDI was chosen because it is a valid measure of expressive vocabulary for children with hearing loss (Thal, DesJardin, & Eisenberg, 2007). Total number of words said is highly correlated with expressive scores on the Reynell Developmental Language Scales (ρ = .84) (Thal et al., 2007). Number of words (out of 376 words) was used to estimate the child's vocabulary size at each time point.

Maternal stimulation and sensitivity

Maternal sensitivity and stimulation was measured during a standardized play-based interaction. Mothers were observed interacting with their child in the clinic with a standard set of toys for 20 min at each time point. Mothers were instructed to play as they usually would. The interactions were transcribed, coded, and analyzed using the Systematic Analysis of Language Transcripts (SALT; Miller & Chapman, 1985) software. Maternal stimulation was estimated from the number of different words used by the adult and was summarized using the SALT analysis package. Reliability on word-level agreement within transcripts exceed 90%. Maternal sensitivity included all spoken parent communication that was temporally and topically contingent. Temporal responsiveness included statements that occurred within 3 s of any child communication (eye contact, gesture, vocalization, or word). Parent responses were topically responsive if they were related to the child's focus of attention. Maternal sensitivity was measured as the percentage of child communicative acts to which the mother responded within 3 s with a response that was related to the child's focus of attention. Examples include labeling a ball to which a child is pointing, expanding a child's communication, or reciprocating a greeting. Non-examples include asking the child if she wants a car when she points to the ball, giving a direction, or labeling an item the parent is holding when the child is playing with something different. Reliability in scoring was rated for 20% of the observations, and point-by-point agreement averaged 84% [range = 79–94%].

Sequential associations

Sequential associations between child communicative behaviors and parent responsiveness were rated and analyzed using the Mangold InterAct software (Mangold, 2015). Child communicative acts were coded as: a single mode (gesture, vocalization, or spoken word alone) or multimodal (a combination of gesture and vocalization or gesture and spoken word). The CSBS definitions of each of these behaviors were used. Parent verbal utterances that occurred within 3 s of a child communicative act and met the definition for temporal and topical contingency, were used to compute the sequential association. The sequential associations were calculated by considering the contingency table of all possible combinations first for single mode child acts and then multimodal child acts: a child communicative act followed by a responsive adult verbal utterance (A), or not (B), and something other than a child communicative act followed by a responsive adult verbal utterance (C), or not (D). Thus, the exhaustive sequential association accounts for all possible combinations of conversational behaviors: $\frac{A}{A+B} - \frac{C}{C+D}$. In addition, the sequential associations were compared between population groups using an odds ratio to estimate the difference between populations in the probability of a parent responding to a single mode or multimodal communicative act.

Design

To answer the first research question, this study used a cross-lagged correlational design (Moyle, Weismer, Evans & Lindstrom, 2007) to examine the relationship among prelinguistic communication skills and spoken words. All correlational analyses used a Pearson correlation computed using the Hmisc package in R-studio running R version 3.3.2 (Harrell & Dupont, 2016; R Core Team, 2014; R Studio, 2012). To answer the second research question, this study used cross-lagged correlations to examine the relationship among maternal sensitivity (topic and temporal contingency) and multimodal communication skills (gestures, vocalizations, spoken words). To answer the third research question, within- and between-subjects *t*-tests were used to compare parent sensitivity to different child communicative acts of toddlers with hearing loss and typical hearing.

Results

Preliminary Analysis

The means, standard deviations, and ranges for each communication mode and maternal behavior observed in the children with hearing loss are presented in Table 3. Words and vocalizations increased on average over time, but gestures plateaued after an increase over the first 18 months. Maternal stimulation and sensitivity showed an inverse pattern such that when maternal stimulation was highest (6 and 24 months) maternal sensitivity was lowest. All concurrent and cross-lag correlations are presented in Table 4.

Gestures and Vocalizations

Across age-points, child use of gestures and vocalizations were not significantly correlated when measured concurrently. However, in early communicative development, the cross-lag correlations between gestures were significantly related to vocalization use at the next developmental stage. Gestures at 6-months were significantly associated with vocalizations at 12-months ($r = .64$, $p = .03$) and similarly gestures at 12-months were associated with vocalizations at 18-months ($r = .68$, $p = .01$) but this pattern did not remain at 24 months. Conversely, the cross-lag correlations of vocalizations were not significantly related to gesture use at the next stage of development across age-points. Gestures at 12 months were concurrently significantly related to word use ($r = .52$, $p = .04$). All other associations between gestures and word use were non-significant. These results suggest that for children with hearing loss, prelinguistic gestures use during infancy may be positively associated with later vocalizations and spoken vocabulary in toddlerhood.

Vocalizations and spoken words

Vocalizations and spoken words had a strong bidirectional relationship across development. Vocalizations and words

Table 3 Summary of multimodal measures across time for children with hearing loss

Mean (SD) [range]	6 months, $n = 12$	12 months, $n = 15$	18 months, $n = 14$	24 months, $n = 15$
Maternal sensitivity				
Responsiveness	53.17% (19.19) [19–80%]	58.00% (18.00) [19–86%]	64.00% (21.00) [29–98%]	53.00% (22.00) [12–86%]
Maternal stimulation				
Number of different words	121.33 (39.77) [41–176]	100.57 (33.92) [36–152]	114.57 (43.73) [46–209]	121.38 (37.79) [43–169]
Gesture				
CSBS behavior sample	3.25 (4.20) [0–11]	8.27 (5.26) [0–16]	9.14 (4.90) [2–18]	7.00 (5.04) [0–16]
LENA™ vocalizations	122.41 (56.87) [65–255]	98.98 (36.48) [49–186]	154.37 (65.40) [63–274]	214.62 (122.58) [34–428]
MCDI: words produced	2.00 (5.41) [0–19]	5.20 (9.48) [0–30]	70.14 (73.70) [1–221]	196.60 (192.94) [0–603]

Table 4 Cross-lag and concurrent correlations

	6-months					12-months					18-months					24-months				
	Gestures	Vocs	Words	Sensitivity	Stimulation	Gestures	Vocs	Words	Sensitivity	Stimulation	Gestures	Vocs	Words	Sensitivity	Stimulation	Gestures	Vocs	Words	Sensitivity	Stimulation
6-months																				
Gestures	1																			
Vocalizations	0.01	1																		
Words	0.28	−0.21	1																	
Sensitivity	0.64*	0.01	0.49	1																
Stimulation	−0.11	−0.52	0.32	−0.00	1															
12-months																				
Gestures	0.25	−0.04	0.51	0.75**	0.13	1														
Vocalizations	0.64*	0.11	0.84**	0.58	0.03	0.43	1													
Words	0.57	0.26	0.98**	0.52	−0.02	0.52*	0.81**	1												
Sensitivity	0.18	−0.03	−0.03	−0.35	0.14	−0.30	0.25	0.04	1											
Stimulation	0.75**	−0.20	0.06	0.41	−0.06	0.14	0.38	0.14	0.50	1										
18-months																				
Gestures						0.30	0.02	−0.10	0.08	0.41	1									
Vocalizations						0.68**	0.57*	0.69**	−0.12	0.57*	0.43	1								
Words						0.49	0.67*	0.68**	0.00	0.64*	0.23	0.77**	1							
Sensitivity						0.09	0.68*	0.48	0.73**	0.65*	0.22	0.35	0.44	1						
Stimulation						0.57*	0.72**	0.76**	0.26	0.70**	0.28	0.65*	0.51	0.68**	1					
24-months																				
Gestures											−0.15	−0.04	−0.28	−0.53	−0.48	1				
Vocalizations											0.40	0.88**	0.55	0.50	0.66*	−0.08	1			
Words											0.11	0.80**	0.92**	0.57	0.70*	−0.24	0.67**	1		
Sensitivity											0.54	0.30	0.30	0.58*	0.57	−0.20	0.52*	0.48	1	
Stimulation											0.40	0.24	0.26	0.50	0.31	0.48	0.09	0.13	0.37	1

Note. Vocs = Vocalizations.
*p <.05, **p < .01.

were significantly correlated concurrently at each age-point except during infant development (6 months, $r = -.21$, $p = .49$). Vocalizations had strong cross-lag correlations with spoken words at 18 and 24 months ($r = .67$, $.80$; $p = .01$, $.001$), but in early development these associations were not observed.

Sensitivity and Child Communication

Maternal sensitivity was associated with gesture use concurrently at 6-months ($r = .64$, $p = .02$), but was unrelated to all other concurrently measured child variables over development until 24-months where sensitivity was concurrently related to vocalizations ($r = .52$, $p = .01$, $p = .04$). The cross-lag associations indicate that, maternal sensitivity at 6-months was strongly related to gesture use at 12-months ($r = .75$, $p = .01$) but this relationship did not maintain in later cross-lag associations. Child vocalizations at 12-months were associated with later parent sensitivity at 18 months ($r = .68$, $p = .01$), and in turn, sensitivity at 18-months had a strong but non-significant relationship with vocalizations at words at 24 months ($r = .50$, $p = .052$) providing some evidence towards a transactional model of language learning. It should be noted that parent sensitivity was not correlated with stimulation at each concurrent and cross-lag comparison except at 18 months where they were significantly correlated ($r = .68$, $p = .01$).

Stimulation and Child Communication

Maternal stimulation was not concurrently related with any child variables except child vocalizations at 18 months ($r = .65$, $p = .01$). Maternal stimulation at 6-months was not associated with any child variables. Maternal stimulation at 12-months was associated with vocalizations and word use at 18-months ($r = .57$, $.64$; $p = .02$, $.01$). This pattern remained between 18 and 24 months ($r = .66$, $.70$; $p = .02$, $.01$). Child use of gestures at 6-months and child use of each mode of communication at 12 months was significantly related to maternal stimulation at the next age-point, providing some preliminary support for a transactional model of language in which maternal sensitivity results in changes in child communication which in turn results in stimulation that sustains language learning.

Maternal Sensitivity by Communication Mode

Table 5 presents the probabilities of maternal response to single and multimodal communicative acts from the child across children with and without hearing loss. Parents of children with hearing loss had a meaningful ($d = -0.61$) but non-significantly lower probability of responding to single-mode communicative acts than parents of children without hearing loss ($t = -1.69$, $p = .10$). Yet, parents of children with and without hearing loss responded similarly to multimodal communicative acts. Within the group of mothers of children with hearing loss, mothers were 1.5 times more likely to respond to multimodal utterances than single modal utterances ($d = 0.70$), although this relationship was large it did not reach statistical significance ($t = 1.99$, $p = .06$). This relationship was different for mothers of hearing children, who were equally likely to respond (OR = 1.1, $d = 0.51$) to single and multimodal communicative acts ($t = 1.45$, $p = .14$).

Discussion

Communication is a complex, multifaceted system that involves vocal and non-vocal (gestures) behaviors that function within a social environment that involves communication partners. This preliminary study examined the child and parent factors that influence a child's complex communication system. Though small, this was the first study to explore this relationship longitudinally for children with hearing loss. Three findings emerge from this study that help to build a theoretical model of the cascading effects of communication and a transactional model within the mother–child dyad. First, prelinguistic communication skills in infants with hearing loss were associated with spoken vocabulary in toddlerhood. Second, maternal sensitivity was associated with gesture use, child gesture use with maternal stimulation, and consequently maternal stimulation was associated with child spoken words. This suggests that an underlying cascading model of language learning may exist such that early communicative behaviors used by a child may elicit more responses from communication partners and this increased input may subsequently result in better long-term child language outcomes. Third, overall rates of maternal sensitivity did not significantly differ between mothers of infants with hearing loss and mothers of hearing infants. Mothers of infants with hearing loss were more likely to respond to multimodal child communicative acts than single, isolated child communicative acts, and this relationship was not present for mothers of hearing infants. These findings provide preliminary support for the importance of prelinguistic skills and maternal responsivity for spoken vocabulary development in children with hearing loss.

The results of these findings may have several clinical implications. Gestures and vocalizations may be important targets for early intervention for two reasons. First, preintentional communicative behavior (such as vegetative sounds or non-intentional vocalizations) may facilitate the transition from prelinguistic to linguistic stages of communicative development (Paavola, Kunnari, Moilanen, & Lehtihalmes, 2005). Vocalizations serve as the initial manner in which infants elicit responses from their parents. Child vocalizations at 18 months were associated with spoken vocabulary at 24 months. Like vocalizations, gestures

Table 5 Maternal sensitivity by communication mode and hearing loss status

Probability of adult response to	Mean (SD) Hearing loss	Mean (SD) Typical	*t* (*p*) Difference	*d* Effect size
Between groups				
Single	0.46 (0.26)	0.60 (0.19)	−1.69 (0.10)	−0.61
Multimodal	0.66 (0.37)	0.71 (0.27)	−0.41 (0.68)	−0.15
Within groups				
Hearing loss: single vs. multi			−1.99 (0.06)	−0.70
Typical: single vs. multi			−1.45 (0.17)	−0.51

play a critical role in spoken word development. While results of the current study and previous cross-sectional findings indicate that gesture use is not associated with spoken vocabulary when measured concurrently (Ambrose, 2016; Dromi, 2003; Zaidman-Zait & Dromi, 2007), gesture use at 12 months was related to child vocalizations at 18 months. These results are similar to findings in hearing children (Iverson & Goldin-Meadow, 2005). Taken together, these findings suggest that these prelinguistic skills may play an important role in later spoken vocabulary skills. As such, teaching parents to model gestures may facilitate the entry into spoken language skills in children with hearing loss. When parents are taught to use symbolic gestures, children learn to use the gesture before the word (Goodwyn & Acredolo, 1993), and this increased gesture use supports later spoken language development (Goodwyn, Acredolo, & Brown, 2000).

Second, in addition to the potential facilitative effects of gesture use and vocalizations on spoken language skills, gestures and vocalizations may be more readily taught. While spoken word development depends on access to an auditory model of words, vocalizations and gestures may be taught via a social shaping mechanism (Gros-Louis et al., 2014). This social shaping mechanism (i.e., caregivers respond to and interpret gestures and vocalizations as communicative; Carpendale & Carpendale, 2010) may be applied to both gestures and vocalizations. The social shaping mechanism is illustrated by the fact that hearing infants with more responsive caregivers direct more vocalizations at their caregivers, such that when caregivers alter their response rates, infants also change their vocalizations (Miller, 2014). Furthermore, infants who learn the social effects of vocalizations have larger spoken vocabularies (Goldstein, Schwade, & Bornstein, 2009). As such, parents can teach their children the social effects of vocalizations by responding contingently to these vocalizations. In turn, this may impact their ability to eventually develop spoken words.

However, the effects of maternal responsiveness may not be immediate. The results of the current study and previous work have suggested a sleeper effect of maternal sensitivity, such that maternal sensitivity does not concurrently predict language skills but predicts future language skills (Pressman et al., 1999). As such, while maternal sensitivity may not have an immediate effect, the long-term effects of a responsive caregiver appear to be strong.

Given the transactional model of language development (Sameroff & MacKenzie, 2003) in which parents and children have bidirectional influences on one another, it is also important to consider how child communicative acts may influence maternal sensitivity. Results of this study illustrate the bidirectional nature of mother–child interactions. These results also indicate that mothers of children with hearing loss are more likely to respond to a multimodal communicative act than a single act (gesture alone, vocalization only, word alone). As such, teaching multimodal early communication skills may have a cascading effect on language outcomes for children with hearing loss. By teaching children prelinguistic skills (gestures and vocalizations), their parents may be more likely to respond to these communicative acts, which in turn may result in greater spoken language skills.

Parents are a child's first communication partner. Regardless of hearing status, gestures and vocalizations may be an important precursor to spoken language skills. Teaching parents to respond to all modes of communication may have a cascading effect on spoken language. While maternal sensitivity appears to have an earlier association with prelinguistic skills, maternal stimulation appears to be related to spoken vocabulary skills at a later age. These results are similar to findings from hearing children and children with hearing loss, in which maternal sensitivity was a stronger predictor of language during the first two years of life (Ambrose et al., 2015; Vallotton et al., 2016). Taken together, these findings suggest that it may be beneficial to teach parents to recognize and respond to all types of communicative acts.

Limitations

There are several limitations that should be considered when interpreting these results. First, the sample size is relatively small and as such the age span for each group is large. Given this small sample size, it was not possible to control for other variables such as SES or degree of hearing loss in the analyses. Additionally, missing data are present at each age point which limits our interpretation of the outcomes. Having a small sample increases the likelihood of a type 2 error, or accepting the null hypothesis when a true effect exists.

Second, this analysis is correlational, and therefore the directionality of each relationship cannot be determined. It remains true that additional variables could exist that may be driving these patterns over time. For example, maternal sensitivity may be reduced when intelligibility is low in children with hearing loss, resulting in an alternative explanation for the differential responding to single and multimodal communicative acts. Although this study provides some evidence of cascading effects over time, it may be that another underlying model may explain these findings. Future studies which specifically manipulate these variables should be conducted to better understand these relationships and test this theoretical model. However, this correlational analysis is a first step in understanding underlying mechanisms of language learning across development in this population. These analyses may generate new and important hypotheses about the importance of prelinguistic skills in infants and toddlers with hearing loss.

Future Directions

While results of the current study are an important first step in understanding child and parent factors associated with multimodal communication outcomes, additional analyses may reveal different patterns and relationships. As such, a replication of these results with a larger sample is necessary. In addition, manipulation and observation of parent behaviors is necessary to understanding the direction of the association among parent and child factors. Furthermore, a more fine-grained analysis of type of child vocalizations and gestures may provide more information as to the relationship among different prelinguistic modes of communication and long-term spoken vocabulary development. For example, more sophisticated consonant–vowel combinations or object-directed vocalizations may have a different relationship with spoken language skills than it does in hearing children. Similarly, object-directed gestures or number of symbolic gestures may also impact spoken language. The extent to which caregivers differentially respond to these different types of vocalizations and gestures should also be considered. Additionally, this work has potential to impact early intervention practices. Future intervention research should focus on the effectiveness of interventions that target improving maternal sensitivity and teaching gestures and vocalizations. Although gestures are avoided in many intervention approaches for children with hearing loss (Kaipa & Danser, 2016), this current study suggests that this may not be necessary, as gestures may be facilitative of spoken language development. Further intervention research targeting parental gesture use is needed.

Summary

The findings from this study suggest that prelinguistic behaviors (gestures, vocalizations) may play a key role in facilitating language learning in young children with hearing loss. Additionally, these behaviors are influenced by early maternal sensitivity and may provide a feedback loop for parent responsivity that may ultimately maximize spoken word learning. However, because parents of children with hearing loss are less likely to respond to a single mode as compared to multimodal communication, future intervention research should consider facilitating sensitivity to all communicative modes (baby sign, cued speech, American Sign Language in children with hearing loss).

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Conflicts of Interest

No conflicts of interest were reported.

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