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The Effect of Hearing Loss on the Perception of Infant- and Adult-Directed Speech

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Purpose: Infant-directed speech (IDS) facilitates language learning in infants with normal hearing, compared to adult-directed speech (ADS). It is well established that infants with normal hearing prefer to listen to IDS over ADS. The purpose of this study was to determine whether infants with hearing impairment (HI), like their NH peers, show a listening preference for IDS over ADS.
Method: A total of 36 infants—9 HI infants (mean chronological age of 19.1 with mean listening age of 7.7 months), 9 NH infants with similar average listening age (7.8 months), and 9 NH infants with similar average chronological age (18.6 months)—were tested on their listening preference for IDS compared with ADS using the central fixation preference procedure.
Results: Infants with HI significantly preferred listening to IDS over ADS. The preference for IDS was also seen in the younger NH infants, but not older NH controls. Additionally, HI infants showed shorter overall looking times as compared to either NH group.
Conclusion: Although infants with hearing loss displayed a shorter looking time to speech compared to NH controls, HI infants nonetheless appear to have sufficient access to the speech signal to display a developmentally appropriate preference for IDS over ADS.

Key Words: audiology, infants, speech perception, hearing loss

Infant-directed speech (IDS) is thought to play an important role in infant language acquisition. IDS reveals higher mean fundamental frequency (F_0), wider and more varied F_0 range, frequent utterance repetitions, shorter utterances, slower tempo, longer durations, increased variability in amplitude, and an enlarged vowel space (Cooper & Aslin, 1990; Fernald & Simon, 1984; Kuhl et al., 1997; McRoberts & Best, 1997; Stern, Spieker, Barnett, & MacKain, 1983). The exaggerated nature of IDS is thought to capture infant attention, regulate arousal, communicate emotion, and facilitate language learning (Garnica, 1977; Kemler Nelson, Hirsh-Pasek, Jusczyk, & Cassidy, 1989; Thiessen, Hill, & Saffran, 2005). In addition, typically developing infants show a preference for listening to IDS compared to adult-directed speech (ADS; Cooper & Aslin, 1990; Fernald, 1985; Pegg, Werker, & McLeod, 1992; Werker & McLeod, 1989).

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Initial studies of infant attention to IDS focused on understanding the characteristics of IDS that capture infant attention. For example, Fernald and Kuhl (1987) examined the effect of F_0, intensity, and temporal patterns on infant preference for IDS compared to ADS. Infants had a significant preference for the IDS that had F_0 contours with higher mean F_0 and larger F_0 range than the ADS. Additionally, Werker and McLeod (1989) examined infant preference for IDS over ADS as spoken by male and female talkers. Their results showed that infant listening preference for IDS extends to male voices, indicating that the exaggerated pitch modulation in the speaker's F_0 range may be more salient than mean F_0. Singh, Morgan, and Best (2002) further revealed that preferences for IDS may be primarily driven by its characteristic positive affect. Thus, these initial landmark studies on infant listening preference to IDS over ADS have found that infants from the neonate period to 6 months of age typically show listening preferences for IDS over ADS. The question of whether older infants also prefer to listen to IDS has received less attention in the literature, and results have been contradictory. Preference for IDS over ADS has been demonstrated in infants as old as 18 and 21 months (Glenn & Cunningham, 1983; Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011); however, other studies have failed to find preferences for IDS in infants as young as 7 to 13 months (Hayashi, Tamekawa, & Kiritani, 2001; Newman

& Hussain, 2006). Varying reports of IDS preference at different ages likely depends on the characteristics of the particular IDS stimuli used across different studies. Although speech directed at both younger and older infants is typically lumped together, IDS changes considerably over the second year of life. For example, F_0 variability and pause durations are greater in speech directed to newborns and 4-month-olds than in speech directed at 12- and 24-month-olds (Stern et al., 1983). Thus, age and stimulus characteristics appear to jointly affect preferences for IDS in a rather complex way (e.g., Hayashi et al., 2001; McRoberts, McDonough, & Lakusta, 2009).

More recently, studies have started to show how IDS may play a role in early language acquisition. Specifically, it has been shown that infants benefit from IDS during phonetic category learning (Werker, Pons, Dietrich, Kajikawa, Fais, & Amano, 2007), speech segmentation (Thiessen et al., 2005), and word learning (Graf Estes, 2008; Ma et al., 2011) through increasing infants' access to the distributional characteristics inherent in the speech signal. For example, Thiessen et al. (2005) found that IDS facilitates word segmentation from fluent speech in infants. In their study, one group of infants listened to nonsense sentences spoken in ADS, and a second group listened to the same nonsense sentences spoken in IDS. The only cue to word boundaries in either speech condition was the statistical structure of the speech. Their results showed that infants who were familiarized with the IDS were able to discriminate words from syllable sequences that spanned word boundaries. However, infants in the ADS condition listened to words and part-words for equal amounts of time, suggesting that they had not segmented the words from the fluent speech. Thiessen and colleagues (2005) suggested that IDS facilitates speech segmentation by providing infants with easier access to the statistical cues that define word boundaries.

Thus, interest in and sensitivity to IDS may be helpful to multiple developmental processes during the first years of life. Although it has been demonstrated that typically developing infants have access to IDS, much less is known about whether infants with congenital hearing loss have access to this important information, and whether they develop similar listening preferences for IDS. The early auditory experience of infants with hearing loss is significantly different from that of infants with normal hearing and, thus, infants born with hearing impairment may not have the same type of access to IDS as typically developing infants. First, access to IDS depends on the infant being able to hear the IDS. Consequently, depending on the nature and degree of hearing loss, infants may not be able to hear the difference between ADS and IDS. Second, the developmental time period at which infants with hearing loss may access IDS may differ from that of typically developing infants and may depend on age of identification and intervention. As a result, infants with hearing impairment may not be able to benefit from IDS as much as typically developing infants. Finally, the type of device worn (cochlear implant or hearing aid) may affect access to IDS differentially. In general, there is relatively little research on the early perceptual preferences for IDS over ADS in infants with hearing loss who wear hearing aids or cochlear implants (CIs).

Bergeson, Miller, and McCune (2006) demonstrated that, like mothers of typically developing infants, mothers of infants with hearing loss use IDS when speaking with their children. In their study, they recorded and acoustically analyzed the speech that mothers produce when speaking to their children. Participants included one group of mothers with children who use CIs (age range = 10–37 months) and two groups of mothers with normal hearing children, one that was matched to the hearing experience of the CI group and one that was matched to the chronological age of the CI group. Results showed that mothers seemed to adjust their speech style to the children with CIs according to the hearing experience of the infant rather than to the chronological age of the infant. Thus, measures of mean F_0, pitch range, and duration of utterances produced by mothers of the children with CIs more closely matched the measures obtained for the mothers of the younger, experience-matched control infants with normal hearing. This study is important as it shows that mothers of infants with hearing loss are intuitively adjusting their language style to the perceived language level of the child. The question of whether infants with hearing loss can access the IDS and subsequently benefit from it is therefore an important one.

Recently, Segal and Kishon-Rabin (2011) investigated listening preferences for IDS versus white noise and IDS versus time-reversed speech in infants with normal hearing and infants with profound hearing loss who use CIs (age range = 14–33 months). Results from their study showed that children with CIs preferred listening to IDS over both white noise and time-reversed speech. Thus, they concluded that the CI device allows children to develop similar listening preferences to infants with normal hearing, although listening preference for IDS over ADS was not tested.

In another study, Kishon-Rabin, Harel, Hildesheimer, and Segal (2010) examined the listening preferences of infants with hearing impairment for Hebrew versus English IDS, two languages that differ in their rhythmic patterns, with Hebrew having a predominantly weak-strong (iambic) stress pattern (Bat-El, 1993) and English having a predominantly strong-weak (trochaic) stress pattern (Cutler & Carter, 1987). The goal of the study was to determine whether infants who use CIs are able to develop a listening preference to IDS in their native language as compared to IDS of a nonnative language. Results showed that both infants with normal hearing ($n = 19$) and infants who use a CI ($n = 9$) preferred listening to their native language (Hebrew) over the nonnative language (English). The authors suggested that the CI must provide infants with sufficient access to the auditory signal to differentiate the iambic stress pattern of Hebrew from the trochaic stress pattern of English, even when both sets of stimuli are produced in an infant-directed register. One problem with this study was that the researchers could not say unequivocally that the infants were using the rhythmic unit, as the phonemic detail of the stimuli also varied across the two languages. Thus, infants may have been responding to the phonemic differences between the two languages and simply demonstrated a

preference for listening to the familiar phonetic detail of their native language.

The research on listening preferences for IDS in infants and children with hearing loss has been limited to exploring listening preferences for IDS versus nonspeech and IDS across languages that differ in syllable stress and phonetic pattern. These studies examined listening preferences for broad categories of signals (speech to nonspeech, and native versus nonnative language). The goal of the present study was to expand upon previous research to determine whether infants with hearing loss develop a bias for listening to IDS over ADS in their native language. ADS is a speech type that is ecologically relevant in infant language acquisition, as ADS comprises a large portion of overheard speech (Akhtar, 2005; Akhtar, Jipson, & Callanan, 2001; Floor & Akhtar, 2006; Oshima-Takane, 1988). In addition, because parents of infants with hearing loss tailor their production of IDS to their infant's hearing age, rather than to the infant's chronological age (Bergeson et al., 2006), older infants with hearing loss are receiving a greater proportion of IDS than their chronologically matched peers with normal hearing. Thus, it is important to determine how hearing status and age affect preferences for IDS versus ADS.

The Current Study

Currently, there is a paucity of research on the effect of hearing loss on the perceptual bias for IDS. Studies have not specifically targeted preferences for IDS versus ADS. The goal of this study was to investigate how early congenital hearing loss affects the perception of IDS and ADS by infants with hearing aids and CIs. The first research question addressed whether infants with hearing loss prefer IDS over ADS, like their peers with normal hearing. It was expected that infants with hearing loss would prefer IDS over ADS, showing a similar pattern to typically developing infants. If infants show a preference for IDS over ADS it suggests that amplification devices provide sufficient access to the speech signal to allow the perceptual biases important for language learning to emerge. If infants with HI prefer ADS over IDS or show no preference between IDS and ADS, then this suggests either an effect of hearing loss or amplification on the emergence of perceptual biases for IDS. The second question addressed by the present study was whether infants with hearing loss display listening preferences comparable to infants with normal hearing who have a similar listening experience or to those with similar chronological age. It was expected that infants with hearing loss would display preferences that are consistent with their hearing experience (hearing age) rather than their chronological age, mirroring patterns of maternal input (Bergeson et al., 2006).

Method

Participants

Infants with normal hearing and infants with impaired hearing participated in this study. All infants came from monolingual, English-speaking families. The group of infants with hearing impairment (HI) consisted of nine infants (2 girls, 7 boys) with sensorineural hearing loss and a mean chronological age of 19.1 months (range = 8.9–32.2 months). Data from seven additional infants with HI were excluded from the analysis because of poor head control (one infant), not paying attention (one infant), hearing age less than 3 months (one infant), insufficient aided audibility (i.e., Speech Intelligibility Index below 20%; two infants), or hearing or chronological age too old for the study (two infants). In addition, three infants with HI were too fussy to complete the study on their first visit and returned 1 week later to complete the study, at which point they successfully completed the study. This research received approval from the University of Tennessee's Health Science Center's Institutional Review Board. Infants with HI were recruited from the University of Tennessee's Child Hearing Services Clinic, through contacts with private otolaryngologists and audiologists, and through advertisements placed in local and regional association newsletters. All participants were screened, via parent report, for severe cognitive and motor delays prior to inclusion in the study. The criteria for participation in the HI group included: (a) confirmed bilateral sensorineural hearing impairment, (b) use of hearing aids or CIs for at least 5 months, and (c) no severe motor or cognitive delays. All children had parents with normal hearing and were participating in aural/oral early intervention programs with minimal use of sign language. Hearing loss was identified during the first year of life (range = 1–12 months; mean age = 5.4 months, SD = 4.3). The average age of amplification or CI activation was 11.2 months (range = 2–19 months; SD = 6.6). The average amount of experience with the hearing aid or CI device (i.e., hearing age) was 7.7 months (range = 5.1–13.1 months; SD = 2.8). *Hearing age* is a term used to denote amount of auditory experience after device fitting. It does not mean that prior to device use, the infant had no hearing. Unless infants have profound hearing loss, they will have some access to sound prior to device use. Infants with mild hearing loss, for example, have more access to speech sounds than do those infants with more severe hearing loss, and thus the hearing age approximation for them is likely underestimated. However, there is no clear method established in the literature to determine actual hearing age for infants with hearing loss. Thus, hearing age was calculated from the day that the infants received amplification or from the day of implant activation, depending on the device they were using at the time of testing. The demographic information for the infants with hearing loss is provided in Table 1. The infants in Table 1 are arranged by device worn. In brief, five infants (mean chronological age = 13.0 months) had mild-to-severe sensorineural hearing loss and wore binaural hearing aids. Four infants had severe-to-profound hearing loss (mean chronological age = 26.8 months) and used CI devices. For the infants using hearing aids, the average age of identification, age of device fitting, and hearing age (amount of listening experience with the device) was 3.8, 6.4, and 6.4 months, respectively. The infants who used CI devices had an average age of identification, age of CI activation, and amount of experience with the device of 7.5, 17.3, and 9.4 months, respectively. Thus, the infants who

Table 1. Demographic characteristics of infants with hearing loss.

Participant	Gender	CA (mos.)	Age of ID (mos.)	Age at device fitting (HA/CI)	Hearing age (months)	Degree of HL (right ear)	Degree of HL (left ear)	Device
H8	M	15.0	5	7	7.3	Mod–sev	Mod–sev	HA
H9	M	12.4	3	7	5.1	Mod–sev	Mod–sev	HA
H12	F	8.9	1	2	6.9	Mod–sev to prof	Prof	HA
H14	M	11.4	1	4	7.1	Mild–mod	Mild–mod	HA
H16	M	17.3	9	12	5.5	Normal–mod	Normal–mod	HA
M (SD)		**13.0 (3.2)**	**3.8 (3.3)**	**6.4 (3.7)**	**6.4 (1.0)**			
H3*	M	30.7	5	19	11.5	Prof	Prof	CI (bilateral)
H6*	F	32.2	11	19	13.1	Prof	Prof	CI (right)
H11*	M	20.9	2	13	7.8	Prof	Prof	CI (right)
H15*	M	23.3	12	18	5.3	Sev–prof	Sev–prof	CI (right), HA (left)
M (SD)		**26.8 (5.5)**	**7.5 (4.8)**	**17.3 (2.9)**	**9.4 (3.5)**			
Overall Group *M (SD)*		19.1 (8.3)	5.4 (4.3)	11.2 (6.6)	7.7 (2.8)			

Note. Asterisk (*) denotes infant who uses cochlear implant(s) (CIs). CA = chronological age; HA = hearing aid; CI = cochlear implant; HL = hearing loss; mod = moderate; sev = severe; prof = profound; HF = high frequency.

used hearing aid devices were identified much earlier than the CI children, and they received their amplification devices at a much younger age compared to the CI users. However, the CI users had approximately 3 months more listening experience with their device. Infants using hearing aids had a real-ear–to–coupler measurement done prior to testing to confirm audibility of signal, and they had a hearing aid check to determine normal hearing aid function prior to testing.

The Infant Toddler Meaningful Auditory Integration Scale (IT-MAIS; Zimmerman-Phillips, Robbins, & Osberger, 2001) was administered on the day of participation. The IT-MAIS is a parent interview that evaluates the child's spontaneous response to sound in the everyday environment. This outcome measure is used clinically to track the development of auditory skills in relation to changes in audibility, such as prior to and after implantation, and is sensitive to the auditory development of the infant (Bagatto, Moodie, Seewald, Bartlett, & Scollie, 2011; McConkey Robbins, Burton Koch, Osberger, Zimmerman-Phillips, & Kishon-Rabin, 2004). It is used routinely in early intervention programs, and it has been used in the previous studies of IDS preference in children with hearing impairment (Kishon-Rabin et al., 2010; Segal & Kishon-Rabin, 2011). The mean IT-MAIS score was 65.9 (SD = 19.3) for infants with hearing impairment (see Table 2). According to the normative data provided by the IT-MAIS, this mean score is consistent with a normal-hearing age equivalence of approximately 9 months (Kishon-Rabin, Taitelbaum, Elichai, Maimon, Debyiat, & Chazan, 2001).

In order to ensure that our NH controls reflected both the approximate hearing ages and chronological ages of the infants with HI, we tested a wide age range of NH controls (range = 5.3–25.3 months). Our sample was then divided into two groups, based on chronological age. There were nine infants in the younger group who ranged in age from 5.3 months to 9.3 months (mean = 7.8, SD = 1.2), thus approximating the hearing age range of infants with HI (mean = 7.7). There were nine infants in the older group who ranged in age from 15.0 to 25.3 months (mean = 18.6, SD = 3.5) and thus had a mean chronological age similar to the chronological age of the infants with HI (mean = 19.1). Although the mean ages of the groups match, it should be noted that the age ranges of the HI group have much higher variability than either of the NH control groups. This high variability in the ages of the HI group may obscure age effects within the HI group. Data from four additional participants with normal hearing were excluded due to fussiness (two infants) and being highly distracted (two infants).

Infants with normal hearing were recruited through the University of Tennessee's Child Development Research Group database and from local day care centers. They were all born full-term, had fewer than four prior ear infections, and had no history of hearing or vision impairments. In addition, on the day of testing, infants with normal hearing passed a hearing screening using distortion product otoacoustic emissions (DPOAEs) and had normal middle-ear function established through tympanometry. The mean IT-MAIS score was 74.7 (SD = 16.3) for the younger group and 92.3 (SD = 11.1) for the older group. These results are shown in Table 2. According to the normative data provided by the IT-MAIS, the younger and older infants had mean auditory function equivalencies of 10 months and 19 months, respectively.

Procedure

Speech stimuli. Two children's short stories (Eastman, 1960; Yolen, 2000) were read by a female talker and were recorded at a sampling rate of 44.1 kHz using a Sennheiser e-845s microphone and Maranz PMD 670 Professional Digital recorder. The scripts for the stories can be found in the Appendix. The female talker was a trained speech-language

Table 2. Demographic characteristics, IT-MAIS scores, and looking times for the three groups of infants.

Participant	Gender	Age at test (mos.)	Hearing age (mos.)	IT-MAIS (%)	Looking time (sec)	
					IDS	ADS
			HI group			
H8	M	15.0	7.3	73	7.15	4.80
H9	M	12.4	5.1	38	5.87	7.48
H12	F	8.9	6.9	55	6.70	6.57
H14	M	11.4	7.1	78	8.83	5.10
H16	M	17.3	5.5	68	6.20	3.73
H3*	M	30.7	11.5	100	15.32	7.55
H6*	F	32.2	13.1	78	6.75	6.28
H11*	M	20.9	7.8	43	6.03	4.90
H15*	M	23.3	5.3	60	6.70	2.52
M (SD)		**19.1 (8.3)**	**7.7 (2.8)**	**65.9 (19.3)**	**7.73 (2.98)**	**5.44 (1.69)**
			Younger NH control group			
C34	M	5.3	—	61	5.78	3.98
C9	F	7.1	—	64	14.78	10.82
C22	M	7.4	—	89	6.55	5.13
C17	F	7.6	—	53	21.92	19.38
C19	M	7.6	—	64	8.32	9.20
C20	M	8.3	—	100	11.45	10.80
C36	M	8.5	—	75	5.72	7.27
C23	F	9.1	—	94	11.70	7.05
C27	M	9.3	—	72	18.82	13.85
M (SD)		**7.8 (1.2)**		**74.7 (16.3)**	**11.67 (5.85)**	**9.72 (4.75)**
			Older NH control group			
C14	M	15.0	—	67	7.18	6.89
C8	M	16.3	—	100	9.97	18.05
C24	F	16.5	—	100	7.75	9.38
C25	F	16.5	—	100	10.62	4.40
C28	F	16.9	—	92	8.50	9.42
C11	F	17.9	—	92	4.87	6.48
C13	M	19.5	—	83	17.18	10.68
C1	M	23.1	—	100	22.52	18.62
C2	F	25.3	—	97	17.17	19.52
M (SD)		**18.6 (3.5)**		**92.3 (11.1)**	**11.75 (5.85)**	**11.49 (5.75)**

Note. Asterisk (*) denotes infant who uses CI(s). mos. = months; sec = seconds; IT-MAIS = Infant Toddler Meaningful Auditory Integration Scale; ADS = adult-directed speech; IDS = infant-directed speech; HI = hearing impaired; NH = normal hearing.

pathologist who worked with children with hearing loss. Each story was read once in IDS and once in ADS; however, there were no infants, children, or other adults present in the room when the scripts were recorded. A total of four scripts (two IDS and two ADS) were used for this study. As is typical of IDS (Cooper & Aslin, 1990; Fernald & Simon, 1984; Stern et al., 1983), the IDS scripts were longer in duration ($M = 54.9$ s) than the ADS scripts ($M = 35.4$ s). However, only the first 30 s of each script was used in the behavioral testing. The first 30 s of each script was acoustically analyzed for pitch, duration, and intensity using Praat (Boersma & Weenink, 1996). Pitch analysis revealed that there was greater overall variability in F_0 and higher average F_0 in the IDS than in the ADS (for specific script analysis, see Table 3). These values are consistent with values presented in previous research (Fernald, 1993; Garnica, 1977; Jacobson, Boersman, Fields, & Olson, 1983). All scripts were adjusted in Adobe Audition to have the same average root-mean-square power and were presented at 60 dB SPL.

To ensure that the IDS and ADS were perceptually distinct, 10 graduate students in speech-language pathology at the University of Tennessee participated in a rating experiment in which they were presented with the four test scripts, as well as two filler scripts (one IDS and one ADS), in two randomized blocks. On each trial, participants indicated whether the speech was infant- or adult-directed. All of the

Table 3. Acoustic analysis for the stimuli used in the experiment.

Variable	Script 1 (Hz)		Script 2 (Hz)	
	ADS	IDS	ADS	IDS
Mean F_0	194	294	196	326
F_0 range	100–541	100–627	100–574	103–629
SD	37.23	101.46	37.42	110.08

Note. Total duration for ADS and IDS in both Script 1 and Script 2 was 30.0 seconds. F_0 = fundamental frequency.

listeners categorized 100% of the speech types correctly, suggesting that, perceptually, the ADS differed from IDS stimuli.

Experiment procedure. We assessed infants' listening preference for IDS versus ADS using an infant-controlled central fixation preference procedure (Cooper & Aslin, 1990; Houston, Pisoni, Kirk, Ying, & Miyamoto, 2003). Infants were seated on a parent's lap in a double-walled sound-attenuated booth, approximately 1 meter from a 23-inch flat-screen monitor. The stimuli were presented using Habit X 1.0 (Cohen, Atkinson, & Chaput, 2004). An observer who sat outside of the booth viewed infants' responses on a monitor and indicated looking times by pressing a button on the computer running Habit. To avoid potential bias, the observer was blind to the identity of the materials being presented, and the parent listened to masking music over headphones.

In order to direct infant attention to the center monitor, each trial began with an attention-getting visual display of a pinwheel, accompanied by music. Once the infant fixated on the center screen, a button press by the experimenter extinguished the attention-getter and started the presentation of the experimental stimuli (ADS or IDS script), which was coupled with an unrelated visual display. The trial continued while the infant looked at the center monitor and terminated when the infant looked away for 2 s or when a maximum trial length of 30 s was reached. Each of the four scripts (two ADS and two IDS) was presented three times, randomized within block, for a total of 12 test trials. Infants' looking times to the test stimuli were recorded, using Habit, by the same Mac computer that controlled the stimulus presentation.

Results

A two-way repeated-measures analysis of variance (ANOVA) with hearing status (NH and HI) as the between-subjects factor and speech type (IDS and ADS) as the within-subjects factor revealed a significant main effect of speech type, $F(1, 25) = 5.99$, $p = .022$, reflecting an overall preference for listening to IDS versus ADS. Consistent with previous research (Kishon-Rabin et al., 2010; Segal & Kishon-Rabin, 2011), there was also a significant main effect of hearing status, $F(1, 25) = 6.57$, $p = .02$; HI infants showed shorter mean looking times overall (6.58 s, $SD = 2.0$) compared to the NH infants (11.16 s, $SD = 5.12$). There was not a significant Speech Type × Hearing Status interaction, $F < 1$, $p = .40$.

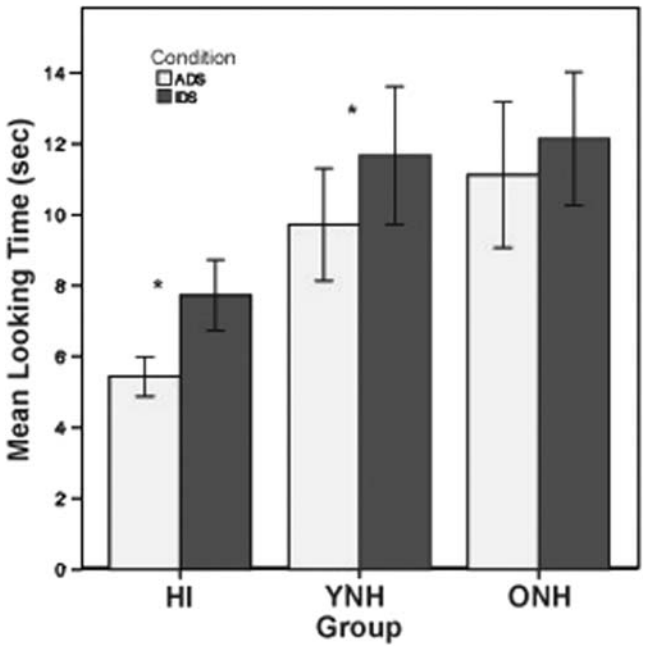
To directly compare the performance of the HI infants with the younger NH controls with similar mean listening experience, we performed a repeated-measures ANOVA with speech type (ADS and IDS) as the within-subjects factor and group (HI and younger NH) as the between-subjects factor. Again, there was a significant main effect for speech type, $F(1, 16) = 12.54$, $p = .003$, suggesting that in general, looking times for IDS (9.7 s, $SD = 4.94$) are greater than looking times for ADS (7.58 s, $SD = 4.10$). The Speech Type × Group interaction was not significant, $F < 1$, $p = .78$, reflecting a similar trend of decreased looking time for ADS relative to IDS for both groups, as expected. In addition, the test of between-subjects effects was significant, $F(1, 16) = 4.92$, $p = .04$, suggesting that there is a difference in mean looking times across the two groups.

Next, in order to compare the performance of HI infants with that of the older NH controls who have similar mean chronological age, we performed a repeated-measures ANOVA with speech type (ADS and IDS) as the within-subjects factor and group (HI and older NH) as the between-subjects factor. The main effect of speech type was nonsignificant, $F(1, 16) = 2.01$, $p = .18$, suggesting that, in general, looking times for IDS (9.74 s, $SD = 4.96$) are not different from those of ADS (8.46 s, $SD = 5.16$). The Speech Type × Group interaction was not significant, $F(1, 16) = 1.28$, $p = .28$. In addition, the test of between-subjects effects was significant, $F(1, 16) = 7.09$, $p = .02$, suggesting that there is a difference in mean looking times across groups, with the older NH infants looking significantly longer overall than the HI infants.

We were specifically interested in whether infants with hearing loss listened longer to IDS than to ADS, thus, we ran a paired-samples t test of mean looking times for IDS and ADS for each group. The t test revealed that, on average, the HI group looked significantly longer while listening to IDS ($M = 7.7$ s, $SD = 2.98$) than to ADS ($M = 5.4$ s, SD = 1.69), $t(8) = 2.50$, $p = .04$. Eight out of the nine infants with hearing loss preferred listening to IDS. Similarly, a paired-samples t test comparing the IDS and ADS looking times of younger infants with normal hearing showed that they looked significantly longer, $t(8) = 2.52$, $p = .04$, when listening to IDS ($M = 11.7$ s, $SD = 5.85$) than when listening to ADS ($M = 9.7$ s, $SD = 4.75$). Seven out of the nine younger infants with normal hearing preferred listening to IDS. Finally, the older infants with normal hearing did not show a significant difference in preference for IDS (11.75 s, $SD = 5.85$) over ADS (11.49 s, $SD = 5.75$), $t(8) = 0.168$, $p = .87$. Four out of the nine older infants with normal hearing preferred listening to IDS. Figure 1 shows the mean looking time for IDS and ADS for the three groups.

Relationship between IDS preference and IT-MAIS. We were interested in determining whether there was a correlation among IDS preference, listening experience, and IT-MAIS scores. For this analysis, IDS preference was calculated by subtracting each infant's average looking time to ADS from their average looking time to IDS. Positive numbers indicate a preference for IDS. In order to explore potential relationships between listening experience and other predictors, we collapsed the data for the two groups of infants with normal hearing into one data set so that the age range of 5–25 months could be analyzed as a whole. For NH infants, the chronological age was used as a measure of listening experience, whereas for infants with hearing impairment, hearing age was used as a measure of listening experience. This is consistent with how Segal and Kishon-Rabin (2011) analyzed their data. The relationship between IDS preference and listening experience, examined using a Pearson correlation, was not significant for either NH infants ($r = –.16$,

Figure 1. The mean looking times to adult-directed speech (ADS) and infant-directed speech (IDS) for three groups of infants: hearing impaired (HI), younger normal hearing (YNH), and older normal hearing (ONH). The dark bars depict looking times for IDS, and the light gray bars depict ADS looking times. Error bars indicate ±1 standard error. Asterisk (*) denotes statistical significance of $p < .05$.



$p = .54$) or infants with hearing impairment ($r = .28$, $p = .47$). The lack of relationship between listening experience and IDS preference may simply reflect the high variability typically associated with IDS preference data.

The relationship between preference for IDS and IT-MAIS was investigated next. For infants with hearing impairment, there was a strong significant correlation ($r = .78$, $p = .01$) between IT-MAIS and IDS preference (see Figure 2). For NH infants, the correlation was not significant ($r = –.21$, $p = .41$).

The Pearson correlation between the IT-MAIS and listening experience was significant for infants with NH ($r = .61$, $p = .01$), as expected. In addition, the correlation between listening experience and the IT-MAIS approached significance for infants with hearing impairment ($r = .63$, $p = .07$; see Figure 3).

Finally, we wanted to determine if listening experience and IT-MAIS scores were significant predictor variables of IDS preference. A linear regression analysis was performed with IDS preference as the dependent variable and IT-MAIS and listening experience as predictors. For infants with hearing impairment, the regression model was significant ($p = .01$) and the adjusted R^2 was .75. The only predictor that contributed significantly to the model was the IT-MAIS. The regression model was not significant for infants with NH ($p = .69$).

Discussion

Recent studies of IDS preference in infants with hearing loss have shown that infants with hearing loss who use CIs prefer IDS over nonspeech signals (Segal & Kishon-Rabin, 2011), and IDS of their native language over that of a nonnative language (Kishon-Rabin et al., 2010). Those studies do not directly compare listening preferences for IDS relative to ADS. The present study extends these findings by examining listening preference for IDS in relation to ADS, a contrast that is ecologically valid in the daily language environments of infants. The primary goal of this study was to determine whether infants with hearing loss who use hearing aids or CIs prefer listening to IDS over ADS like their peers with normal hearing. Due to the exaggerated nature of IDS, and the results of previous literature on HI infants' listening preferences for broad categories of signals (IDS vs. nonspeech, and native vs. nonnative language produced in IDS), we hypothesized that infants with hearing loss may show a preference for IDS over ADS. Indeed, the results of the present study showed that infants with hearing loss look longer when listening to IDS than to ADS. Our results suggest that infants with hearing loss who use CIs or hearing aids are provided with sufficient information by their devices to detect the differences between IDS and ADS and to show a preference for IDS.

Figure 2. The relationship between preference for IDS and IT-MAIS score for infants with hearing impairment (HI) and normal hearing (NH). The dotted line depicts the regression slope for infants with NH (filled triangles). The solid line depicts the regression slope for HI infants (open circles).

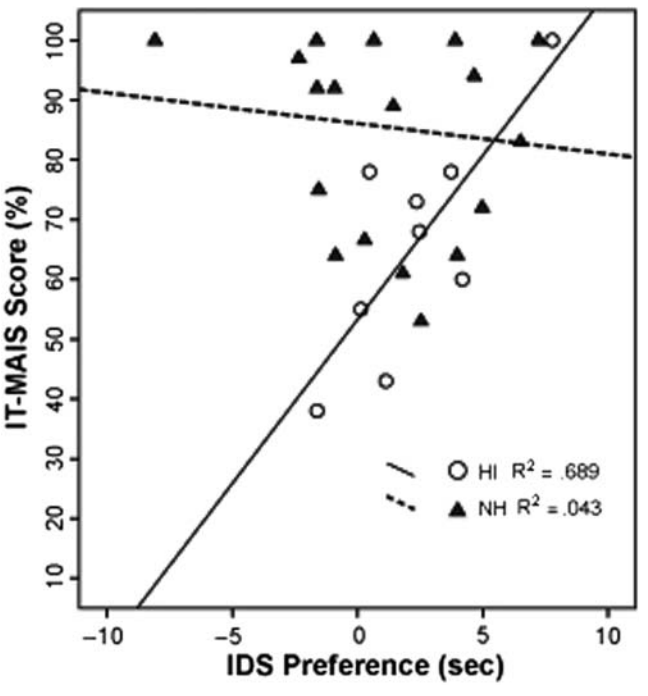
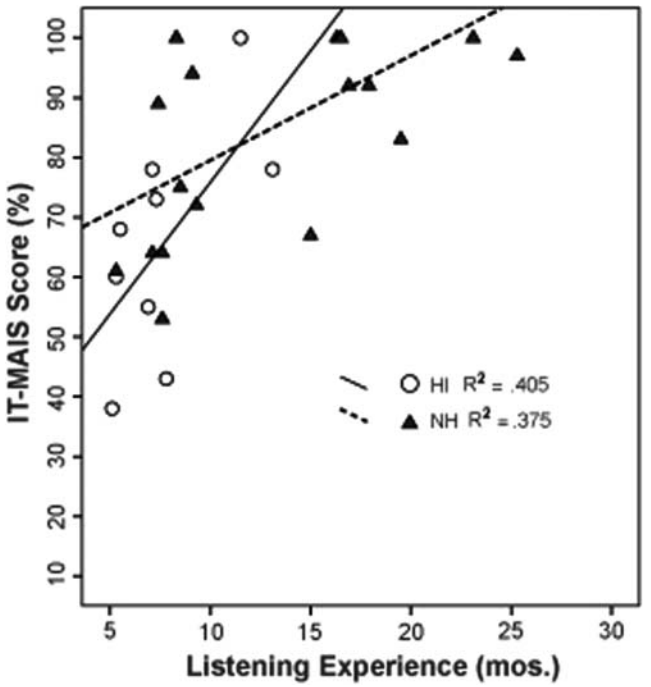


Figure 3. The relationship between listening experience and IT-MAIS scores for HI and NH infants. The dotted line shows the regression slope for infants with NH (filled triangles). The solid line shows the regression slope for infants with HI (open circles).



The question of whether infants with hearing loss show a bias toward IDS is important because it is thought that IDS may facilitate language acquisition by drawing infants' attention to speech (Soderstrom, 2007), thus acting as a perceptual enhancer. As infants get older, IDS continues to play a role in facilitating language acquisition. For example, IDS has been shown to facilitate word learning in 21-month-olds but then begins to diminish between 22 and 27 months of age (e.g., Ma et al., 2011). Taken together, the previous studies show that the perceptual enhancement provided by IDS allows infants to hone in on speech input at multiple levels of analysis. The present study suggests that infants with hearing loss who are appropriately fit with hearing aids or CIs are benefiting from their device sufficiently to show a bias for IDS over ADS. If infants with hearing loss show a bias for IDS, then, theoretically, they may also have access to the acoustic cues relevant to numerous dimensions of early language acquisition, and specifically those cues that are enhanced in IDS. Future studies should confirm that perceptual preference for IDS in infants with hearing loss is, in fact, linked to facilitated language acquisition.

A secondary goal of this study was to determine whether the HI infants' IDS preference was more similar to the younger NH control group, or whether their patterns were more similar to the chronologically older group. We predicted that infants with hearing loss would display preferences that are consistent with their hearing experience (hearing age) rather than their chronological age, mirroring patterns of maternal input (Bergeson et al., 2006). Specifically, research by Bergeson and colleagues (Bergeson et al., 2006; Kondaurova & Bergeson, 2011) has shown that mothers of infants with hearing loss use IDS with their children for a prolonged period of time. In their study, mothers appeared to adjust their speech style to their infants with CIs according to the hearing experience of the infant rather than to the chronological age of the infant. Measures of mean F_0, pitch range, and duration produced by mothers of the children with CIs more closely matched the values produced by the mothers of the younger, NH control infants.

In the current study, the general pattern of results suggests that the infants in the younger NH group have a preference for IDS, and this is generally consistent with previous research (e.g., Cooper & Aslin, 1990; Fernald, 1985; McRoberts et al., 2009) suggesting that infants up to about 13 months of age prefer listening to IDS (but see Hayashi et al., 2001; Newman & Hussain, 2006, for exceptions). The older NH group had an age range that spanned 15.0 to 25.3 months of age, with a mean age of 18.6 months, and did not show a clear preference for IDS (for evidence of continued IDS preference in older infants, see Glenn & Cunningham, 1983; Ma et al., 2011). Unfortunately, we were unable to obtain exact hearing- and chronological-age matches in our control groups. In addition, our statistical analysis did not show evidence of a significant Speech Type × Group interaction. Thus, it remains unclear, at this point, whether the preference for IDS in infants with hearing loss aligns better with those of younger or older infants with normal hearing. Future research should continue to explore this question, as it would increase understanding of the effect of listening experience on preference patterns for IDS in infants with hearing loss.

The results of the present study align well with those of Bergeson and colleagues (Bergeson et al., 2006; Kondaurova & Bergeson, 2011) in that they show that older infants with hearing loss are still sensitive to IDS, even when older infants with normal hearing no longer show a clear preference. Preference for IDS in these chronologically older HI infants may be due to the fact that mothers are using IDS, despite the fact that the infant is older. Consistent with this hypothesis, the HI infants who participated in this study were all receiving early intervention services that focused primarily on auditory-verbal and auditory-oral approaches. These intervention approaches focus primarily on maximizing use of auditory information. For example, the auditory-verbal approach uses a combination of emphasizing learning through listening, and learning through naturalistic conversations (see a review by Rotfleisch, 2009). This approach educates parents on the importance of the listening environment and the importance of using "parentese" with young infants with hearing loss. Parents are trained to use repetitive speech and speech that is rich in melody, expression, and rhythm (Rotfleisch, 2009; Simser, 1993). In addition, parents who receive these types of early intervention services are also trained to use what is referred to as *acoustic*

highlighting, techniques that allow parents to emphasize the part of speech they are trying to teach. In fact, parents are taught to (a) prolong or sustain sounds being highlighted, (b) pause before the target that is being emphasized, or (c) accent the target. These strategies result in a perceptually enhanced signal for the child with hearing loss and are IDS-like in many respects. Thus, parents whose children are hearing impaired who use these intervention approaches are consciously using these techniques that mimic IDS. It may be the case that infants with hearing loss attend longer to IDS than ADS because this may be the type of speech that is being presented to them and, therefore, they may be more familiar with it. This is an empirical question, which we are currently investigating.

Research examining perceptual preferences in infants and children with hearing loss has primarily focused on children using CI devices. Hearing aids and cochlear implants process the signal in very different ways, and it is likely that perceptual differences may result related to device use. Thus, it is unknown whether preferences for IDS in infants with hearing loss are influenced by type of device used. In this study, the HI group comprised infants using hearing aids (n = 5) and CIs (n = 4). Although there is not sufficient data to statistically analyze the effect of device on IDS preference in the present data set, we thought it important to examine the data for potential device-related trends. The looking times for IDS and ADS for the CI infants were 8.7 s and 5.3 s, respectively. For infants using hearing aids, the looking times for IDS and ADS were 7.0 s and 5.5 s, respectively. In general, both groups had a preference for IDS, with the CI group having a slightly greater preference (3.4 s) than the hearing aid group (1.5 s). However, the mean hearing age for the infants with CIs was greater (9.4 months) than that of the infants with hearing aids (6.4 months), thus the trend observed may be due to amount of listening experience or type of device used. Future research should continue to explore whether device-related trends or amount of listening experience impact preference for IDS in infants with hearing loss.

The results of the regression analysis showed that the IT-MAIS is a significant predictor of listening preference for IDS in infants with hearing loss. This is consistent with data from Segal and Kishon-Rabin (2011), who found a significant correlation between preference for IDS and IT-MAIS scores for children using CIs (r = .70; correlation in the current study was r = .78). They also found a moderate correlation for the NH group (r = .51). They suggested that the weaker correlation between IT-MAIS and IDS for NH infants relative to the CI infants may be due to the fact that many of the NH infants were performing at ceiling (> 90%) on the IT-MAIS. Similarly, in the present study, nine out of the 18 infants with NH (seven of the infants in the older NH group and two of the infants in the younger NH group) were at ceiling, likely accounting for the lack of a significant correlation for the NH infants in our study.

Analysis of Figures 2 and 3 shows that Infant H3, in the HI group, outperformed other HI infants on both preference for IDS and the IT-MAIS. Although his score was within two standard deviations from the mean on IDS preference, his score on the IT-MAIS (100%) aligns much closer to the average IT-MAIS score of the older infants (92%) over that of the younger infants (74%). His score may have influenced the correlations observed between IT-MAIS and IDS preference and between IT-MAIS and listening experience. His pattern of results can be better understood in the context of his hearing history. Specifically, H3 was identified with hearing loss at 5 months of age, received early intervention, and had a hearing age of 11.5 months. Given the fact that he was identified early, and had a hearing age of 11.5 months, his IT-MAIS score makes sense, as it is representative of his hearing age. However, hearing age alone will not account for the individual performance in infants with hearing loss. For example, Infant H6 had a hearing age of 13 months, but her IT-MAIS score was much lower than that of H3, who had less experience. Although H6 had a hearing age of 13 months, she was not identified until the age of 11 months. Thus, she had a longer period of auditory deprivation during the first year, and this may be influencing this infant's pattern of results. These two cases highlight how multiple factors can contribute to the individual variability observed in infants with hearing loss. Thus, like all research with HI infants, these data should be interpreted with individual variability issues in mind.

An analysis of the looking time data for the three groups of infants in this study shows some important differences between the infants with normal hearing and infants with hearing impairment. Although the infants with HI attended longer to IDS than ADS, they exhibited shorter overall listening times for both types of stimuli than the infants with normal hearing. This may suggest that HI infants may have reduced attention to speech, relative to infants with normal hearing. To see if this was due to a block effect, the looking time data across blocks were analyzed. There was no significant difference to looking time across blocks for any of the groups. The results showing reduced looking time for HI relative to NH infants are consistent with those of Segal and Kishon-Rabin (2011), who found that HI infants looked for shorter durations when listening to speech (3.55 s) than NH infants (8.09 s). Reduced looking times to speech were also reported by Houston and colleagues (2003), who found that infants with 6 months of CI experience (mean age = 20.7 months) did not show a preference for speech over silent trials. In that study, as listening experience with the CI increased, the infants began showing a preference for speech over silence. To date, the studies showing reduced looking times to speech by infants with hearing loss have presented audio stimuli only, or audio stimuli presented with an unrelated visual display. This type of presentation is not representative of naturalistic settings, in which children hear and see the speaker. It is unclear how reduced looking times to speech in unrelated laboratory audiovisual presentations relates to attention to speech in naturalistic settings, when infants are functionally interacting with adults. Based on the present results, it cannot be concluded that infants attend less to speech when engaged in naturalistic interactions with adults.

Nevertheless, the results do show that early-identified infants with hearing loss do not look as long as infants with

normal hearing when listening to IDS. Thus, it is important to consider what the potential implications of this may be. If, in fact, infants with hearing loss have reduced attention to speech, this may have important implications, as it may mean that infants with hearing loss may not benefit as readily from IDS as infants with normal hearing. As stated earlier, the question of whether infants with hearing loss show a bias toward IDS is important because it is thought that IDS may facilitate language acquisition by drawing infants' attention to speech (Soderstrom, 2007). IDS facilitates important language acquisition skills such as word segmentation (Thiessen et al., 2005), phoneme categorization (Kuhl et al., 1997), and word learning (Graf Estes, 2008; Ma et al., 2011). Future research should continue to examine if in fact this pattern of results holds in naturalistic settings and whether this pattern of results has any negative consequences for language acquisition in infants with hearing loss.

Although the results of the IT-MAIS suggest that infants are performing at age equivalency in gross auditory skills, the IT-MAIS may not be adequately capturing decreased levels of attention to speech in infants with hearing loss. Thus, clinicians should interpret the results of the IT-MAIS with caution, because age equivalency on gross auditory skills may not appropriately indicate age equivalence in attention to speech. Therefore, it is recommended that this outcome measure should be used as part of a battery of outcome measures that can help clinicians determine effectiveness of early intervention. Future research should investigate the factors that contribute to auditory attentional mechanisms in infants, as well as intervention methods that may help infants with hearing loss increase attention to speech. These results suggest that intervention methods should include methods of increasing attention to speech in general, in addition to improving auditory access, through amplification devices or CIs.

Conclusion

This study confirms that with appropriate access to the speech signal, infants with hearing loss are able to detect the difference between IDS and ADS, thus allowing them to experience a developmentally appropriate preference or bias toward IDS. In addition, the preference for IDS was shown for infants with hearing loss and for younger infants with normal hearing. Preference for IDS over ADS was not observed in the older group of infants with normal hearing. Finally, although infants with hearing loss showed a preference for IDS over ADS, they tended to show overall shorter looking times to speech (IDS or ADS) compared to infants with normal hearing, regardless of age. This reduced attention to the speech signal is occurring despite the fact that infants are showing age equivalency on the gross auditory skill outcome measure, IT-MAIS, and despite having received early intervention.

Although infants frequently encounter both IDS and ADS in their everyday listening environment, IDS functions to capture infants' attention and highlight cues that are important in learning language. The results of the present study suggest that infants with hearing loss who have received early identification and intervention with amplification or implantation may have access to the information provided by IDS for the purposes of language learning. Consequently, infants with hearing loss theoretically may benefit from having auditory access to such information. It is unknown whether observed shorter looking times to speech in unrelated audiovisual presentations contribute to measureable differences in language development for children with hearing loss. Establishing that infants with hearing loss can display a preference for IDS is an important first step. However, if one role of IDS is to enhance access to different aspects of language learning, then future studies should determine whether IDS also facilitates language learning in infants with hearing loss.

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Appendix

Story Scripts

Script 1
A mother bird sat on her egg. The egg jumped. “Oh oh!” said the mother bird. “He will want to eat. I must get something for my baby bird to eat!” she said. “I will be back!” So away she went. The egg jumped. Out came the baby bird! “Where is my mother?” he said. [*IDS script ends here.*] He looked for her. He looked up. He did not see her. He looked down. He did not see her. “I will go and look for her,” he said. Down, out of the tree he went. *[ADS script ends here.]*

Script 2
How does a dinosaur say good night when Papa comes in to turn off the light? Does a dinosaur slam his tail and pout? Does he throw his teddy bear all about? Does a dinosaur stomp his feet on the floor and shout: “I want to hear one book more!”? Does he swing his neck from side to side? Does he up and demand a piggyback ride? Does he mope, does he [*IDS script ends here.*] moan, does he sulk, does he sigh? Does he fall on the top of his covers and cry? No, dinosaurs don’t. They don’t even try. *[ADS script ends here.]*