

Research Note

Preference for Infant-Directed Speech in Infants With Hearing Aids: Effects of Early Auditory Experience

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Purpose: It is well established that (a) infants prefer listening to infant-directed speech (IDS) over adult-directed speech (ADS), and (b) IDS facilitates speech, language, and cognitive development, compared with ADS. The main purpose of this study was to determine whether infants with hearing aids (HAs), similar to their peers with normal hearing (NH), show a listening preference for IDS over ADS.

Method: A total of 42 infants participated in the study. In Experiment 1, 9 infants with hearing loss, who had approximately 12 months of experience (mean chronological age of 17.57 months) with HAs, and 9 infants with NH, who had similar chronological age (17.54 months), were tested. In Experiment 2, 10 infants with hearing loss, who had approximately 4 months of experience (mean chronological age of 9.86 months) with HAs, and 14 infants with NH, who had similar chronological age (9.09 months), were tested. Infants were tested on their listening preference in 3 randomized blocks: IDS versus silence, ADS versus silence, and IDS versus ADS blocks, using the central fixation preference procedure.

Results: Experiment 1 showed that infants with HAs, similar to their peers with NH, listened longer to both IDS and ADS relative to silence; however, neither infants with HAs nor infants with NH showed a listening preference for IDS over ADS. In Experiment 2, both infants with HAs and infants with NH showed a listening preference for IDS and ADS relative to silence; in addition, both groups preferred listening to IDS over ADS.

Conclusions: Infants with HAs appear to have sufficient access to the acoustic cues in the speech that allow them to develop an age-equivalent IDS preference. This may be attributed to a combination of being able to use the hearing they do have before receiving HAs and early device fitting. Given previously demonstrated positive associations between IDS preference and language development, this research encourages early interventions focusing on maximizing early auditory experience in infants with hearing loss.

Supplemental Material: <https://doi.org/10.23641/asha.6906365>

When interacting with infants, caregivers typically use a speech style referred to as *infant-directed speech* (IDS; Fernald, 1993; Snow, 1977). IDS differs from adult-directed speech (ADS) in a range of properties, such as slower speaking rate, expanded vowel space, higher pitch, wider pitch range, and longer pauses (Albin & Echols, 1996; Bergeson, Miller, & McCune, 2006; Cooper & Aslin, 1990; Fernald & Simon, 1984; Fernald

et al., 1989; Papoušek, Papoušek, & Symmes, 1991; Wieland, Burnham, Kondaurova, Bergeson, & Dilley, 2015). Acoustic modifications in IDS appear to reflect universal parental behavior, namely, to express caregivers' positive affect and to encourage infant attention (Fernald et al., 1989; Grieser & Kuhl, 1988; Trainor, Austin, & Desjardins, 2000; Werker & McLeod, 1989).

IDS Preference in Infants With Normal Hearing

Infants with normal hearing (NH) are sensitive to the acoustic properties in the speech input and prefer listening to IDS over ADS (Fernald, 1985, 1989; Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2001; Werker & McLeod, 1989). For example, Fernald (1985) found that 4-month-old infants turned their heads more often in the direction necessary to activate a recording of IDS than ADS. Young infants showed a preference for IDS over ADS even when speech samples were presented

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Editor-in-Chief: Frederick (Erick) Gallun

Editor: Lori J. Leibold

Received March 13, 2018

Revision received April 13, 2018

Accepted May 2, 2018

https://doi.org/10.1044/2018_JSLHR-H-18-0086

Disclosure: The authors have declared that no competing interests existed at the time of publication.

in a foreign language (Werker, Pegg, & McLeod, 1994), by an unfamiliar voice (Cooper, Abraham, Berman, & Staska, 1997), or in synthesized speech, which preserved prosodic information (Fernald & Kuhl, 1987). However, listening preference for IDS over ADS seemed to decrease during the latter half of the second year, although some studies indicated it to be earlier (Cooper & Aslin, 1990; Fernald, 1985; Robertson, von Hapsburg, & Hay, 2013; Wang, Bergeson, & Houston, 2017). For example, whereas Robertson et al. (2013) found that 7-month-old but not 19-month-old infants preferred listening to IDS over ADS, Newman and Hussain (2006) revealed that only 4.5-month-old, but not 9-month-old, or 13-month-old infants showed a preference for IDS over ADS. This might result from a complex interaction between infants' dramatically changing perceptual, attentional, and cognitive systems and the nature of the test stimuli.

Enhanced attention to IDS increases opportunities for learning, as children are presumably more likely to learn from signals that they attend to. Indeed, there is growing evidence for the role of IDS on language development in infants with NH (Cristia & Seidl, 2014; Liu, Kuhl, & Tsao, 2003; Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011; Song, Demuth, & Morgan, 2010; Weisleder & Fernald, 2013; although see Wang, Lee, & Houston, 2016; Mani & Pätzold, 2016). For instance, infants showed better speech discrimination (Karzon, 1985), speech segmentation (Thiessen, Hill, & Saffran, 2005), word recognition (Singh, Nestor, Parikh, & Yull, 2009), and word learning (Ma et al., 2011) under IDS conditions as compared with ADS conditions. Longitudinal studies also revealed significant associations between the quantity and quality of linguistic inputs to infants and language development (Hartman, Ratner, & Newman, 2017; Hurtado, Marchman, & Fernald, 2008; Liu et al., 2003; Weisleder & Fernald, 2013). For example, infants who experienced a larger amount of IDS at home became more efficient in word processing, leading to a larger expressive vocabulary by 24 months of age (Weisleder & Fernald, 2013). Other studies also found that caregiver's vowel clarity early in life was significantly related to their children's speech discrimination skills (Liu et al., 2003) and vocabulary outcomes (Hartman et al., 2017).

A puzzle arising from these two lines of research is that, although studies suggest that IDS preference declines toward the end of the first year, language-learning infants still appear to benefit from this speech style even later in the development. It should be noted that IDS is a part of a multimodal communication system that undergoes dynamic adjustment as a result of an interaction with a range of factors, such as the caregiver, the infant, and the nature of communication (Kalashnikova, Carignan, & Burnham, 2017; Masapollo, Polka, & Ménard, 2016). Therefore, recordings of IDS used as stimuli in the majority of previous studies examining IDS preference do not fully capture the contingent and responsive adaptation of the IDS occurring in the natural communication. In view of the evidence of adjustment of IDS as a function of infant age and developmental stage (Hayashi, Tamekawa,

& Kiritani, 2001; Kalashnikova & Burnham, 2018), it is likely that older infants will still prefer IDS where the property and/or structure of the IDS stimuli optimally sustain infants' attention.

IDS Preference in Infants With Hearing Loss

While much information about the acoustic properties of IDS and its role in language development is available to infants with NH, research has only recently begun to examine the properties of linguistic input to infants with hearing loss (HL; Bergeson, 2011; Bergeson et al., 2006; Kondaurova & Bergeson, 2011; Wieland et al., 2015). The extant literature suggests that caregivers use the typical IDS style when addressing their infants with HL. For example, at the prosodic level, IDS directed to infants with cochlear implants (CIs), similar to the IDS directed to infants with NH, showed higher pitch, expanded pitch range, shorter utterance, and longer pauses, compared with ADS (Bergeson et al., 2006). At the segmental level, Wieland et al. (2015) measured formant frequencies of point vowels /i/, /a/, and /u/ in IDS and ADS from mothers of children with CIs, hearing aids (HAs), or NH. They found larger vowel spaces and vowel dispersion in IDS compared with ADS regardless of infant hearing status.

Infants with HL seemed to be sensitive to the acoustic properties of the linguistic input and showed a perceptual preference for IDS (Robertson et al., 2013; Segal & Kishon-Rabin, 2011; Wang et al., 2017). Segal and Kishon-Rabin (2011) tested infants' listening preference for IDS compared with either white noise ($n = 12$) or time-reversed speech ($n = 9$) in infants with CIs. They found that infants with CIs, similar to their peers with NH, preferred listening to IDS over both white noise and time-reversed speech. Similarly, Robertson et al. (2013) directly compared the listening preference for IDS versus ADS on 19.1-month-old infants ($n = 9$) with HL who had approximately 7.7 months of *hearing age* (defined as the amount of time from the initial CI/HA fitting until the day of the test) using either CIs ($n = 4$) or HAs ($n = 5$) and two control groups with NH: a younger control group with a similar hearing age and an older control group with a similar chronological age. Infants with HL, similar to the younger control group, preferred listening to IDS over ADS. In a recent publication in this journal, Wang et al. (2017) tested 27-month-old prelingually deaf infants ($n = 12$) who had 12 months of experience with CIs and two control groups with matched hearing age or chronological age in three blocks: IDS versus silence, ADS versus silence, and IDS versus ADS. They found that both infants with CIs and the hearing age-matched group with NH showed a significant preference for IDS over both silence and ADS. These two studies also revealed that the degree of IDS preference was associated with concurrent auditory skills (Robertson et al., 2013) and later language outcomes (Wang et al., 2017) in infants with HL.

Whereas the findings from these studies consistently suggest that the CI devices allow infants sufficient access to the acoustic signal in the input and develop an IDS

preference that is equivalent to their hearing age, the picture regarding IDS preference in infants with HAs is less clear. Note that in Robertson et al. (2013)'s study, the group with HL comprised both infants with CIs ($n = 4$) and infants with HAs ($n = 5$), with infants with CIs having a slightly greater IDS preference (looking time difference = 3.4 s) than the infants with HAs (looking time difference = 1.5 s). Note also that the average hearing age for the infants with CIs was greater (9.4 months) than that of the infants with HAs (6.4 months). These differences, along with a small sample size, make it difficult to determine whether the findings can be generalizable to infants with HAs.

Current Study

Therefore, in the current study, we extended the previous work to investigate preferences for IDS in infants with HAs. Given that early experience with speech and language has been shown to have a significant effect on language development in infants with NH, it is imperative to understand how early auditory experience affects IDS preferences in infants with HAs. Although infants with 12 months of experience with CIs prefer listening to IDS over ADS (Wang et al., 2017), we have reasons to suspect that different patterns of IDS preference may emerge in infants with HAs. This is because infants with HAs and who are not CI candidates, in general, have a larger amount of unaided hearing than infants who receive CIs and thus have earlier access to a significant amount of auditory input. This earlier auditory experience with the linguistic input may provide sufficient opportunity to encode and process speech sounds during a sensitive period to develop an age-appropriate preference for IDS.

Experiment 1

Method

Participants

Infants with HAs (the HA group) and infants with NH (the NH group) participated in this experiment. The HA group consisted of nine infants with sensorineural HL who were fitted with HAs (three girls, six boys). They received HAs prior to 12 months of age (mean HA fitting age: 5.27 = months, range: 1.18–10.59 months) and had approximately 12 months of hearing age (chronological age: 17.57 months, range: 13.51–22.66 months; mean hearing age: 12.30 months, range: 11.34–13.15 months). We first tested the infants with HAs who had 12 months of hearing age because infants with CIs who had a similar hearing age showed an IDS preference over ADS (Wang et al., 2017). The demographic information for the infants with HAs is provided in Table 1. Each infant with HAs was matched with an infant with NH on the basis of chronological age. Therefore, the control group with NH also consisted of nine infants (six girls, three boys, mean age: 17.54 months, range: 13.22–22.68 months). The stimuli, design, and procedure were the same as in Wang et al.'s study (2017).

Stimuli

Four female adult native speakers of American English produced the following passage in both IDS and ADS styles in a sound-attenuated room: "Good morning! How are you today? What are you doing? Let's go for a walk." They were instructed to produce the sentences as if they were talking to an infant (IDS) and as if they were talking to an adult (ADS). The sentences were then digitized at a sampling rate of 44.1 kHz. Supplemental Material S1 lists the acoustic measures (average F0, F0 range, and utterance durations) of the stimuli. The visual stimuli consisted of an attention getter (a small dynamic video display of a blue and white expanding and shrinking wheel) and a visual display (a white and red static checkerboard pattern).

Design

Each infant was tested with three blocks of stimuli: an IDS versus silence block, in which infants received four IDS and four silent trials; an ADS versus silence block, in which infants received four ADS and four silent trials; and an IDS versus ADS block, in which they received four IDS and four ADS trials. The IDS versus silence and ADS versus silence blocks served as the baseline for the infants' auditory attention. During each of the four IDS (or ADS) trials, infants heard one of the four speakers' IDS (or ADS) passages, who was not the speaker of the rest of the three IDS (or ADS) trials. During the silent trials, no sound was played. The presentation order of the eight trials within each block was randomized across the participants, as was the order of the three blocks.

Apparatus and Procedure

We used the central fixation procedure (Houston, Pisoni, Kirk, Ying, & Miyamoto, 2003) to test the infants. Each infant was seated on the caregiver's lap in front of a TV monitor in a double-walled IAC sound booth. Speech stimuli were presented to the infants via loudspeakers at 65 ± 5 dB SPL. The caregiver wore headphones, which played continuous music and speech babbles, and was therefore blind to the speech stimuli. The experimenter was seated outside the booth in the control room and coded the infants' eye movements online. All trials began by showing the attention getter at the center of the monitor. Once the infant looked at the attention getter, the test trials began. During the test trials, the infant was presented with the static checkerboard at the center of the monitor and the speech stimuli. Each trial continued until the infant looked away for 1 s or more. If the infant turned away from the monitor for less than 1 s, that time was not included into the looking time, although the monitor continued to display the checkerboard and the loudspeaker to play auditory stimuli. The trial duration was infant controlled. The dependent measures were the average looking times across trials to each type of auditory stimuli within each block.

Table 1. Demographic information for infants with hearing aids.

Experiment	ID	Sex	CA	Age at device fitting	Duration of device use	Degree of HL	Mean PTA unaided (dB)
Experiment 1	4840HA	M	20.49	7.34	13.15	Mod-sev	80
	4882HA	M	14.96	2.07	12.89	Mild-mod	55
	HA07	F	17.72	4.87	12.85	Mild-mod	41
	HA03	M	13.51	1.18	12.33	Mild-mod	Unknown
	4653HA	M	15.29	3.13	12.16	Mild-mod	Unknown
	HA10	F	22.66	10.59	12.07	Mod-sev to prof	96
	HA11	M	18.58	6.61	11.97	Mild-mod	48
	HA24	M	17.13	5.23	11.90	Mild-mod	38
	HA25	F	17.75	6.41	11.34	Mod-sev	80
	<i>M (SD)</i>			17.57 (2.83)	5.27 (2.90)	12.30 (0.57)	
Experiment 2	4916HA	M	11.98	4.84	7.14	Mild-mod	55
	3664HA	F	15.14	8.91	6.23	Mild-mod	42
	HA13	M	7.91	2.01	5.90	Mild-mod	40
	HA18	F	9.65	3.75	5.90	Mild-mod	36
	3031HA	F	9.69	6.41	3.28	Mod-sev	72
	4892HA	M	10.06	7.70	2.36	Mild-mod	Unknown
	HA08	M	8.12	6.22	1.90	Mild-mod	54
	HA22	F	10.30	8.82	1.48	Mild-mod	46
	HA14	M	7.27	6.09	1.18	Mild-mod	54
	4894HA	M	8.52	7.83	0.69	Mild-mod	Unknown
<i>M (SD)</i>			9.86 (2.31)	6.26 (2.22)	3.61 (2.44)		50 (11)

Note. All ages are reported in months. CA = chronological age; HL = hearing loss; PTA = pure-tone average before device fitting; M = male; mod = moderate; sev = severe; F = female; prof = profound.

Results and Discussion

The means and standard deviations of the looking times to each stimulus type for the HA and the NH groups tested in Experiment 1 are reported in Table 2. We ran three repeated-measures analysis of variance on looking time with Hearing Status (HA, NH) as the between-subjects factor and Type as the within-subjects factor for each block (IDS vs. silence, ADS vs. silence, and IDS vs. ADS). We also conducted nonparametric Wilcoxon signed-ranks tests to corroborate the parametric analyses when applicable.

For the IDS versus silence block, the main effect of Type was significant, $F(1, 16) = 9.72, p = .007, \eta_p^2 = .378$, because the two groups in general looked significantly longer to IDS ($M = 10.68, SD = 7.46$) than to silence ($M = 6.64,$

$SD = 3.40$). A Wilcoxon signed-ranks test also showed that the looking time was significantly longer for IDS compared with silence, $Z = 2.85, p = .004$. However, neither the Hearing Status \times Type interaction, $F(2, 16) = 1.21, p = .287$, nor the main effect of Hearing Status, $F(1, 16) = 0.17, p = .683$, was significant. For the ADS versus silence block, the main effect of Type was marginally significant, $F(1, 16) = 4.42, p = .052, \eta_p^2 = .216$, because there was a trend for the two groups to look longer to ADS ($M = 9.59, SD = 7.51$) than to silence ($M = 6.37, SD = 3.76$). A Wilcoxon signed-ranks test did not show significantly different looking times to ADS as compared with silence, $Z = 1.63, p = .102$. Neither the Hearing Status \times Type interaction, $F(2, 16) = 0.06, p = .807$, nor the main effect of Hearing Status, $F(1, 16) = 0.18, p = .676$, was significant. For the IDS versus ADS block, no significant interaction or main effects were found,

Table 2. Average (standard deviation) looking times (s) to different types of stimuli in the two experiments, separated by hearing status (HA [hearing aid], NH [normal hearing]) and block (the IDS [infant-directed speech] vs. silence, the ADS [adult-directed speech] vs. silence, and the IDS vs. ADS blocks).

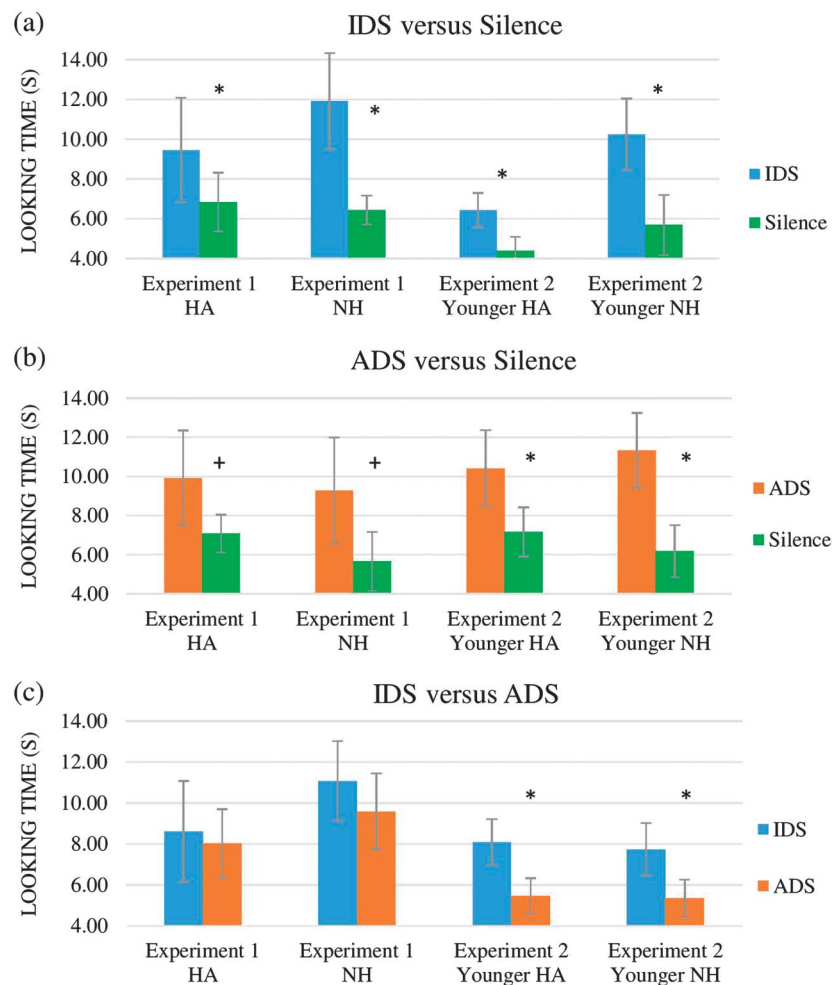
Block	Type	Experiment			
		Experiment 1		Experiment 2	
		HA group	NH group	Younger HA group	Younger NH group
IDS versus silence	IDS	9.45 (7.89)	11.91 (7.25)	6.44 (2.70)	10.24 (6.72)
	Silence	6.84 (4.43)	6.43 (2.19)	4.38 (2.25)	5.69 (5.66)
ADS versus silence	ADS	9.92 (7.29)	9.27 (8.15)	10.41 (6.17)	11.34 (7.14)
	Silence	7.08 (2.92)	5.66 (4.51)	7.16 (3.97)	6.18 (4.97)
IDS versus ADS	IDS	8.60 (7.40)	11.08 (5.83)	8.09 (3.53)	7.74 (4.80)
	ADS	8.02 (5.04)	9.59 (5.59)	5.46 (2.71)	5.35 (3.41)

$F_s < 0.67$, $p_s > .426$, indicating that both groups looked equally long to IDS and ADS. Infants' looking times to the stimuli are also presented in Figure 1.

Overall, Experiment 1 demonstrated that both the HA and the NH groups preferred IDS over silence and showed a trend in preferring ADS over silence, suggesting that infants with HAs may have developed normal attention to *speech* skills. Note that infants with CIs with similar amounts of device experience showed reduced attention to speech, ADS in particular (Houston et al., 2003; Wang et al., 2017). However, neither group showed a preference for IDS over ADS. Our findings that the NH group (mean age: 17.54 months) did not show an IDS preference over ADS are consistent with previous findings of reduced preference for IDS in older infants due to development (Fernald, 1985; McRoberts, McDonough, & Lakusta, 2009; Wang et al., 2017). However, the HA group did not show a preference for IDS over ADS. Recall

that in Wang et al.'s (2017) study, the CI group and the hearing age-matched group with NH, who had 12 months of hearing experience, preferred IDS over ADS. One possibility is that infants with HAs were not able to detect acoustic differences between IDS and ADS, thus not showing an IDS preference. It is also possible that because infants with HAs have access to a significant amount of auditory input even before receiving their devices, they were able to develop an age-equivalent IDS preference; therefore, their performance was similar to the chronological age-matched infants with NH. To tease apart these two possibilities, in Experiment 2, we tested a younger group of infants with HAs using the same stimuli and experimental design. If the first hypothesis is true, then the younger infants with HAs would not show an IDS preference over ADS; however, if the latter is true, then we predict that younger infants with HAs would listen longer to IDS than to ADS.

Figure 1. The average looking times (s) in the three blocks: (a) the IDS versus silence block, (b) the ADS versus silence block, and (c) the IDS versus ADS block, for the four groups of infants tested in Experiments 1 and 2. Error bars indicate standard error. * indicates statistical significance of $p < .05$; + indicates marginal significance $.05 < p < .1$. IDS = infant-directed speech; HA = hearing aid; NH = normal-hearing; ADS = adult-directed speech.



Experiment 2

Method

Participants

A new group of 10 infants with sensorineural HL fitted with HAs (the younger HA group: four girls, six boys) participated in the study. They had approximately 4 months of hearing experience (chronological age: 9.86 months, range: 7.27–15.14 months; mean hearing age: 3.61 months, range: 0.69–7.14 months). Because IDS preference can be stimuli specific, we also tested a group of infants with NH as the baseline (the younger NH group). The younger NH group consisted of 14 infants (10 girls, four boys, mean age: 9.09 months, range: 8.03–10.26 months), who had similar ages as the younger HA group. Stimuli, design, and apparatus and procedure were the same as in Experiment 1.

Results and Discussion

The means and standard deviations of the looking times to each stimulus type for the younger HA and the younger NH groups tested in Experiment 2 are reported in Table 2. We found a main effect of Type for all three blocks, namely, IDS versus silence block, ADS versus silence block, and IDS versus ADS block, $F_s > 11.58$, $p_s < .003$, $Z_s > 2.77$, $p_s < .006$. This was because both groups listened longer to IDS ($M = 8.66$, $SD = 5.66$) than silence ($M = 5.15$, $SD = 4.53$), ADS ($M = 10.95$, $SD = 6.63$) than silence ($M = 6.59$, $SD = 4.52$), and IDS ($M = 7.88$, $SD = 4.24$) than ADS ($M = 5.40$, $SD = 3.07$). Neither the Hearing Status \times Type interaction nor the main effect of hearing status was significant in all three blocks, $F_s < 1.86$, $p_s > .187$.

To better understand the nature of the different performances of the HA group (Experiment 1) and the younger HA group (Experiment 2), we also compared the amount of residual hearing (measured by pre-HA pure-tone average) and age at device fitting between these two groups. There were no group differences in residual hearing, $t(13) = 1.40$, $p = .185$, or age at device fitting, $t(17) = 0.84$, $p = .414$, suggesting that different patterns of IDS over ADS preference between these two groups are less likely due to differences in their residual hearing or age at device fitting but more likely due to differences in the amount of auditory experience.

To determine which demographic factors contributed to explaining the IDS over ADS preference of the young HA group in Experiment 2, we ran Pearson bivariate correlations between IDS preference, chronological age, age at device fitting, duration of device use, and residual hearing. The IDS preference was calculated by subtracting each infant's looking time to ADS from IDS, with positive values indicating a preference for IDS. The results showed marginal associations between IDS preference and age at device fitting, $t(10) = -0.613$, $p = .059$, and between IDS preference and duration of device use, $t(10) = 0.574$, $p = .083$. However, other bivariate correlations were not significant, $t_s < 0.134$, $p_s > .752$.

Discussion

Previous studies have shown that infants with NH prefer listening to IDS over ADS (Cooper & Aslin, 1990; Fernald, 1985). Recent studies have also demonstrated that infants with CIs show perceptual preference for IDS compared with nonspeech signals and ADS (Segal & Kishon-Rabin, 2011; Wang et al., 2017). However, very little is known about whether infants with HAs would show similar bias. Therefore, this study extended previous findings by examining a perceptual preference for IDS in infants with HAs.

The main finding of this study was that 10-month-old infants with HL who had approximately 4 months of experience with HAs, similar to their chronological age-matched controls with NH, showed a preference for IDS over ADS. These findings are of considerable importance as they indicate, for the first time, that infants with HAs, similar to infants with NH and infants with CIs, prefer listening to IDS over ADS. The question of whether infants with HAs show a preference for IDS relative to ADS is important because it is proposed that the underlying mechanism of IDS to facilitate language development is by drawing and enhancing infants' attention to speech (Cristia & Seidl, 2014; Soderstrom, 2007). Our finding suggests that infants with HAs have sufficient access to the acoustic cues in the speech, especially those enhanced cues in IDS, which may be relevant to numerous dimensions of early language development.

Another finding from this study was that 17-month-old infants with HL who had approximately 12 months of experience with HAs, similar to their chronological age-matched controls, did not prefer listening to IDS over ADS. These results support and complement previous research in several ways. First, that older infants with NH did not show IDS over ADS preference aligns well with previous findings that show a developmental change in infants' IDS preference (Fernald, 1985; McRoberts et al., 2009; Robertson et al., 2013; Wang et al., 2017). Second, the results showed that infants with HAs developed an IDS preference that was more similar to their chronological age-matched controls, rather than the hearing aged-matched infants with NH. In contrast, the IDS preference over ADS in infants with CIs was more similar to their age-matched peers with NH (Wang et al., 2017). These discrepancies may actually reveal the important role of early auditory experience on the development of the IDS preference. Specifically, infants with HAs, who, in general, have a larger amount of residual hearing and receive amplification devices earlier than infants with CIs, may have more opportunity to access and encode the auditory input early in their life. There is evidence that early auditory experience has a measurable effect on language skills in children with HL (Conway, Pisoni, Anaya, Karpicke, & Henning, 2011; Fernald, Perfors, & Marchman, 2006; Houston, Stewart, Moberly, Hollich, & Miyamoto, 2012; Rose, Feldman, & Jankowski, 2009). For instance, Houston et al. (2012) examined the effect of an early auditory experience on word

learning skills in infants with CIs. They found that the early implanted group, who received CIs by around 1 year, performed similarly to their peers with NH; however, the late implanted group, who received CIs between 14 and 21 months of age, did not show an evidence of learning.

Interestingly, we found that both infants with HL who had 4 months and 12 months of experience with HAs, similar to infants with NH, preferred an ADS over silence. In contrast, infants with CIs showed reduced attention to speech (ADS stimuli) as compared with their peers with NH (Houston et al., 2003; Wang et al., 2017). For example, infants with CIs who had 6 months of hearing experience showed reduced attention to repetitions of syllables as compared with their age-matched infants with NH (Houston et al., 2003). Similarly, infants with CIs who had 12 months of hearing experience did not prefer ADS over silence (Wang et al., 2017). Therefore, our findings suggest that infants with HAs have developed chronological age-equivalent attention to speech skills as their peers with NH. Perceptual bias for speech is important as it sets the stage for learning by allowing infants to maximize their exposure to speech, thus providing them better opportunity to develop speech perception skills or processing strategies. Indeed, both theoretical and empirical evidence has suggested the important role of attention to speech in language development (Houston & Bergeson, 2014; Jusczyk, 1993; Vouloumanos & Curtin, 2014; Werker & Curtin, 2005). For instance, infants' attention to speech pitted against sine-waves at 12 months of age predicted expressive vocabulary at 18 months (Vouloumanos & Curtin, 2014). In addition, attention to speech skills 3 to 6 months post-implantation predicted word recognition in infants with CIs over a period of 10 years following implantation (Wang, Shafto, & Houston, 2018).

Finally, we also found that the age at device fitting and the duration of device use were associated with IDS preference in infants with HA. Specifically, infants who received HAs earlier and who used HAs for a longer time showed enhanced attention to IDS relative to ADS. These findings are generally consistent with previous research suggesting earlier device fitting and increased use of assistive device would result in advancement of perceptual skills (Houston et al., 2003; Houston et al., 2012; Segal & Kishon-Rabin, 2011; Zwolan et al., 2004). These findings encourage early intervention focusing on maximizing access to auditory inputs early in life in infants with HL. However, the findings that the amount of residual hearing did not correlate with IDS preference should be interpreted with caution because of the small sample size. Note that pure-tone average measures from two infants in this group were not reported. In addition, the amount of residual hearing in this group was rather homogenous, which may partly contribute to the nonsignificant association between the IDS preference and the amount of residual hearing.

Several limitations of this study are noted. First, recordings of IDS used as stimuli in our study did not fully capture the dynamic adjustment of IDS in the natural communication. Future research will use age-appropriate IDS stimuli

whose properties would optimally sustain infants' attention. In addition, linking IDS preference during infancy and later language development is of both theoretical and clinical significance. Therefore, future studies are encouraged to explore whether the degree of IDS preference early in life is associated with language development in infants with HAs.

Conclusions

Infants with NH and CIs prefer listening to IDS over ADS early in the development, which may play an important role in their language development. This study extended previous findings and confirmed that infants with HAs also show an IDS preference comparable to their peers with NH, which may have significant implications for later language learning. In addition, our findings suggest that the infants with HAs develop an IDS preference and attention to speech skills that are equivalent to their chronological age-matched peers with NH, probably due to early experiences in processing and encoding speech sounds. These findings have significant clinical implication for infants with HL to receive early identification and intervention with amplification.

Acknowledgments

This research was supported in part by National Institute on Deafness and Other Communication Disorders Grant R01 DC008581 to Derek M. Houston and Laura Dille.

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