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The Production of English Inflectional Morphology, Speech Production and Listening Performance in Children with Cochlear Implants

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Abstract

Objective: To compare how children who use either cochlear implants (CIs) or hearing aids (HAs) express English inflectional morphemes during conversation, i.e., with voice, with sign, or with both. A secondary objective was to investigate the relationship between morpheme use in pediatric CI users and their speech perception skills, length of experience with the device, and accuracy of phoneme production.

Design: Group 1 consisted of 25 children who used CIs, and Group 2 consisted of 13 children who used HAs. All children were prelingually deafened and all used simultaneous communication. A 12 minute spontaneous conversation was elicited, transcribed and coded. Between group comparisons were performed to evaluate differences in modality and number of morphemes used. Additionally, use of morpheme endings was related to length of CI experience, accuracy of phoneme production, and closed-set speech recognition performance.

Results: Children who had CI experience produced significantly more English inflected morphemes than children in the HA group. CI participants also expressed the inflected endings by using voice-only mode 91% of the time, whereas HA participants used voice-only mode 1% of the time. In the CI group, a strong relationship was found between number of morpheme endings used and speech recognition scores, length of CI experience and accuracy of phoneme production. The results of this study indicate that input from the CI facilitates children's ability to perceive and comprehend bound morphemes.

This investigation focused on the use of English inflectional morphology by young cochlear implant (CI) users who communicate primarily with Signed English. Our goal was to evaluate the acquisition of inflectional endings, and to explore the role of CI use in their development. The first section of the following review indicates that little research exists concerning the language skills of young CI users. In the next sections, we note that these children often acquire the speech skills necessary to produce the sounds associated with plurals and third person possessive, /s, z/, past tense /t, d/, as well as the /m/ associated with first person possessive (i.e., I'm), and the /ng/ associated with the present progressive tense. As will be noted, CI children can often hear these sounds, so they may receive exposure to them during everyday listening.

Language TOP

Few studies to data have investigated the language skills of CI users. The current literature is limited by small sample sizes, mixed samples of children with prelingual and postlingual deafness, and pools of participants who utilized different educational methods or communication modalities. Nevertheless, there are indications that use of a CI may affect language development **(Hasenstab & Tobey, 1991; Robbins, Osberger, Miyamoto, & Kessler, 1995)**.

Improvements in receptive and expressive vocabulary and syntax skills often follow receipt of a CI **(Geers & Moog, 1994; Miyamoto, Osberger, Robbins, Myres, Kessler, & Pope, 1992)**. For instance **Miyamoto et al. (1992)** reported small improvements in receptive vocabulary in a group of children after they used a CI for 2.5 yr as indexed by quotient scores on the Peabody Picture Vocabulary Test-Revised**(Dunn & Dunn, 1981)**.**Geers and Moog (1994)** reported that after 3 yr of devise use, children who used CIs performed better than children who used hearing aids (HAs) on the receptive language test, Rhode Island Test of Language Structure **(Engen & Engen, 1983)**. Conversely, expressive language test results did not reveal a statistically significant group difference.

No studies have focused specifically on the use of morphological endings by CI users. However much research suggests that deaf children who use HAs tend not to use morphological endings, or tend to use them inappropriately**(Cooper, 1967; Crandall, 1978; Gaustad, 1986; Quigley & Paul, 1990)**. For instance,**Bornstein, Salunier, and Hamilton (1980)** examined the use of inflectional endings (in either sign-only mode or voice-and-sign mode) by 20 young HA users over a 4 yr time period. At an average age of 47.6 mo, the children used no endings. Four yr later, the percent of inclusion was better, albeit delayed. The children were least likely to use third person singular endings (11% of the time when use would be appropriate) and most likely to use regular plural endings (67%). There is some evidence that the developmental order for morpheme endings may be the same for deaf children who use Signed English and for hearing children, although deaf children may be more inconsistent in their use **(Crandall, 1978: Schick & Moeller, 1992)**. Signed English generally has one sign to denote one meaning, using primarily American Sign Language (ASL) signs in English word order. Compound and complex words are formed by adding invented signs and endings to form one word (see **Wilbur, 1987**).

One factor that contributes to morphological deficits may be that most deaf children cannot articulate the sounds necessary to convey the endings. For example, many children are unable to articulate an /s/ or distinguish between /t/ and /d/ **(Smith, 1975)**. They may not produce these language structures in part, because they cannot speak them.

Perhaps more importantly, deaf children who use HAs may not receive models of many inflectional endings during every day conversation, and therefore, do not incorporate them into their own language outputs. For instance, young HA users often cannot hear the low-intensity, high-frequency sounds such as /s, z/, and low-frequency, low-intensity sounds such as /m, n, ng/. They thus may not be aware of when the endings occur in everyday speech, particularly because many people often omit inflected endings when using Signed English**(Kluwin, 1981; Marmor & Pettito, 1979)**.

Recent evidence suggests that CI children may not have as extensive production and perceptual difficulties. Next, we will briefly review some of this evidence.

Speech Production TOP

As a group, children who use CIs demonstrate improved speech production skills **(Osberger, Maso, & Sam, 1993; Tobey, Geers, & Brenner, 1994; Tobey & Hasenstab, 1991; Tobey, Pancamo, Staller, Brimacombe, & Beiter, 1991; Tye-Murray & Kirk, 1993; Tye-Murray, Spencer, & Woodworth, 1995)**. For instance they tend to increase their imitative and spontaneous phonetic repertoires and consonant features, and improve overall speech intelligibility **(Osberger, Robbins, Berry, Todd, Hesketh, & Sedey, 1991, Osberger, Robbins, Todd & Riley, 1994)**. In one study, **Tobey et al. (1994)** reported that children who use CIs imitated vowels and consonants better than children who used HAs and who had similar hearing losses.

Speech Perception TOP

Two yr postimplantation, children with prelingual deafness may demonstrate improved pattern recognition, improved word and phoneme identification, and in some cases, open-set word recognition **(Fryauf-Bertschy, Tyler, Kelsay, & Gantz, 1992; Fryauf-Bertschy, Tyler, Kelsay, Gantz & Woodworth, 1997; Miyamoto, Osberger, Robbins, Myres, & Kessler, 1993; Staller, Beiter, Brimacombe, Mecklenburg, & Arndt, 1991)**. There is some evidence that a CI provides information that allows children to perceive the segments of the speech signal that correspond to inflectional endings.**Tye-Murray, Tyler, Woodworth, and Gantz (1992)** performed an information transmission analysis on initial position consonant recognition errors of adult CI users. The adults utilized the nasality feature relatively well and had some ability to recognize the frication feature. **Tye-Murray, Spencer, and Gilbert-Bedia (1995)** performed a comparable study with children who use CIs. The children achieved highest accuracy recognizing the nasality feature, and lowest for the place feature. They were able to utilize some information about frication. Interestingly, those children who perceived these features were likely to speak them accurately, whereas those children who did not perceive them were likely to err in producing them. This finding suggests that access to the acoustic signal can influence speech production. In this investigation, we will extend this finding to suggest that access to the acoustic signal can influence language use in specific ways as well.

Purpose TOP

Children who use CIs and benefit from auditory speech input may perceive and produce the phonemes that comprise inflected endings better than children who are deaf and use HAs, or children who use CIs but receive little benefit. They may therefore follow a different pattern with respect to inflected morpheme acquisition and production.

In this investigation we compared the communication mode (i.e., voice-only, sign-only, or voice-and-sign) used to produce English inflectional morphology in two groups of children with prelingual profound deafness: CI users and HA users. Both groups communicated primarily with Signed English. We also examined the relationship between speech production, speech perception and the expressive development of English inflected endings in children CIs. The following questions were addressed:

1. Do young CI users produce inflected endings differently than HA users, as indexed by measures of frequency of occurrence and mode of communication?

2. Is there a relationship between speech perception skill and use of inflected endings?

3. Does the duration of CI experience relate to accuracy of phoneme production and use of inflected endings?

Methods
TOP

Participants
TOP

Twenty-five children who were prelingually deaf and who had a minimum of 2 yr of CI experience at the time of testing, and 13 children who were prelingually deaf and wore HAs participated in this study. Demographic data are presented in **Table 1**. All of the children were identified as being deaf before 18 mo of age, with the exception of participants CI4 and CI19 who were 30 mo and 26 mo, respectively. They demonstrated limited verbal language skills and their functional communication skills at the time of implant surgery were similar to the test group. Participants were assigned an identification number.

TABLE 1. Individual demographic information for participants who use a cochlear implant (CI) or a hearing aid (HA).

Participant	Months of CI Experience	Age at Testing (Mo)	Age Loss First Noted by Parents (Mo)	Age at CI Hookup (Mo)	Etiology	Encoding Strategy	Number of Electrodes
CI1	36	67	9	31	Meningitis	Mpeak	21
CI2	36	93	14*	57	Unknown	Mpeak	20
CI3	48	106	12*	58	Unknown	F0F1F2	22
CI4	36	96	30	60	Meningitis	Mpeak	11
CI5	48	99	12	51	Meningitis	Mpeak	22
CI6	60	103	11*	46	Unknown	Mpeak	22
CI7	60	117	6*	57	Unknown	F0F1F2	22
CI8	72	119	8*	47	Unknown	F0F1F2	19
CI9	60	125	3*	65	Unknown	Mpeak	20
CI10	36	152	8*	116	Unknown	Mpeak	20
CI11	72	161	4*	89	Unknown	Mpeak	20
CI12	24	154	15	130	Meningitis	Mpeak	22
CI13	36	194	18*	158	Hereditary	Mpeak	19
CI14	24	86	12	62	Meningitis	Mpeak	22
CI15	36	79	14*	43	CMV	Mpeak	22
CI16	36	98	11*	62	Meningitis	Mpeak	22
CI17	48	106	16*	58	Unknown	Mpeak	21
CI18	36	169	1*	133	Hereditary	Mpeak	20
CI19	36	149	26	113	Meningitis	Mpeak	20
CI20	36	86	9	50	Meningitis	Mpeak	20
CI21	24	87	18*	63	Unknown	Mpeak	22
CI22	48	117	9*	69	Unknown	Mpeak	21
CI23	36	90	5*	54	Unknown	Mpeak	22
CI24	48	99	14*	51	Unknown	Mpeak	22
CI25	24	63	7*	39	Unknown	Mpeak	22
Mean	**43**	**9 yr 5 mo**	**12**	**70**			
SD	**14**	**2 yr 7 mo**	**7**	**33**			
HA1	NA	136	6*	NA	Unknown		
HA2	NA	114	9*	NA	Unknown		
HA3	NA	97	9	NA	Ototoxicity		
HA4	NA	118	8*	NA	Unknown		
HA5	NA	81	3*	NA	Hereditary		
HA6	NA	81	6*	NA	Unknown		
HA7	NA	84	8*	NA	Unknown		
HA8	NA	129	6*	NA	Unknown		
HA9	NA	149	9*	NA	Unknown		
HA10	NA	171	16*	NA	Unknown		
HA11	NA	167	3*	NA	Premature birth		
HA12	NA	171	8*	NA	Meningitis		
HA13	NA	171	6*	NA	Unknown		
Mean		**10 yr 2 mo**	**7**				
SD		**2 yr 9 mo**	**3**				

* *Suspected congenital onset.*

TABLE 1. Individual demographic information for participants who use a cochlear implant (CI) or a hearing aid (HA).

Children in the CI group ranged in age between 5 and 16 yr, and had a mean age of 9 yr 5 mo (SD = 2 yr 7 mo). They received their CIs between the ages of 31 mo and 16 yr, with a mean of 5 yr 7 mo (SD 2 yr 6 mo). Children in the HA group ranged in age between 6 and 14 yr, and had a mean age of 10 yr 2 md(SD = 2 yr 9 mo). There was not a statistically significant difference in age between the two groups [$t(36) = -1.35$, $p = 0.184$.]

Participants CI4, CI5, and CI8 used the F0F1F2 processing strategy, which is designed to present first formant information to the 5 most apical of the 22 electrodes, and second formant information to the remaining electrodes. Fundamental frequency information is conveyed by pulse rate duration during voiced segments of the signal and random intervals during unvoiced segments. The remaining children in the CI group used the MPeak processing strategy, which presents the same information as the FOF1F2 strategy, additional information about the third and fourth formants during voiced segments, and more high-frequency information during unvoiced segments. For a review of processing strategies, see **Staller, Beiter, and Brimacombe(1994)**. One participant was stimulated on only 11 electrodes, and within 1 yr after this language sample was obtained, his device failed. He was subsequently explanted and then reimplanted.

All the children in the HA group were considered candidates for cochlear implantation on the basis of their audiological evaluations. They scored below chance on the following tests: Monosyllable, Trochee, Spondee test**(Erber & Alencewicz, 1972)**, the Four-Choice Spondee test from the Early Speech Perception test battery **(Geers& Moog, 1990)**, the Vowel Perception Test **(Tyler, Fryauf-Bertshcy, & Kelsay, 1991)**, and the Phonetically Balanced Kindergarten Word Lists, **(Haskins, Reference Note 1)**(See **Fryauf-Bertschy et al., 1997**). Participants HA1-HA4 subsequently received CIs.

All children lived at home and attended a public school within their community or 60 miles thereof. One child in the CI group attended a state school for the deaf, but returned home each day. According to all parental reports, the children used simultaneous communication (Speech and Signed English) at home and in the school.

Speech and Language Testing TOP

The speech production testing and the language sample were videotaped using a camcorder with audiovideo tracks. Phoneme production accuracy was assessed using a sentence repetition task consisting of 14 short and expanded sentences (e.g., "The girl runs." and "The girl runs to catch the school bus."). The examiner presented the sentences in both speech and sign, and the child repeated the sentence. Phonetic transcriptions of the sentences were compared with the target sentences to derive a percent phoneme correct score. This test was chosen because it provided a standardized sample from each child in that all children were given the same sentences to repeat.

A conversational language sample was collected using the protocol from the Systematic Analysis of Language Transcripts (SALT) manual**(Miller & Chapman, 1993)**. The clinician had a 15 minute conversation with all the children. During this time at least one topic absent from time and space was introduced (e.g., "Tell me what you did over summer vacation."). Typical topics discussed included pets, family, and school activities, and in some instances the child provided some narrative within the sample. All language samples were elicited by the first author, a fluent signer of Signed English with 14 yr of signing experience and extensive experience working with deaf children. Twelve minutes of each sample were transcribed by the first author and coded using SALT conventions. The words produced by voice and sign were transcribed, and the modes used to express each word and each bound morpheme was coded. The code [vs] indicated the word was produced with voice-and-sign, [s] indicated sign-only was used and [v] indicated voice-only was used. If the child signed "My dad work on a farm" but spoke "Dad works on a farm", the message was transcribed as My[s] dad[vs] work/s[vs:root][v:end] on[vs] a[vs] farm[vs]. The child was given credit for use of a spoken word or morpheme if the vocalization was produced in the appropriate temporal sequence of a signed utterance.

Transcriber reliability was calculated on language samples from five children. The second transcriber was an educational interpreter who held an associate degree from an interpreter training program, an interpreter's license and a quality assurance Level 2 from the state of Wisconsin. Reliability was calculated on both the speech and sign transcription. The interpreter reviewed the transcriptions and noted any discrepancies. Mean intertranscriber item-by-item agreement was 0.96 Agreement regarding the specific occurrence of the bound morphemes was 0.98

General language measures extracted from the SALT analysis included total words used, type/token ratio, and unique words used. The bound morphemes coded in this analysis included plurals, possessives, third person singular, present progressive, and regular past tense. The child was given credit for an ending if it was judged to be vocalized, signed, or produced with both sign and voice, and the mode used was noted.

Omitted bound morphemes were coded. The obligatory context was defined as an instance where the ending would be required for the utterance to be grammatical, as in the following example: "When it is hard to say, she spell/*3s it out." The third person singular tense is represented as 3s, and the * indicates it was omitted. There were instances where the structure of the sentence was ambiguous. In these cases an ending was not judged to be obligatory as in the example: "Then coach need sit down."

Because the purpose of this study was to investigate use of inflectional morphemes in English, morpheme codes were not completed on words that included ASL sign markers, such as when a plural was indicated by repeating a sing. The ending was, however counted as obligatory. Six children used utterances that included elements and syntax unique to ASL. Utterances that were primarily ASL in nature were counted, transcribed, and marked with a code (ASL).

Speech Perception Testing TOP

The 6-choice Word Intelligibility by Picture Identification Test (WIPI) by **Ross and Lerman (1971)** was administered live-voice in a quiet room. This test was performed in an audition-only condition. The children's familiarity with the vocabulary of the test was established before testing by asking the child to name, via voice or sign, each of the six words on the answer plate of the test before preceding with that test foil. All of the children could identify all of the vocabulary of the test before testing with the following exceptions: participant number CI16, who was not tested, and participants CI1 and CI25. These children were given a reduced set WIPI, which included 10 plates that contained words within their vocabulary.

The WIPI test was not administered to children in the HA group. They were unable to hear the stimuli.

Results TOP

Information on use of communication mode and bound morphemes can be found in **Tables 2 and 3**, respectively. Speech production, perception and language data are presented in **Table 4**.

	Whole Words (% of total)		Morpheme Endings (% of total)	
Mode	CI Group	HA Group	CI Group	HA Group
Voice only	21	1	94	2
Sign only	9	31	5	94
Voice and sign	70	68	1	4

CI = cochlear implant; HA = hearing aid.

TABLE 2. Mode of communication used to express whole words and bound morphemes.

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Participant	Plural /s/	Possessive /s/	Present Pro-gressive /ing/	Third Person Singular	Past Tense /ed/	Total Used
CI1	1/1	0/1	5/6	3/8	0/1	9/16
CI2	9/11	1/1	1/1	1/1	4/4	16/18
CI3	2/5	1/4	2/2	2/3	1/9	8/23
CI4	0/4	0/0	0/0	0/3	0/1	0/8
CI5	4/5	5/5	5/6	1/1	1/6	15/23
CI6	5/10	0/2	0/0	1/1	0/3	6/16
CI7	5/11	1/3	0/0	2/5	0/4	8/23
CI8	27/27	9/9	3/3	12/12	8/8	59/59
CI9	2/3	1/1	7/7	0/0	1/4	11/15
CI10	12/12	5/5	13/13	4/4	10/10	44/44
CI11	24/24	1/1	10/10	14/15	5/7	54/57
CI12	13/15	1/1	1/1	2/2	0/1	17/20
CI13	16/16	0/1	1/1	5/11	2/2	24/31
CI14	2/2	0/0	3/3	1/1	0/0	6/6
CI15	24/25	4/4	6/6	6/6	0/0	40/41
CI16	0/2	0/0	0/0	0/0	0/0	0/0
CI17	2/3	0/2	0/0	0/1	0/2	2/8
CI18	2/4	0/0	0/1	0/0	0/1	2/6
CI19	0/6	0/0	0/0	0/1	0/4	0/11
CI20	1/1	0/1	3/5	1/1	1/4	6/12
CI21	0/3	0/0	0/1	0/3	0/2	0/9
CI22	16/17	1/3	1/1	1/3	0/3	19/27
CI23	3/5	0/1	1/1	0/2	0/1	4/10
CI24	12/16	6/7	9/9	1/2	1/3	29/37
CI25	0/3	2/2	19/20	1/1	0/3	22/29
Total	**182/231**	**38/53**	**89/99**	**59/93**	**40/81**	**401/549**
%	**79**	**70**	**90**	**68**	**49**	**73**
HA1	6/15	1/1	0/1	0/6	0/2	7/25
HA2	0/1	0/1	0/0	0/2	0/2	0/6
HA3	10/10	0/0	2/2	0/0	0/0	12/12
HA4	4/10	0/0	0/2	0/1	0/4	4/17
HA5	0/1	0/3	1/2	0/2	0/3	1/11
HA6	8/8	0/2	0/0	0/5	0/4	8/19
HA7	2/5	0/1	0/0	0/1	0/2	2/9
HA8	2/4	0/0	0/0	1/3	0/1	3/8
HA9	0/2	0/0	1/2	2/4	0/14	3/22
HA10	0/0	0/0	0/0	0/0	0/0	0/0
HA11	0/10	0/2	0/0	0/0	0/1	0/13
HA12	0/4	0/0	0/0	0/0	0/1	0/5
HA13	7/17	0/1	1/1	0/2	0/2	8/23
Total	**39/66**	**1/11**	**5/11**	**3/29**	**0/40**	**48/170**
%	**59**	**9**	**45**	**10**	**0**	**28**

TABLE 3. Total number of bound morphemes used (by category) over total obligatory instances by individual participants in each group.

TABLE 3. Total number of bound morphemes used (by category) over total obligatory instances by individual participants in each group.

		Produced Correctly in a Short-Long Sentence Production Task (% Correct)		Produced within a 12 minute Conversation Sample				
Participant Number	WIPI* (% Correct)	Phonemes	Words	MLU	Total Words	Unique Words	Number of Utterances	Total Bound Morphemes
CI1	65	44	8	3.95	281	115	75	9
CI2	40	42	11	6.68	598	217	97	16
CI3	80	72	41	6.74	475	186	79	8
CI4	26	46	14	3.98	210	98	59	0
CI5	72	65	35	4.91	302	138	66	15
CI6	48	57	24	5.42	346	154	68	6
CI7	36	38	19	4.58	296	126	69	8
CI8	80	93	70	8.96	675	232	88	59
CI9	56	54	16	4.88	417	186	89	11
CI10	80	80	43	8.32	530	208	74	44
CI11	56	75	46	8.11	929	289	126	54
CI12	36	45	16	7.92	466	183	62	17
CI13	70	67	30	8.32	676	237	88	24
CI14	44	49	16	5.18	139	68	70	6
CI15	86	79	49	6.07	446	169	84	40
CI16	—	17	3	3.16	262	110	87	0
CI17	38	36	11	3.92	202	95	59	2
CI18	46	37	11	5.23	311	146	63	2
CI19	16	27	3	5.73	556	229	99	0
CI20	44	50	24	7.26	188	82	47	6
CI21	36	31	6	2.55	191	111	76	0
CI22	94	76	46	5.08	281	127	61	19
CI23	72	53	16	2.99	211	112	75	4
CI24	86	69	38	4.69	473	186	109	29
CI25	96	54	14	3.40	315	100	101	22
HA1	NA	54	19	6.0	345	155	60	7
HA2	NA	30	5	2.70	108	67	42	0
HA3	NA	19	0	2.07	108	77	63	12
HA4	NA	55	46	4.34	210	135	73	4
HA5	NA	43	5	4.27	264	142	63	1
HA6	NA	20	0	2.25	152	86	75	8
HA7	NA	40	19	3.41	216	119	66	2
HA8	NA	35	0	3.48	192	121	56	3
HA9	NA	34	3	4.71	387	205	85	3
HA10	NA	66	41	2.94	106	78	36	0
HA11	NA	60	13	4.72	307	156	65	0
HA12	NA	59	30	7.40	444	184	61	0
HA13	NA	78	46	4.64	261	147	58	0

* Percent correct on the Word Intelligibility by Picture Identification Test.

TABLE 4. Perceptual, speech production, and language data for individual participants in the cochlear implant (CI) and the hearing aid (HA) groups.

TABLE 4. Perceptual, speech production, and language data for individual participants in the cochlear implant (CI) and the hearing aid (HA) groups.

Communication Mode TOP

The number of total words produced via voice-and-sign mode, voice-only mode, and sign-only mode was tallied and divided by the total number of words produced. The percent of words produced via each modality was calculated(**Table 2**). Voice-and-sign mode was used to express whole words within conversations a majority of the time for both the CI group and the HA group. For the CI group voice-only mode was the next most frequently used mode, but for the HA group, sign-only mode was the next most popular mode.

The total number of word endings produced via voice-and-sign mode, voice-only mode, and sign-only mode was tallied and divided by the total number of word endings produced. These results also appear in**Table 2**. This analysis revealed differences between the two groups, and was also in contrast with the whole word data. The CI participants most often used voice-only mode. In contrast, the HA participants tended to use sign-only mode to mark endings. Neither group tended to use voice-and-sign mode.

Use of Bound Morphemes TOP

We next analyzed use of bound morphemes, independent of communication mode. Analysis of the 12 minute conversation samples revealed that the total number of morphemes used by individual members of the CI group ranged from 0 to 59, with a mean of 16 (SD = 17). Totals for the HA group ranged from 0 to 12, with a mean of 3 (SD = 1). The difference in the use of bound morphemes between groups was statistically significant [$t(36) = 2.56$, $p = 0.015$]. **Table 3** lists the morpheme endings used; the numerator indicates the number of endings produced by each participant, and the denominator indicates the number of obligatory contexts possible. The number of tokens of each morpheme used by each group was computed. The two groups were similar in their frequency patterns, using plural morphemes most often, followed by present progressives, possessives, third person singular forms, and regular past tense forms.

The CI group used the present progressive tense (-ing) most consistently in the obligatory context (90% of the time). They used the past tense (-ed) in the obligatory context with the least consistency (49% of the time). The HA group used the plural (-s) in the obligatory context most consistently (56% of the time), but no one in the HA group used the past tense (-ed) form.

Bound Morpheme use and Speech Perception TOP

Pearson correlations were performed between each CI participants' scores on the WIPI and the total number of bound morphemes they used.**Table 4** lists raw scores. Because of the number of correlations performed a hypothesis-wide alpha level of 0.01 was adopted as the level of significance. For readers who wish to apply a more conservative approach, the absolute probability levels for all correlations are given. The analyses revealed a significant relationship between WIPI scores and total bound morphemes used (r = 0.574, p = 0.003). These results indicate that there was a tendency for children who scored better on the WIPI to include more English inflected endings within conversation.

Bound Morpheme Use and Speech Production Skills TOP

The relationship between accuracy of phoneme production and ending use was investigated within the CI group and the HA group. The accuracy of phoneme production was correlated with the use of inflected endings only for the CI group.

First we will consider the CI group. Correlations between the percent of phonemes produced correctly in the imitative sentence task and the number of endings produced within the conversation task were as follows: Plurals(r = 0.750, p = 0.0001); possessives (r= 0.688, p = 0.0001); third person singular (r = 0.662, p = 0.0001), and regular past tense (r = 0.574,p = 0.003). Use of present progressive was the only ending that did not show a significant relationship with phoneme production. The combined use of all five morpheme endings was also significantly related to accuracy of phoneme production (r = 0.815, p = 0.0001).

The relationship between use of endings and phoneme accuracy for the HA group was not statistically significant.

Speech and Language Results and Experience with a CI TOP

Pearson correlations revealed relationships were significant between CI experience and use of third person singular tense (r = 0.550, and$p$ = 0.003). Length of experience with a CI was correlated with accuracy of words produced correctly on the imitative sentence task(r = 0.568, p = 0.004). The relationship between age at testing, phoneme accuracy, use of plurals, possessives, present progressives, third person singular or regular past was not statistically significant.

To determine whether age at testing was a confounding variable in determining the relationship between phoneme production, use of bound morphemes, and months of CI experience, a partial correlation was completed with age at testing partialed out. The correlations were significant for phoneme production and length of experience with a CI (r = 0.836,p = 0.0001) and for total bound morphemes used and length of experience (r = 0.437, p = 0.0001).

Discussion TOP

Children with prolonged experience with CIs used inflected endings conversationally significantly more often than a group of similarly aged children with profound hearing loss who use HAs. In this study both CI and HA users marked plurals most commonly, followed by present progressives, possessives, third person singular, and regular past tense. Thus, they appear to have a similar progression in their mastery of endings, but differ primarily in their skill levels.
A previous investigation by **Tye-Murray, Spencer, and Woodworth (1995)** revealed that during a story retell task, children who used simultaneous communication tended to use voice-and-sign mode 83% of the time, voice-only mode 9% of the time, and sign-only mode 7% of the time. In the present investigation, which used open-ended conversation, this trend was replicated for both the CI group and the HA group. The primary mode of communication used to express a majority of words within conversation for both HA users and CI users was voice-and-sign. In contrast, the mode used to express bound morphemes for CI users was usually voice-only. When HA users produced bound morphemes, they used sign-only modality.

The use of voice-only mode to express English endings by CI users is significant because these morphemes are marked acoustically by mid- and high-frequency information in the speech signal. It suggests the following process: first, the CI offers them acoustic access to the sounds; second, as the CI users begin to perceive these sounds they incorporate them into their phonology; and finally, the sounds are expressed in their spoken morphology.

Two caveats to the above explanation must be appended. First, this study did not assess competence in grammatical morphology for either group. That is, no testing was completed to determine how well the children understood when a morpheme should or should not be included in a specific context. It is possible that the CI children have increased accuracy in production of all phonemes in general as a result of CI experience and thus, are better able to speak endings. Improvements in phonologic repertoire may give these children a means of marking a previously gained competence in morphology. A second caveat is that there were some participants who did not use endings, or due to the nature of their productive language structure it was not possible to derive which ending would have been obligatory. In these cases it was not possible to assess the child's knowledge of an ending.
Use of inflected endings was not related to the age of the participants in either the CI group or the HA group. This finding replicates the data of**Schick and Moeller (1992)**, who examined inflected endings in profoundly deaf children of a similar age group. In the current study, bound-morpheme use was related to the length of experience that a child had with a CI and speech perception. These findings suggest that use of English inflected endings may be less affected by mutation and aging, and more affected by auditory inputs available via the CI. We speculate that once the children in this study acquired a stable vocabulary base through sign and listening, they may have then extracted the significance of bound morphemes, perhaps through listening, and generalized their use to many contexts.

This scenario corresponds with several models of language acquisition described for children with normal hearing **(Bloomfield, 1933; Connell, 1989; Swisher & Snow, 1994)**. It may be that once a child has reached an understanding of a word meaning and the relationship that a bound morpheme has to the word, the child can develop production skills to mark the morpheme. Given that there is a relationship between accuracy of phoneme production and production of morphemes, it also possible that children must first incorporate the sound associated with bound morphemes, namely/ s, z, t, ng/, into their phonology before they demonstrate their linguistic knowledge via the production mode. Further longitudinal data regarding children's phonological development after implantation may reveal the exact nature of this relationship.

More research is needed to understand how information provided from the CI influences the user's ability to code verbal information during everyday listening. For instance it would be beneficial to know whether CI users tend to use of phonologically based or a sign-based coding strategy (e.g.,**Bellugi & Fisher, 1972; Lichtenstein, 1985**). In the present study children with CI experience used the voice-and-sign mode to communicate a word but relied on the voice-only mode to communicate the morpheme ending. This findings suggests that the sound cue is an important part of their coding process even when they use a sign-based coding strategy. The use of a phonological template as a building block for language acquisition may ultimately enable children who use CIs to develop a better representation of English grammar than children who use HAs.

Acknowledgments: TOP

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