Vocal development in two young cochlear implant users: Preliminary results

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Abstract

This study investigates prelinguistic vocal development in two young cochlear implant users during their first eight months of hearing. Audio recordings of two girls' babbling were made and analyzed both auditorily and instrumentally. Results show for both changes in production from simple to more complex syllable structures. For both girls, the pattern of preferred places of consonant articulation changes over time and the duration of CV-dyads decreases. The data allow the conclusion that their developmental patterns are similar to those found for normal-hearing infants.

Introduction

During the first 2 years of life infants' prelinguistic vocalizations gradually become more complex and speech-like. Progress in vocal development is considered crucial for the acquisition of a phonological system: from producing early isolated consonantal and vocalic elements the infant must learn to combine vowels and consonants into adult-like syllables that can function as the phonetic building blocks of words (Oller, 2000). Childhood hearing loss can have a severe impact on early vocal development. This includes late onset of adult-like syllable production and smaller consonant and vowel inventories (Oller, 2000). It is, however, shown that prelingually deaf children who receive cochlear implants (CI) at an early age make significant progress in vocal development during the first year of device use. Main findings in a study made by Ertmer, Young and Nathani (2007) showed that milestones in vocal development were achieved within fewer months of hearing experience than observed by normal-hearing infants. Wie (2010) found that children receiving CIs between 5 and 18 months had expressive and receptive language skills within normal range. However, a large variation in rate of development has been identified (Wie, 2010; Ertmer et al., 2002) and also atypically developmental patterns in young CI recipients have been found (Ertmer, Young & Nathani, 2007). These findings indicate that some children remain at various levels of development longer than normal-hearing children and show limited gains in phonetic and syllabic inventories. This variability in performance across children may be due to a combination of several factors, including length of auditory deprivation and age in which a child received CIs.

Additional research is needed to gain a better understanding of factors that influence postimplantation vocal development. The present paper describes prelinguistic vocal development in two young CI users who received bilateral cochlear implants at 5.5 and 7 months of age, respectively. The intention was to explore to what extent these two children show developmental patterns comparable to those of normal-hearing infants.

Method

Subjects

Subjects involved in this study were two girls (G1, G2) both identified at birth with profound hearing loss. G1 received bilateral cochlear implants (CI) at the age of 5.5 months and G2 received bilateral cochlear implants at the age of 7 months. The CI devices in both children were activated within 1 month post-surgery.

Recordings

Both audio and video recordings were made using a Roland HR-9 and a Canon Legria HF G10, respectively, in the children's home environments by their respective parents. They were instructed to interact with the children in their usual manner.

In total, five recordings were made of each of the two subjects at intervals of 2 months (±3 weeks). Each recording comprised 30–40 minutes, in most cases resulting from several recording sessions spread out over a week. G1 got her CIs activated at the age of 6.5 months and a few days later the first recording was made. The first recording of G2 was made at the age of seven months, 1 week before she received her implants.

Analysis

For this investigation only the audio material was evaluated. Audio recordings were stored as wav files with a sampling frequency of 44.1 kHz and 16-bit quantization. Acoustic analysis was performed using Praat (Boersma & Weenink, 2012) and involved auditory evaluation combined with visual inspection of waveform and spectrogram.

Material used for analysis comprised 50 utterances selected from each of the five recordings. For the present purposes, an *utterance* is defined as a single vocalization or a group of vocalizations separated by articulatory pauses.

First step in analysis was the division of an utterance into syllable-like entities. A *syllable* was defined as a vocalic or (in some cases) consonantal nucleus, or could comprise a combination of consonant and vowel.

Consonants were classified according to the usual criteria of place and manner of articulation, and voicing. Due to reasons of space, this paper will deal only with place of articulation. Since the present babbling material precludes conventional fine-grained division of the place dimension, four broader categories were established:

1) bilabial
2) dental/alveolar/palatal (*front*)
3) velar/uvular (*back*)
4) glottal

In addition, vowel quality was analyzed following the usual criteria of degree of opening, backness and lip rounding. Results will be presented in future publications.

Results

Syllable structure

Table 1 displays the percentage of each syllable type produced by G1 and G2 during their first eight months of implant use. Both girls show similar developmental patterns of increasing syllable shape complexity. G1s dominant form of syllables shifted from simple V syllables (59%) in recording 1 to CV syllables (69%) in recording 4. Simple V and C syllables (39% and 27% respectively) dominated G2 production in the first recording, whereas CV structures accounted for 77% of the syllables in recording 5.

Consonants

Place of articulation

Table 2 presents an overview of the places of articulation used in the girls' production of consonantal elements in the five recordings. In spite of sometimes substantial differences between the two girls, similar developments can be observed. For both, the most frequently used place of articulation in the first recording (pre-implant for G2) is bilabial (42% and 63%, respectively). Also, for both of them the use of this place shows a decreasing trend, percentages for recording 5 being 20% and 25%, respectively. Further, a relatively consistent increase in the use of the front region emerged from the data: from 6% in recording 1 to 38% in recording 5 for G1; correspondingly from 2% to 40% for G2. Also, the amount of back (velar/uvular) articulations increases over time, although especially for G1 less clear than the increased use of the front region (G1: 27%–36%; G2: 7%–15%). Finally, both girls show a tendency of reduced use of glottal productions. The trend is clear for G1 (reducing from 24% to 7%) and less consistent for G2 (from 28% to 20%).

CV duration

In this section we shall investigate temporal aspects of the girls' vocalizations. To that aim we selected syllable-like CV units from the recordings as a measure of development towards the production of syllables in adult speech. Recall that CV-dyads represented the most frequent type of vocalization for both girls (around 50% of all productions pooled across recordings 1–5; *Table 1*).

Mean CV durations presented in *Figure 1* show similar trends for G1 and G2. The general trend goes from longer durations at the time of the first recording (mean 551 ms) to shorter durations in the last recording (mean 379 ms). The only striking deviation from this pattern is the mean value of 1097 ms measured in recording 2 productions, corresponding to a hearing age of 2 and 3 months, respectively, for G1 and G2. Although G2 has only one CV unit among the analyzed recording 2 productions (corresponding to 1%; *Table 1*), it has a typical duration (1262 ms).

Table 1. Syllable structure in G1's and G2's vocalizations. V=single vowel; C=single consonant; CV=syllable-like CV-dyad. Numbers represent occurrences in % in recordings (Rec) 1–5. mo=months.

		Rec 1	Rec 2	Rec 3	Rec 4	Rec 5	Rec 1-5
	hearing age	1 week	2 mo	4 mo	6 mo	8 mo	
G1	**V**	59	47	31	17	40	36
	C	9	9	2	2	4	5
	CV	30	31	64	69	47	49
	Other	2	13	4	12	9	7
	hearing age	w/o CI	3 mo	4 mo	7 mo	8 mo	
G2	**V**	39	0	18	13	11	16
	C	27	75	10	1	2	17
	CV	21	1	63	57	77	52
	Other	13	24	9	29	11	16

Table 2. Place of articulation in G1's and G2's consonantal productions. Numbers represent occurrences in % in recordings (Rec) 1–5. mo=months; front=dental/alveolar/palatal; back=velar/uvular.

		Rec 1	Rec 2	Rec 3	Rec 4	Rec 5	Rec 1-5
	hearing age	1 week	2 mo	4 mo	6 mo	8 mo	
G1	**bilabial**	42	39	64	36	20	40
	front	6	9	3	38	38	23
	back	27	18	5	26	36	23
	glottal	24	33	27	1	7	14
	hearing age	w/o CI	3 mo	4 mo	7 mo	8 mo	
G2	**bilabial**	63	90	33	11	25	38
	front	2	0	23	48	40	28
	back	7	3	4	33	15	14
	glottal	28	8	40	8	20	20

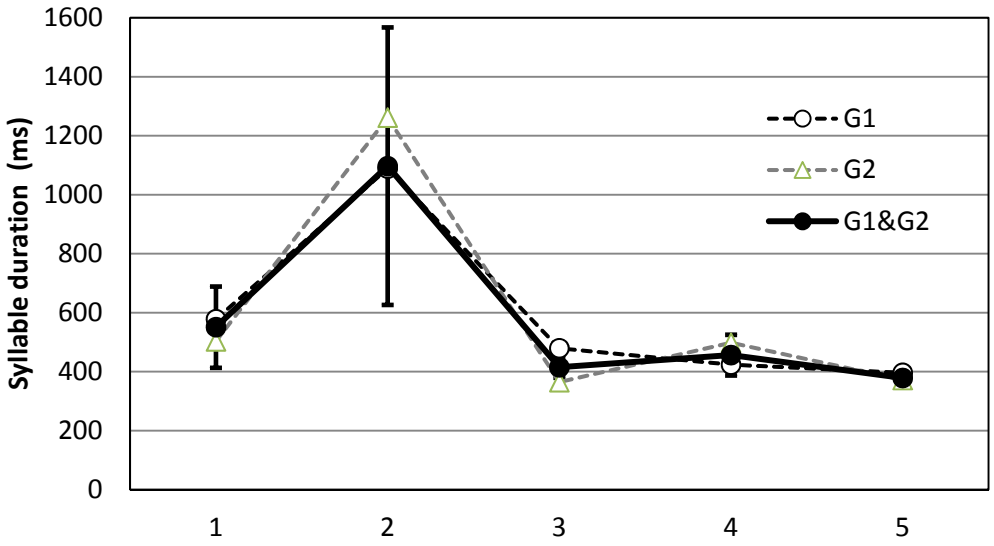

Figure 1. CV durations in ms for G1 and G2 separately and pooled for recordings 1–5. Vertical bars indicate 95% confidence intervals for pooled durations.

The internal structure of this token is a long bilabial nasal (1066 ms) followed by a much shorter vowel (196 ms). In contrast, mean duration of the consonantal element in G1's CV tokens is only 192 ms, while the vowel is relatively long (mean of 879 ms).

To study variation of individual CV durations, in *Figure 1* the 95% confidence interval was chosen as a measure. The results show that the pattern found for mean CV durations in recordings 1–5, i.e. a general downward trend with the exception of recording 2, is also present in the variation of durations. Generally, the width of the confidence interval is relatively small, decreasing from 276 ms for recording 1 to 58 ms for recording 5. The corresponding width calculated for recording 2 is substantially larger (941 ms). This value reflects the wide range of CV durations for this condition, varying between 237 ms and 3874 ms.

Discussion

The most important conclusion that can be drawn from the data collected thus far is that the girls' prelinguistic development is similar to patterns observed for normal-hearing infants. During their first eight months of hearing both girls made substantial progress. Vocalizations developed from predominantly simple V and C nuclei to CV syllables as the most frequent shape. Further, a typical trait is the increasing use of the front region of the mouth as place of articulation. As to temporal organization, CV durations appeared to become gradually shorter. This whole picture emerging from the data is in line with findings reported by Oller (2000) and Frank (2009) for normal-hearing children.

Generally, the patterns found for the present infants were rather similar, in particular with regard to CV syllable durations. It should be noted, however, that we are dealing with two case studies here and that similarities are in all probability accidental. Syllable duration in eight normal-hearing infants in Frank (2009) gradually decreased from the age of 6 months to 24 months. Considerable between-subject variation was found, however, especially at ages of 6, 8, and even 20 months.

Apart from between-subject variation the data revealed also considerable within-subject variation. For many categories, tendencies of increase or decrease were not monotonic but characterized by larger up-and-down changes. For example, for G1 the clear predominance of CV shaped syllables at the hearing age of six months was diminished two months later. Another example is the most frequent use of bilabial place of articulation, which was not found at the time of the first recordings but in the third recording of G1 and the second recording of G2. Also for this kind of within-subject variation it can be noted that it is not atypical but also found in children without hearing impairment.

Conclusion

The conclusion seems justified that young cochlear implant recipients can achieve prelinguistic vocal development comparable to that of normal-hearing infants.

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