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The development of the prosodic word in the speech of a hearing-impaired child with a cochlear implant device

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Abstract

The paper provides an analysis of the development of the prosodic word in the speech of a Hebrew-speaking, hearing impaired child using a cochlear implant device. The data were collected during 38 sessions, from the age of 1;5 years (three months after the operation) till 3;4, using spontaneous speech and picture naming. The analysis is couched within the theoretical framework of Prosodic Phonology, and compared with that of normally hearing Hebrew-speaking children. The comparison reveals that the development of the prosodic word in the speech of the implanted child is within the normal range, in terms of both developmental path and age. There were, however, two phenomena in the speech of the implanted child that were not reported in the studies on normally hearing children. The implanted child's vocabulary included mono- and disyllabic words consisting of vowels only, and his vocalic inventory included long vowels. The clinical implications of our findings are discussed.

Keywords: prosodic development, prosodic word, hearing impairment, cochlear implant, Hebrew.

Introduction

One of the basic components of speech perception and production is the proper function of the auditory system. In the course of language development, children receive their linguistic input from the speech of others, which serves as their target. In addition, their own auditory feedback allows them to gradually correct their speech, until it matches their target (Borden, 1979; Northern and Downs, 1991; Stoel-Gammon and Kehoe, 1994; Wallace, Menn and Yoshinaga-Itano, 2000; Kuel, 2000; Obenchain, Menn and Yoshanaga-Itano, 2000).

Auditory deprivation arising from hearing loss in the early stages of life affects the different aspects of language development, including the patterns of speech

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production (Lee and Canter, 1971; Pressnell, 1973; McGarr and Osberger, 1978; Oller, Jensen and Lafayette, 1978; Quigley and King, 1982; Wood, 1984; Levitt, McGarr and Geffner, 1987; Madison and Wong, 1992; Tobin, 1997). The speech production of hearing impaired children is characterized by a variety of segmental and suprasegmental errors. Segmental errors may include omissions, distortions, and substitutions of one sound for another (Hudgins and Numbers, 1942; Markides, 1970; Smith, 1975; Monsen, 1976; Stevens, Nickerson and Rollins, 1978; Geffner, 1980; Osberger and McGarr, 1982; Tobin, 1997). Suprasegmental errors are found in the intonation and stress pattern, which affect the prosody and the rate of the spoken utterance (Boothroyd, Nickerson and Stevens, 1974; Osberger, 1978; Parkhurst and Levitt, 1978; Rosenhouse, 1986; Frank, Bergman and Tobin, 1987).

The rehabilitative devices for the hearing impaired population are varied, and they may all be useful in providing feedback via a sensory system that facilitates the development of spoken communication skills. However, the cochlear implant is the most advanced hearing aid device known today, and it has had a major impact in improving the speech production of hearing impaired children (Tobey, Geers and Brenner, 1994). The cochlear implant provides electrical stimulation to the auditory nerve, bypassing the usual transducer cells that are absent or nonfunctional in a deaf cochlea. The nerve impulses travel along the auditory pathways to the cortical level, and are interpreted by the brain as sound.

The electrical stimulation of the cochlear implant provides its user more information than the acoustical stimulation of the conventional hearing aids; e.g. fundamental frequency, a wider dynamic range, a wider frequency range. Therefore, it allows audibility of sounds that were not accessible to the child, and thus provides greater potential for development of speech perception and production skills in comparison to other rehabilitative devices (Parsier and Chute, 1991; Chin and Pisoni, 2000).

Most studies of the speech production of hearing impaired children suggest significant improvement following cochlear implantation, in comparison to other sensory aids. Several studies examine the speech production of hearing impaired children using cochlear implants, tactile aids and conventional hearing aids. These studies, which deal primarily with the segmental features of the phonological system, show that the speech production of children using a cochlear implant is better than that of children using tactile aids (Osberger *et al*., 1991; Geers and Tobey, 1992; Tye-Murray and Kirk, 1993; Tobey *et al*., 1994; Sehgal, Kirk, Svirsky, Ertmer and Osberger, 1998) and conventional hearing aids (Geers and Tobey, 1992; Tobey *et al*., 1994; Kirk, Diefendort, Riley and Osberger, 1995).

The non-segmental aspects of the speech of cochlear implant users have been studied as well (Kirk and Hill-Brown, 1985; Tobey, Pancamo, Staller, Brimacombe and Beiter, 1991; Tobey and Hasenstab, 1991; Tobey *et al*., 1994). Most relevant to the present discussion is Carter, Dillon and Pisoni (2002), who examined the ability of the children to imitate the stress patterns and the correct number of syllables in nonce words, given a repetition task. Their findings show a relatively high accuracy in these prosodic properties; the children were able to produce the correct number of syllables as well as the primary stress position in almost two-thirds of their imitations of nonce words. Moreover, the errors with respect to the number of syllables revealed a pattern similar to that of normal hearing children, i.e. a tendency to delete rather than add syllables, and a better performance in words with initial stress, compared to words with non-initial stress (Fikkert, 1994; Demuth, 1995, 1996a; Gerken, 1994, 1996, among others). This study emphasizes that 'investigation of the prosodic development of children with cochlear implants may provide new insights into their phonological development and how their development compares to normal development processes' (Carter *et al.*, 2002: 621). Such an investigation was carried out in the case study presented in this paper; we followed the prosodic word development of a Hebrew-speaking child with a cochlear implant and compared it to the development of normally hearing Hebrew-speaking children.

Our results suggest that the deficient auditory system involved with a cochlear implant device, which was implanted at an early age (1;2;10), does not cause a significantly delayed or deviant phonological system in comparison to normal development. Our case study is part of a larger ongoing study, which follows 10 children (six with a cochlear implant device and four with a conventional hearing aid) from their initial stage of language development.

We begin the discussion with a review of the theoretical framework of Prosodic Phonology and the stages of prosodic acquisition of normally hearing Hebrew-speaking children. This is followed by information regarding the subject and the methods of assessment. We then provide an analysis of the development of the prosodic word in the speech of the implanted child, and show that it is similar to that of normally hearing children. We continue with a discussion of the consonant-free words and the long vowels, which do not appear in the speech of normally hearing children. We conclude with remarks and clinical implications.

Theoretical background

The theory of prosodic phonology asserts that words consist of prosodic units, which are hierarchically organized (the same is true for phrases, which are beyond the scope of this paper). The prosodic hierarchy, as proposed in Selkirk (1984) and Nespor and Vogel (1986), assumes the following dominance relations among the prosodic units—figure 1.

A prosodic word has only one primary stress. It may dominate one or more feet, but only one of these feet is strong, the foot dominating the stressed syllable.

We adopt here the principle stating that feet are binary (Prince, 1980; Kager, 1989; Prince and Smolensky, 1993), consisting of two syllables (or moras). The foot is a unit of rhythm, expressing a fixed uneven strength of the syllables within it, strong-weak (a trochaic foot) or weak-strong (an iambic foot). A monosyllabic foot (called a degenerate foot) appears mostly in words with an odd number of syllables and exhaustive footing, i.e. when all the syllables in a word are parsed into feet ([σ][$\sigma\sigma$] or [$\sigma\sigma$][σ]).

PrWd (prosodic/phonological word)
|
Ft (foot)
|
σ (syllable)
|
μ (mora)

Figure 1. *The prosodic hierarchy of words*

Allen and Hawkins (1980) claim that the foot structure in the child's speech reflects that in his/her target language. Thus, children acquiring English exhibit a trochaic foot while children acquiring French exhibit an iambic foot. However, children acquiring Hebrew cannot identify a specific foot on the basis of their input, since they are exposed to lexically distinct stress patterns, ultimate as well as penultimate (e.g. todá 'thank you', óto 'car'), including a few cases of free variation (e.g. búba ~ bubá 'doll'). Nevertheless, they exhibit preference for the trochaic foot, by producing both syllables of disyllabic target words with penultimate stress (séfer 'book') at the stage where they still produce only one syllable of disyllabic target words with ultimate stress (dú for kadúr 'ball'). That is, there is a stage in the acquisition path, the pre-minimal word stage (see below), where the children produce only monosyllabic words and disyllabic words with penultimate stress. Hayes' (1995) study of foot typology suggests that in quantity insensitive languages, i.e. where syllable weight does not play a role in the stress system, the unmarked foot is trochaic. Thus, it seems that in the absence of language-specific evidence, Hebrew speaking children first resort to the universally unmarked foot (at the pre-minimal word stage). However, they soon admit the mixed foot system of Hebrew, where some nouns have a trochaic foot and others iambic, and thus add to their vocabulary disyllabic words with ultimate stress (at the minimal word stage).

Below is a demonstration of the prosodic structure of two Hebrew words (from children's target vocabulary), where subscript 's' indicates the strong feet and syllables (secondary stress, associated with a strong syllable in a weak foot, is ignored—figure 2).

Syllable strength often correlates with syllable weight, such that heavy syllables may attract stress. Syllable weight is designated by the number of moras, where a light syllable (CV) has one mora, and a heavy syllable (CVV, CVC) has two (Hyman, 1985; Hayes, 1986). Hebrew does not exhibit a weight contrast, as it does not have phonemic long vowels (i.e. there are no minimal pairs like ma and ma: contrasting in syllable weight). Moreover, CVC syllables do not attract stress, and thus not considered heavier than CV by the stress system. However, as shown in the section headed 'Phenomena', long vowels do appear in the speech of the implanted child, during the earlier stages of acquisition.

The prosodic hierarchy, in conjunction with the principle stating that feet are binary, predicts that the minimal size of the prosodic word is the syllabic (or moraic) foot (McCarthy and Prince, 1986, 1990, 1991). Indeed, many languages exhibit this restriction on their content words (function words, which are not independent prosodic words, are thus exempt). In English, for example, we find bimoraic words like ti:k 'teak', tik 'tick', ti: 'tea', but not monomoraic content words like *tI. The

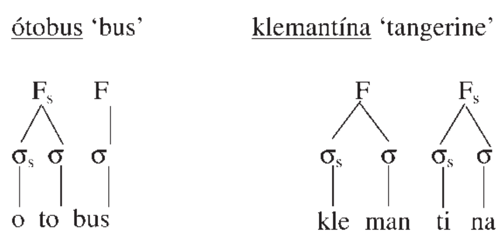

Figure 2. *The prosodic structure of words*

minimal word plays a major role in the course of acquisition. There is a stage during the prosodic development of several languages, where the maximal (though not necessarily minimal) size of the child's words is a binary foot, either monosyllabic bimoraic (CVC or CVV) or disyllabic (Fikkert, 1994; Demuth and Fee, 1995 and Demuth, 1995, 1996b for Dutch and English, Garrett, 1998 for Spanish, Demuth, 2003 for French, Ota, 1998 for Japanese, Ben-David, 2001 and Adam, 2002, 2003 for Hebrew).

Stages of prosodic acquisition are defined in terms of the number of syllables, syllable structure, and foot structure; children gradually increase the number of syllables in a word and produce syllables of greater complexity as their language grows. In our study, we will follow the increase in the number of syllables in the word, with reference to the theory of prosodic phonology as reviewed above.

As our purpose is to compare the development of the hearing impaired child with that of normally hearing children, we will follow Adam's (2002) stages of prosodic acquisition proposed for Hebrew-speaking children. Adam's study is based on data drawn from several longitudinal studies, including her own, as well as cross-sectional structured tests. The stages of the development of the prosodic word are as follows (ages are a rough average of entering the stage):

a The initial state (age 1;2)
  i Production: Monosyllabic words.
  ii Correspondence to target: The produced syllables correspond to any of the syllables in the target word (e.g. bu for bakbúk 'bottle' and ótobus 'bus', ka for kadúr 'ball' and múzika 'music', ba for bubá/búba 'doll' and balón 'balloon').

b The pre-minimal word stage (age 1;3):
  i Production: Monosyllabic and disyllabic words
  ii Correspondence to target: The monosyllabic words correspond to target words with ultimate stress ($\ldots\sigma\acute{\sigma}\rightarrow\acute{\sigma}$; e.g. du for kadúr 'ball', ma for nigmár 'finished'), including target monosyllabic words ($\acute{\sigma}\rightarrow\acute{\sigma}$; e.g. pa for pe 'mouth', at for od 'more'). The disyllabic words correspond to target polysyllabic words with penultimate stress ($\ldots\acute{\sigma}\sigma\rightarrow\acute{\sigma}\sigma$; e.g. nána for banána 'banana', táto for tráktor 'tractor'). In all cases, the syllables in the children's words correspond to the stressed and final syllables in the target word. Therefore, when the stressed syllable is also final, there is only one syllable in the child's word.

c The minimal word stage (age 1;4):
  i Production: A maximum of two syllables in the word.
  ii Correspondence to target: The syllables correspond to the final and stressed syllables in target words with penultimate stress, as in the previous stage ($\ldots\acute{\sigma}\sigma\rightarrow\acute{\sigma}\sigma$), and to final stressed and pre-final syllables in target words ultimate stress ($\ldots\sigma\acute{\sigma}\rightarrow\sigma\acute{\sigma}$; e.g. adú for kadúr 'ball', imá for nigmár 'finished'). Monosyllabic target words are always monosyllabic in the children's production ($\acute{\sigma}\rightarrow\acute{\sigma}$).

d The pre-final stage (age 1;7):
  i Production: A maximum of three syllables in the word.
  ii Correspondence to target: The syllables correspond to the stressed, final and pre-final syllables in the target words. Target words with ultimate stress are disyllabic, as in the previous stage ($\ldots\sigma\acute{\sigma}\rightarrow\sigma\acute{\sigma}$; e.g. odá for avodá 'work',

dusál for kadursál 'basketball'), and target words with penultimate stress, consisting of more than two syllables, are trisyllabic (…$\sigma\acute{\sigma}\sigma \rightarrow \sigma\acute{\sigma}\sigma$; e.g. akévet for rakévet 'train', tatína for klemantína 'tangerine')

e Final state (age 2;2):

i The words in the children's production have the same number of syllables as in the corresponding target words.

The development of a sample of words, extracted from Adam (2002:90) is given below (the initial state, where either syllable can be produced, is ignored—table 1):

The stages outlined above have been reported for other languages as well. The pre-minimal word stage is reported in Demuth and Fee (1995) for English and Dutch, Fikkert (1994) for Dutch, Grijzenhout and Joppen (1999) for German, and Demuth and Johnson (2003) for French. The latter study is of a French-speaking child (1;1 – 1;8), who produces target CVC and disyllabic words as monosyllabic CV words (stress in French is ultimate). However, these productions were preceded by disyllabic reduplicated words, C_iVC_iV, which in Hebrew appeared after, and not before the monosyllabic production. The minimal word stage is reported for languages such as Dutch (Fikkert 1994), Spanish (Demuth 2001), Japanese (Ota 1998), and Sesotho (Demuth 1994). At this stage, there is variation with respect to monosyllabic target words. In Hebrew, French, and Japanese, monosyllabic words are produced as monosyllabic. In Dutch and English, as reported in Fikkert (1994) and Demuth and Fee (1995), monosyllabic words may gain an extra syllable to fulfil the disyllabic requirement. This report is, however, challenged in Taelman's (2004) quantitative study of the acquisition of Dutch prosody, which shows that syllable addition is not only rare, but also not triggered by prosodic requirements. There are also variations beyond the minimal word stage. In Dutch and English, quadrisyllabic words are produced before trisyllabic words (Fikkert, 1994; Demuth and Fee, 1995; Demuth, 2001), while in Hebrew (Ben-David, 2001; Adam, 2002) and Spanish (Lleó, 1997, 2001), children produce trisyllabic words before quadrisyllabic words.

Subject and method

The child, a Hebrew-speaking boy, has a bilateral profound sensorineural hearing loss of unknown etiology. At the age of 5 months, he was fitted with a binaural personal conventional hearing aid (Phonak E-4). His aided thresholds were 80 dB HL in the right ear and 75 dB HL in the left ear (these levels represent the pure tone average of 500, 1000, and 2000 Hz). His hearing aids improved his auditory awareness to environmental and speech sounds, but according to his parents and his

Table 1. *The development of the prosodic word*

	Target				
Stage	kadúr 'ball'	séfer 'book'	avirón 'airplane'	ʃarʃéret 'necklace'	avocado 'avocado'
Pre-minimal word	dúr	séfer	rón	ʃéret	kádo
Minimal word	kadúr	-″-	virón	-″-	-″-
Pre-final	-″-	-″-	-″-	ʃarʃéret	vokádo
Final	-″-	-″-	avirón	-″-	avokádo

clinician's impression, his responses were inconsistent. From the age of 1;2;10, he has been using a cochlear implant device (Nucleus 24) in his left ear, which lowered his auditory threshold for speech to 25 – 30 dB HL. The child has hearing parents and he uses oral communication only.

The data presented in this paper is a sample from a data base which includes 1772 tokens of the child's speech (for 896 target words), collected during 38 recording sessions of 45 minutes each; the first session was at the age of 1;5;0 and the last at the age of 3;4;24. The elicitation was based on both spontaneous speech and picture and object naming. An experienced speech therapist (the first author) played with the child in a quiet room, using toys and objects, which encouraged the child's spontaneous speech. In addition, a constant set of pictures and objects were shown to the child during each recording session, and he was encouraged to name them, but he did not always react to them verbally, if at all.

All sessions were recorded, using a high quality audio recorder. Five audiotapes recording sessions of the child were selected at random, and a second examiner independently transcribed the sample records. The agreement between the examiners for determining transcription reflected a high degree of inter-judged measurement reliability.

The development of the prosodic word

The analysis of the prosodic word development of the implanted child is presented below, accompanied by a sample of data. We follow the stages of development of normally hearing children, noting any discrepancies encountered.

We identified transition from stage n to stage n + 1 on the basis of two parameters: the number of responses that fit stage n + 1 in general, and their percentage. The child tended to avoid responding to target words that did not fit the stage he was in, although he was shown the same set of pictures and objects during all sessions. For example, during the first five sessions, he responded only to monosyllabic target words, which fitted his initial state. During the 6th session, he started responding to a few disyllabic words (and one trisyllabic), which he produced as monosyllabic, and during the 10th session, he started producing disyllabic words. During the last session of the initial state (the 11th), he responded to three disyllabic target words, one of which was monosyllabic. During the following session, he responded to sixteen disyllabic target words, four of which were monosyllabic. The great increase in the number of target words that can fit the stage (from three to 16), and an increase in the number of productions that fit the stage (from 66% to 75%), allowed us to identify this session as the beginning of the minimal word stage.

The initial state (age 1;5)

During the initial state, the child's vocabulary included mostly monosyllabic words, regardless of the number of syllables in the target word. Most target words were initially monosyllabic, a few were disyllabic, and even fewer, trisyllabic, although the child was shown the entire set of pictures and toys, which also included target words with three and four syllables.

For monosyllabic target words, as in table 2, the child produced various monosyllabic forms: CVC, CV, V:, and V.

Table 2. *Target: monosyllabic words—Production: monosyllabic words*

Target	Child		Target	Child	
Target: CV					
Production: CV			Production: V		
mu	mu	'cow' (sound)	lo	o	'no'
pe	me	'mouth'	ga	a	'duck' (sound)'
me	me	'sheep (sound)'	me	e	'sheep (sound)'
Target: CVC					
Production: CVC			Production: CV		
daj	baj, daj	'enough'	dag	da	'fish'
xam	xam	'hot'	jad	ja	'hand'
			pil	mi	'elephant'
Production: V			Production: V:		
lex	e	'go!'	xam	a:	'hot'
tik	e	'bag'	jad	a:	'hand'
			pil	i:	'elephant'
Target: VC					
Production: V			Production: V:, VC		
op	o	'hop'	ec	e:, en	'tree'
en	e	'none'	af	a:	'nose'

Monosyllabic productions are characteristics of the initial state. Also, as expected with regard to the syllable structure, most words were without a coda. However, what was unexpected for a child acquiring Hebrew were the long vowels and the consonant-free words (either long or short vowels). We will discuss these phenomena later on.

For disyllabic target words, as in table 3, the child produced the same types of monosyllabic words, with the addition of CV:. As in Adam's (2002) study, the syllable in the child's production corresponds to any syllable in the target word. That is, the prominent target syllables that are selected by the child at later stages, i.e. the final and the stressed syllable, are not the preferred ones during this state.

Towards the end of the initial state, or more precisely, during the last meeting of this stage, the child started producing a few disyllabic words (table 4), which reflect a transition to the following stage (throughout the paper, adjacent vowels are heterosyllabic).

These data (added to table 5) are discussed in the section headed 'Subject and method', which describes the minimal word stage.

The pre-minimal word stage

It seems as if the child has skipped the pre-minimal word stage. During this stage children produce monosyllabic words for target words with ultimate stress and disyllabic words for target words with penultimate stress. We did not detect this stage

Table 3. *Target: disyllabic words—Production: monosyllabic words*

Target	Child		Target	Child	
Final stressed syllable			Final unstressed syllable		
bubá	ba	'doll'	íma	ma	'mother'
nigmár	ma	'finished'	maim	i, i:	'water'
limór	mo:	proper name			
Non-final unstressed syllable			Non-final stressed syllable		
mocéc	mo	'dummy'	mjáu	a:	'cat' (sound)
balón	bam	'balloon'	íne	i:	'here'
bakbúk	ba:	'bottle'	álo	a:	'hello'

Table 4. *Target: disyllabic words—Production: disyllabic words*

Target	Child		Target	Child	
balón	baó	'balloon'	mjáu	áu	'cat (sound)'
parpár	aá	'butterfly'	máim	mái	'water'
avijá	aá	proper name			

Table 5. *Target: Polysyllabic words—Production: Disyllabic words*

Target	Child		Target	Child	
Target words with ultimate stress			Target words with penultimate stress		
nafál	apá, papá	'fell'	íma	ípa	'mother'
parpár	aá$_{1,2}$, papá	'butterfly'	mástik	mái	'gum'
balón	baó$_{1}$	'balloon'	mjáu	áu$_{1}$, páu	'cat (sound)'
hadár	aá	proper name	máim	mái$_{1}$	'water'
imrí	ií	proper name	álfa	ápa	dog's name
avijá	aá$_{1}$, iá	proper name	banána	nána	'banana'
kubijót	bijó	'blocks'	ofanóa	nóa	'motorcycle'
masaít	maít	'truck'	miʃkafáim	pái:	'glasses'
melafefón	papó	'cucumber'	naaláim	jái	'shoes'

in the prosodic development of our subject. As shown in table 4, out of his first five disyllabic words, three bear ultimate stress. Nevertheless, we claim that this discrepancy does not indicate deviation from the normal path.

We should bear in mind that the stages reported in Ben-David (2001) and Adam (2002) are based on the study of more than 10 children. This relatively wide range allowed the detection of all stages, but it is not necessarily the case that each and every stage was detected in each child, given the time intervals between sessions. That is, the fact that we do not have data from a particular stage does not necessarily mean that the child has skipped a stage; it might as well be the case that we have probably missed this stage.

Moreover, remnants of the pre-minimal word stage in the implanted child's speech were observed during the minimal word stage, supporting our claim that the child has not skipped a stage. During the minimal word stage (see the following section), which is characterized by maximally disyllabic words, the child also produced monosyllabic words for target disyllabic ones. Here is an exhaustive list: pa for levád 'alone', i: for ʃelí 'mine', pa for nafál 'fell', mo: for limór 'proper name', and kok for liʃtót 'to drink'. The crucial property of these target words is that they all have ultimate stress.

Recall that the pre-minimal stage is characterized by disyllabic words for target words with penultimate stress (*…σ́σ→σ́σ*), and monosyllabic words for target disyllabic words with ultimate stress (*…σσ́→σ́*). Had the child skipped the pre-minimal word stage, we would expect residues from the initial state, i.e. monosyllabic words, corresponding to target words with ultimate as well as penultimate stress. However, the fact that the monosyllabic residues corresponded only to target words with ultimate stress suggests that these are residues of the pre-minimal word stage.

The minimal word stage (age 2;1)

The minimal word stage is characterized by words whose maximal size is disyllabic (or bimoraic, in languages that employ the mora). That is, at this stage, the prosodic word equals a binary foot (Demuth and Fee, 1995; Salidis and Johnson, 1997). As noted in the Introduction, Hebrew-speaking children do not add a syllable to monosyllabic target words, and thus the binary foot sets maximal, but not minimal bound on the word size during this stage

The examples in table 5 present a sample of words produced by the hearing-impaired child during the minimal word stage (subscript '1' indicates that the word appeared towards the end of the initial state; when the same word appeared in both the initial state and the minimal word stage, a subscript '2' was added).

Like the normally hearing children, the child selects from the target word the last two syllables, one of which is stressed. The word maít for masaít seems to be exceptional, as it seems that the first and the final stressed syllables are selected. However, we assume that due to the absence of *s* in his segmental inventory, the child picks the consonant from the first syllable to serve as an onset of the pre-final one (see Gnanadesikan, 1995 for similar cases in English). Notice also, that like the normally hearing children reported in Ben-David (2001), the child does not make any errors with respect to the position of stress.

The pre-final (age 2;6) and final state (age 2;9)

At the pre-final state, the child expands the number of syllables in his words to three syllables. Thus, as shown in table 6, tri- and quadrisyllabic target words are trisyllabic in the child's production.

At this stage, all three syllables of the trisyllabic target words appeared in the child's speech (left column in table 6) but the quadrisyllabic target words were still incomplete. For all quadrisyllabic target words with penultimate stress (the first four words in the right columns), the child produced the final, the stressed and the pre-stressed syllables, i.e. the last three syllables. This pattern also appeared also during the minimal word stage, where he produced the final and stressed syllables for target words with penultimate stress, and final stressed and pre-final/stressed

Table 6. *Target: Tri- and quadrisyllabic words—Production: Trisyllabic words*

Target	Child		Target	Child	
Trisyllabic target words			Quadrisyllabic target words		
ótobus	ótobus	'bus'	misparáim	paái	'scissors'
íkale	íkaje	proper name	ofanáim	anái:	'bike'
banána	babáma	'banana'	naaláim	ajái	'shoes'
ʃamáim	ʃamái	'sky'	avatíax	adía, aíax	'watermelon'
onijá	onijá	'boat'	laavodá	javodá	'to work'
avirón	akijó	'airplane'	akordijón	kodijó	'accordion'
masaít	masaí	'truck'	ipopotám	ipotá	'hippopotamus'
xatulá	xatujá	'cat fm.'	melafefón	meʃeʃó	'cucumber'

syllables for target words with ultimate stress. There was, however, inconsistency with regard to the quadrisyllabic target words with ultimate stress. In kodiyó for akordijón 'accordion', the syllables correspond to the last three syllables in the target word. In javodá for laavodá 'to work', we can also assume correspondence to the last three syllables, with a shift of the onset (as in maít for masaít 'truck' in table 5). However, in ipotá for ipopotám 'hippopotamus' and meʃeʃó for melafefón 'cucumber', the final stressed, the pre-final, and the first syllable were selected, while the second syllable was ignored. Similar forms were found in Ben-David's (2001) study of normally hearing children; e.g. agólet for tarnególet 'chicken', adiyón for akordiyón 'accordion'. The scarcity of such examples in both populations does not allow us to propose any generalization at this stage of research.

Later on, after the child has reached the final state, all his words are prosodically correct in terms of the number of syllables: ofanái for ofanáim 'bike', ofanóa for ofanóa 'motorcycle', miʃiʃái for miʃkafáim 'glasses', misparái: for misparáim 'scissors', masaijó: for masaijót 'trucks', melafefó for melafefón 'cucumber', and ipopotá for ipopotám 'hippopotamus'. However, the development of the syllable structure and the segmental make up of the word (which are beyond the scope of this paper) has not yet reached the final state.

Phenomena specific to the implanted child's speech

Two properties that appeared in the speech of the implanted child were not found in that of normally hearing Hebrew-speaking children: long vowels, and consonant-free words. We will discuss each one of these in turn.

Long vowels

Hebrew does not have phonemic long vowels, and there are also no reports of long vowels in the speech of normally hearing Hebrew-speaking children. Therefore, the appearance of long vowels in the speech of the implanted child may be surprising. However, Hebrew has phonetic long vowels that may arise, in casual speech, from the loss of a medial glottal (e.g. ná/ar — > náar — > ná:r 'adolescent'). In addition, the phonetic correlate of stress in Hebrew is vowel length.

Nevertheless, we argue that vowel length in the child's speech is conditioned by syllable structure in the target word. As the data below suggest, the long vowels in the child's speech correspond to target vowels in two specific environments: (i) in a syllable with a coda ($\ldots CV_iC$ — > CV_i:), and (ii) in a pre-final stressed syllable, when the final syllable is deleted ($CV^{@}{}_iCV_j$ — > CV_i:).

During the initial stage, the child produced long vowels in 57% of the target syllables with a coda (17 out of 30 tokens). This number dropped to an average of 25% in the following stages (30 out of 128 in the minimal word stage and 37 out of 144 in the pre-final stage). There were no words with a long vowel in the final stage. There were very few target words with a pre-final stressed syllable where the child deleted the final syllable. During the initial stage the child produced a long vowel to compensate for the omitted syllable in 2 out of 2 words (100%), and during the pre-minimal word stage, in 6 out of 10 words (60%). Later on, he stopped deleting the final syllable in such words, and therefore there was no context for long vowels. There were only two words in the entire data where a long vowel appeared where neither of the abovementioned conditions were met: i: for imrí 'proper name', i: for ʃelí 'mine'.

The data in table 7 suggest that a long vowel compensates for a missing prosodic unit to the right of the syllable produced by the child, where the missing unit is either a coda or a syllable (see Hayes, 1989) for compensatory lengthening in adult languages). This supports the view that the moraic structure of the syllable is innate. Thus, even children whose target language does not employ the mora (as in Hebrew), have access to this structure at the earlier stages of development, until they get positive evidence that this unit is not relevant for the phonology of their target language. That is, during the early stages, a target CVC syllable has two moras, and the loss of the coda leaves an empty mora, allowing the vowel to spread to its position; a vowel linked to two moras is long (see Hayes, 1989). Similarly, the loss of a syllable leaves an empty prosodic unit, which hosts the spreading of the vowel—figure 3.

Table 7. *Long vowels*

Target	Child		Target	Child	
(i) Target syllable – with a coda					
Monsyllabic			Polysyllabic		
pil	i:	'elephant'	balón	baó:	'balloon'
xam	a:	'hot'	tinók	ió:	'baby'
yad	a:	'hand'	masaít	aí:	'truck'
ec	e:	'tree'	miʃkafáim	pái:	'glasses'
af	a:	'nose'	maim	mái:	'water'
or	o:	'light'	kapít	kapí:	'spoon'
an	a:	'car (sound)'	ofanáim	anái:	'bike'
limór	mo:	proper name	misparáim	misparái:	'scissors'
bakbúk	ba:	'bottle'	masaijót	masaijó:	'trucks'
(ii) Target syllable – pre-final stressed					
mjáu	a:	'cat (sound)'	íne	i:	'here'
díjo	i:	'horse (sound)'	álo	a:	'hello'

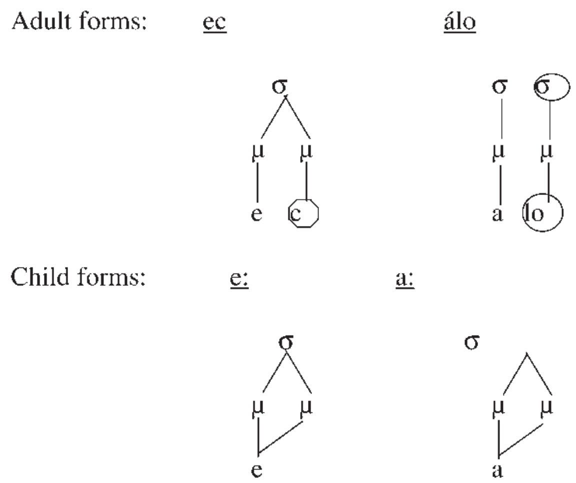

Figure 3. *Vowel lengthening*

The question to be asked is why there are no reports of long vowels in the studies of normally hearing Hebrew-speaking children? One simple explanation could be that the studies on the prosodic acquisition of Hebrew did not control vowel length, as it does not exist in adults' Hebrew (both Adam and Ben-David p.c. informed us that they did not pay attention to vowel length, though Ben-David insisted that she would have noticed long vowels had they appeared).

It should be emphasized that the data of the implanted child were collected during therapy. It is often the case that clinicians speak to the child at a slower rate and higher intensity and frequency than that in normal speech, which may result in vowel lengthening. However, it is not very likely that intervention could lead to the phonological conditions of vowel length noted above.

Another option is that the long vowels do not persist in the speech of normally hearing children beyond the babbling stage. As suggested in the following section with respect to consonant-free words, due to the late onset of sufficient auditory feedback, there was a long period of transition from babbling to speech. Consequently, sounds and structures characterizing babbling, but not the target language, persisted during speech.

Consonant-free words

During the initial state and the minimal word stage, the hearing-impaired child produced quite a few words consisting only of vowels (this phenomenon has been reported by several clinicians who work with Hebrew-speaking hearing-impaired children)—table 8.

According to Ben-David (2001), consonant-free words did not appear in the speech of the normally hearing Hebrew-speaking children. Ben-David emphasizes that there is no stage in the acquisition where the children produced words without a consonant, and explains it, following Tobin (1997), by the requirement to maintain communicative information (see also Nespor, Peña and Mehler, 2003 for the importance of the consonants in speech). The first codas appear in VC words, such as af 'nose' and od 'more'. That is, at the stage where all other words do not have a coda,

Table 8. *Consonant-free words*

Target	Child		Target	Child	
Monosyllabic target words			Polysyllabic target words		
lo	o	'no'	parpár	aá	'butterfly'
ga	a	'duck (sound)'	avijá	aá/iá	proper name
en	e	'none'	imrí	ií	proper name
op	o	'hop'	mjáu	a:/áu	'cat (sound)'
xam	a:	'hot'	sáfta	áa	'grandmother'
pil	i:	'elephant'	tavíi	i	'give me'
af	a:	'nose'	bakbúk	aó	'bottle'
ec	e:	'tree'	adár	aá	proper name

VC words have a coda in order to avoid words without consonants (the only exception is the word or 'light', which appears in the children's speech as o, since r is acquired rather late, and its correspondent in the children's speech is a glottal stop or null).

Studies of consonant-free words are limited, and to the best of our knowledge, there is no explanation at hand. Some studies suggest that consonant-free words may appear in normal development (Bernhardt and Stemberger, 1998; Vihman and Velleman, 2000 for English, Freitas, 1996, Costa and Freitas, 1998 for Portuguese), but others claim that they appear only in disordered development (Menyuk, 1980; Grijzenhout and Joppen, 1999).

We propose that consonant-free words are residues of the babbling stage (this has been suggested by Phiona Margaliyot p.c.). Consonant-free syllables (as well as CV syllables) appear during the babbling stage (Stoel-Gammon and Otomo, 1986; Paul and Quigley, 1994), and they may also persist during the transition phase from babbling to speech (Oller *et al.*, 1978; Stoel-Gammon, 1985). However, the consonant-free words also appeared in the speech of the hearing-impaired child during the minimal word stage, i.e. beyond the initial state. This, we argue, is due to the fact that the child underwent the operation when he was 1;2;10 years old, which means that this is the age when he started getting increased auditory information required for language development (see Introduction for his condition prior to the operation). That is, due to the late onset of sufficient auditory information, the babbling stage lasted longer than usual.

This explanation is supported by the decrease in the number of consonant-free words as the child's language grew. During the initial state, 55% (55 out of 100) of the tokens were consonant-free words, but during the minimal word stage this number dropped drastically to 10.5% (21 out of 200). There were no consonant-free words in the subsequent stages.

Hearing impairment is by no means the only reason for the appearance of consonant-free words. According to Tubul (in progress), children with developmental dyspraxia also produce consonant-free words, which persist even beyond the minimal word stage. At this stage of our research, we maintain the view that consonant-free words are limited to disordered speech and during a short period in the speech of hearing-impaired children (which, on the basis of the present study, we do not consider disordered, given that the child, who has no other developmental problems, has been using the cochlear implant device from an early stage of speech development). Further study is required to determine the conditions under which the appearance of consonant-free words is considered abnormal in the speech of hearing-impaired children.

Discussion and implications

Our study reveals that, with respect to the development of the prosodic word, the acquisition path of the implanted child is similar to that of normally hearing children. We found monosyllabic words in the initial state, whose syllable was selected from the target word without prosodic considerations. We did not find solid evidence for the pre-minimal word stage, but we found signs that the child had passed through this stage. The minimal word stage, where words are maximally disyllabic, was the following one as expected. The further increase in the number of syllables in the word, up to the final state, was also apparent.

As for the age – stage correspondence, the implanted child had a late start, but he certainly caught up towards the end of the development. As shown in table 9 below, the implanted child reached the final state only two months after the slowest normally hearing child in Ben-David's (2001) study. Moreover, it took him only 7 months to progress from the onset of the (pre-)minimal word stage to the final state, much less than it took for the slowest normally hearing child (13 months), and even less than it took for the fastest normally hearing child (9 months).

The two phenomena peculiar to the implanted child, the long vowels and the vowel-only words, have been attributed to a late onset of sufficient auditory input. We believe, following Huttenlocher (1990), Waltzman and Cohen (1998), and Ertmer and Mellon (2001), who studied other phenomena, that the earlier the operation is, the less likely deviant phenomena will appear in the implanted children's speech.

Although the findings of the current study are based on data drawn from one implanted child, they may have important implications for clinical use. The analysis of the data suggests trends in the order of the prosodic development similar to those of normally hearing children. Fee (1997) suggests that prosodic stages provide a model for assessment and treatment of children with delayed phonological development, and we believe that this is also true for assessment and treatment of hearing impaired children. In the evaluation procedure, the clinician should determine the prosodic stage at which the child's speech is, and lead him/her gradually through the following stages.

The dominance of the consonant-free words in the initial stage suggests that at the beginning of the intervention programme, the clinician should be aware of the transition phase from babbling to meaningful speech. This phase is considered within normal development as long as it is a temporary period. Ertmer *et al.* (2002a) suggest that an intervention programme should emphasize prelinguistic vocalization in young children with cochlear implants. They emphasize the importance of presenting

Table 9. *From (pre-)minimal word stage to final state*

Child	Entered (pre-)minimal word stage	Reached final state	Time (months)
Carmel	1;4	2;1	9
Erez	1;6	2;7	13
Implanted child	2;2	2;9	7

speech sounds in isolation and in simple combinations at the beginning of the training programme. Thus, during this period, the clinician should encourage the hearing-impaired child to babble and develop her/his vocal play. This can be done by joining the child in his/her vocal play, while adding meaningful words similar to the sounds produced by the child (Pollack, 1970). Wallace *et al*. (2000) suggest that hearing-impaired children who are not yet speaking, would learn words that match their babble sound patterns better than words that do not. Thus, in planning an intervention programme, the clinician should determine the preferred babble patterns of the child and then add real words that use those sounds and prosodic structures.

However, we should bear in mind that the population of hearing-impaired children is heterogeneous, and there are many variables that may influence their auditory function (age of onset of hearing impairment, degree of hearing impairment, age of rehabilitation, etc.; Tobin, 1997; Quigley and King, 1982; Mayne, Yoshinaga-Itano, Sedey and Carey, 2000). Ertmer, Leonard and Pachuilo (2002b) for example, describe an intervention programme of two children with cochlear implant devices. The children differed in many variables such as age of onset of deafness, pre-implantation communication skills, age of implantation etc. The two children made progress following the treatment programme, but there were differences in the rate and the degree of their achievements.

Moreover, the hearing-impaired child in our study is using a cochlear implant device, which, as noted in the Introduction, allows better perception of speech sounds than conventional hearing aids. Considering the study's results, it is important to investigate the development of the prosodic word of hearing aid users and to compare it to the implanted child's results. This is our future study.

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