Phonotactic Constraints in Young Cochlear Implant Recipients

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1 author:

Paris Binos
Cyprus University of Technology

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ABSTRACT

Considerable attention has been paid to infant vocalization. The aim of the current research is to describe the prelinguistic vocal repertoire of seven young infants wearing cochlear implants and to argue for a strong relation between early developmental stages of speech, as cochlear implantation seems to trigger similar vocal performances to hearing peers. In contrast to previous studies based on typical development which argued for the existence of only one syllable type at each stage of prelinguistic speech, the present study recorded simultaneous co-existence of multi-syllable types of protophones in populations characterized as atypical. Results support a gradual transition from babbling stages into mature, more complex forms of vocalization that we meet on adult speech. Protophonic development is rapid during the first post-implant year. The findings are in agreement with other studies based on typically developing children. The difference is that current data broaden the results to disordered populations, like the infants with cochlear implants. The quantitative classification of protophones, through the combination of acoustic and auditory analyses provides a new reliable perspective for comparisons between populations with similar hearing experience. Speech pathology targets to explore the prelinguistic speech development and current methodology aims to contribute to this direction.

Keywords: Phonotactic constraints; cochlear implant; protophones; prelinguistic repertoire.

1. INTRODUCTION

The “discontinuity theory” [1] arguing for a dissociation between infant speech productions and mature-adult speech. It is important to mention that Jakobson’s studies influenced the literature of language development for many years, since his perspectives were considered as the established theory. The basic argument supporting his theory was the observations he made on babbling stage and the conclusions he draws from the non-existent role of hearing. Many behavioral psychologists have claimed that the development of language over the first two years and beyond is a totally continuous process [2]. It has been documented that roughly 30%-40% of children that are implanted nowadays have been diagnosed with additional developmental problems or handicaps, since hearing loss is often one of the symptoms in pediatric disorders or other medical conditions in childhood [3]. According the “discontinuity theory” babbling contains sounds from the human vocal system repertoire. In contrast, young children use a rule-based mechanism to produce sounds with meaning (words). At the same decade, other studies came supporting the work of Jakobson [1 and 4], from Lenneberg [5] and Lenneberg, Rebelsky and Nicols [6]. Their basic argument comes from the deaf studies, mentioning that deaf infants produce vocalization with similar way as hearing infants do. Their conclusion was that hearing plays no role to language development and deaf vocalization is exactly the same as hearing peers. Curiously, this aspect about the same vocalization between deaf and hearing infants continuous to inspire even today. Children are not born pre-programmed to learn a specific language – any of the world’s approximately 7,000 languages are equally acquirable,8but children not exposed to a language do not learn that language [7].

[1]*Department of Health Sciences, Language and Speech Therapy, European University Cyprus, Cyprus.*
**Corresponding author: E-mail: p.binos@external.euc.ac.cy;*

The aim of the current study is to unravel data supporting that actually there is, a close relation, between pre-linguistic and mature-speech. These aforementioned data will come from the role of babbling, exactly the argument Jakobson and others used, to support the "discontinuity theory". Based on other similar methods of typical development, the current methodology provides, a detailed auditory and acoustical analysis of prelinguistic vocal repertoire of young infants wearing cochlear implants. Respiratory and kinematic studies of the effects of hearing loss on speech patterns inolder children and adults with hearing loss have shown that reduced auditory feedback contributes to disordered segmental and prosodic patterns after speech has been acquired [8].

More recently, a study [9] argued for a strong relationship between first vocals and words. Oller [10] described these first vocals as protophones, supporting the theory of "gradual transition". Supporting data from normal hearing infants come based on the frequency of the place and manner of the consonant-like segments to the input language [9]. They found that, during babbling, NH infants produced more often the consonant-like segments specific to the input language as opposed to other segments, and these were also the segments produced more frequently by adults from the same environment [11]. Other data show a similar trend in the number of vocalization of first stages and latter-adult speech [12].

As can be seen, the study of the babbling period is of great importance since it describes the important stage of early speech development. This high importance of early speech development, it is underlined by the prognostic value that provides to diagnosis of future speech and language disorders. Vocalizations are important for the later speech and language development it is interesting to speculate about reasons why infants possibly vocalize. A part of the reason might be that infants vocalize as a training for early speech development to coordinate the separate devices of the speech apparatus, such as phonation and articulation [11]. If actually there is a relationship among early vocalization and latter speech, it might be the case that a late or deviant vocal development might be related to disordered language development. As Oller, Eilers, Neal and Schwartz [13] stated "delayed onset of canonical babbling can predict delay in the onset of speech production" (p.223). Stoel-Gammon [14] also mentions a transitional step to early language, while Ertmer and Melon [15] mentioned that typical infants reach the canonical babbling stage, at 6-7 months of age producing protophones with the CV type form. A quite different explanation for infant vocalizations might be the (probably unintentional) expression of (pleasant or unpleasant) feelings, especially during the first months of life [11].

From a theoretical and clinical point of view, study of the outcomes of early vocalization of normal hearing infants or young cochlear recipients is a big dare. Many obstacles can arise decreasing the reliability among researchers. For example, there is variability in transcription process about the manner or place of articulation of consonants as well as specifying vowel identity. Oller and Lynch [16] described the limitations of using IPA to transcribe infant speech, which is a common transcription practice for adult speech and they suggested an analysis via an infraphonological framework which the current study also follows. According to a recent perspective [17] more research is needed in the babbling patterns in different languages to support the above hypothesis. It appears that the study of babbling patterns can be developed to serve as an early diagnostic tool for children with cochlear implants, providing indications for the onset of language-specific processing.

2. MATERIALS AND METHODS

Seven infants wearing cochlear implants participated with chronological age at the beginning of the recordings 1:10-4:0 years and post implantation age from 0:0-1:3 years. The infants completed the implantation criteria of the ENT AHEPA University Hospital of Thessaloniki. The participants were not diagnosed with any other developmental disorder or difficulty and had unknown deafness aetiology. The families of the participants were characterized as typical median socio-economic class and they received detailed instructions and frequent face-to-face training during the process. All families provided written consent for the child's participation. The recordings of spontaneous productions performed based on digital equipment, a Sony PCM-D50 portable linear recorder with high recordings standards (sampling rate of 44.1 kHz and 16-bit precision. The results analysed through the classic methodological process of acoustical and auditory analyses. After this step, the number of protophones was classified based on the number of syllables of each protophone type via the wide band spectrography using the necessary analysis software Praat (4.110). Prior to implantation the children had an average unaided hearing loss of more than 90 dB HL in the better ear. A detailed description of participants wearing implants can be seen in Table 1.

During the data collection audio recordings of approximately 40-60 minutes per session aimed to capture spontaneous interactions between caregivers-infants over a span of 6 months during the first-year post-implant. During recordings, subsequent editing was done to remove what called "vegetative data", specifically cries, gulping, sneezes, sudden loud sounds etc. The final corpus used for analysis was 15 minutes long per month and it involved all protophones during a given recording.

The vocalization types (protophones) that were classified into five categories and listed below (where C-consonant & V-vowel):

1. Isolated vowels
2. Monosyllables (CV-CCV-VC-CVC)
3. Disyllables (CVCV-VCV-CVCVC)
4. Trisyllables (VCVCV-CVCVCV)
5. Polysyllables (reduplicated/variegated babbling)

Each vocal type was defined and subsequently analysed independently by using spectrographic analysis via Praat. The current methodology following Oller's infraphonological theory accepted that each syllable type reaches an upper limit of about 500 msec. Consonant-vowel boundaries were defined based on their formant energy structure. Thus, the onset of an utterance was defined to the first glottal pulse and the end to the loss of formant energy structure where is the point of the first cycle with decreased amplitude.

3. RESULTS

In contrast to previous studies based on typical development and argued for the existence of only one syllable type at each stage of prelinguistic speech, the present results recorded simultaneous co-existence of multi-syllable types of protophones (Jakobson, 1968; Lenneberg, 1967). Table 2 depicts the overall number of recorded vocalizations and the respective number for each type separately. Fig. 1 provides a visual depiction of the number of recorded protophones across post-implantation months. The figure shows a clear preference to disyllables structures. Based on current data, as can be seen in Table 2 and Fig. 1, these CI infants show a clear preference to open syllables, since there are not many productions with a consonant as suffix. Overall, 598 spontaneous vocalizations were recorded, classified and analysed via auditory and acoustical analyses.

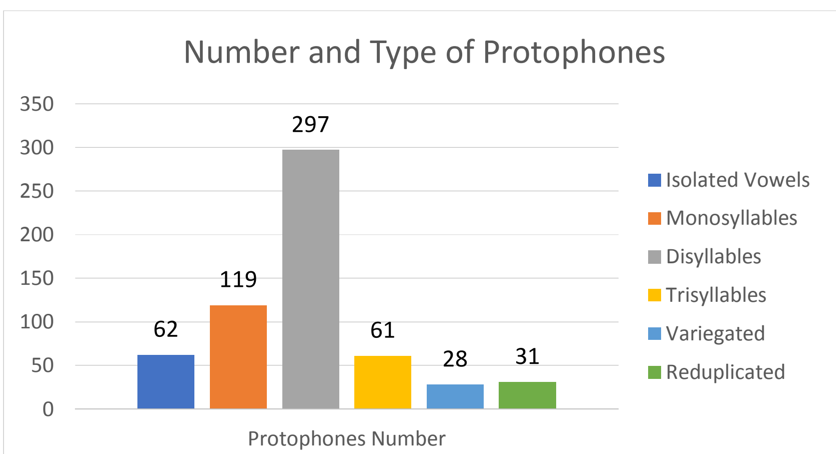

Fig. 1. Number of recorded protophones for each phonotactic structure during post-implant age

Table 1. Participants wearing Cochlear Implant's detailed data

Name & Gender	Chronol Age Start Recording	CI Type	PTA	CA at Implantation	PIA	Diagnosis	Cause	Other Disorder	No of Rec & Record Duration
GR-F	1:10	Cochlear Contour Adv 24RE Freedom	20 dB HL	1:4	0:6	n/s	Congenital	no	5 0:6-0:11
KB-M	2:6	Sonata ti100 Medel Opus 2	18 dB HL	1:11	0:7	n/s	Congenital	no	4 0:7-1:3
SE-F	2:1	Cochlear Adv 24RE Freedom	17 dB HL	2:1	0:0	n/s	Congenital	no	4 0:0-0:6
BP-M	3:11	Cochlear Adv 24RE Freedom	17 dB HL	3:11	0:0	n/s	Congenital	no	5 0:0-0:6
KM-F	3:0	Cochlear Adv 24RE Freedom	13 dB HL	2:10	0:2	n/s	Congenital	no	4 0:2-0:7
BA-M	4:0	Cochlear Straight 24 RE CP810	38 dB HL	4:0	0:0	n/s	Congenital	no	4 0:0-0:7
AK-F	3:6	Cochlear Adv 24RE Freedom	17 dB HL	3:4	0:2	n/s	Congenital	no	4 0:2-0:7

Table 2. Classification of prelinguistic vocalization of seven CI participants

Vocal Type	**CIs**
V	62
Monosyllables	119
Disyllables	297
Trisyllables	61
Reduplicated	28
Variegated	31
Overall	598

Table 3. Vocal classification across the six months post-operatively of two CIs

Child SE	**Number of Protophones (speech productions)**														
PIA	**CA**	**V**	**CV**	**CVV**	**VCV**	**CVC**	**CCV**	**CVCV**	**CVCVC**	**VCVCV**	**CVCVV**	**Reduplicated**	**Variegated**		
0:0	**2:1**	**2**		**1**								**1**			
0:1	**2:2**	**4**			**1**										
0:4	**2:5**														
0:6	**2:7**	**1**	**2**		**1**	**4**	**1**		**1**	**2**	**1**		**2**		
Child GR	**Number of Protophones (speech productions)**														
PIA	**CA**	**V**	**CV**	**VC**	**CVV**	**VCV**	**CVC**	**CVCV**	**VVCVCV**	**CVVCVV**	**VCVVCV**	**CVCVV**	**CVVCV**	**Reduplicated**	**Variegated**
0:6	**1:10**	**22**	**7**		**12**		**1**	**31**		**1**		**1**		**5**	**6**
0:7	**1:11**		**1**		**2**			**11**						**2**	
0:9	**2:1**				**1**	**1**		**7**							
0:11	**2:3**	**2**	**5**	**1**		**5**		**21**	**1**		**1**		**1**	**1**	**1**

Table 3 illustrates the vocal classification of two participants across the first 6 months post-operatively. It can be seen a gradual transition to more complex forms of vocalization. This example, of only two from the seven participants is still representative, to the team's similar gradual trend from simple to complex protophones. For example, for the participant GR, the analyses showed the existence of disyllable structures from the beginning to the completion of the first post-implant year or the continuous presence of multisyllable structures (reduplicated or variegated) from the beginning to 6 months after implantation for the participant SE.

4. DISCUSSION

The current quantitative classification of protophones revealed the simultaneous existence of multiple vocalization types across the first post-implantation months. Each stage of language development contains mixed vocal types, in contrast to other views which argue for the existence of each type only. The results agree with Oller [10] and broaden the conclusions to disordered populations. This assumption is what new commits the current study to the babbling research based on Greek language. Expand previous results of typical development to populations with questionable deviant language development. Even though, it is not clear from what age hearing affects early speech and language development, we can expect that lack of hearing influences vocal development within the first year of life, especially for nowadays young cochlear implant recipients.

The presented classified vocalization of young cochlear implant recipients seems to contain similar vocal structures and similar babbling process that we meet at normal hearing peers. This assumption comes in contrast to studies argued for universal patterns of infant vocal behaviour. These studies see the early vocal behaviour as a gradual maturational process despite the environmental factors affecting the input [5 and 18]. As can be seen, current data show that cochlear implants trigger a similar performance radically different from deaf infants described in the past, since auditory perceptual ability affects vocal behaviour [8, 19 and 20].

DISCLAIMER

This paper was presented in the following conference.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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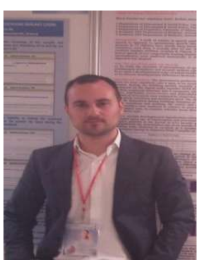
Biography of author(s)



Paris Binos
Department of Health Sciences, Language and Speech Therapy, European University Cyprus, Cyprus.

He is a Certified Speech Pathologist, Certified Clinical Supervisor and Research Associate also the member of the AG Bell Association for the Deaf and Hard of Hearing (USA) and Assoc. Editor of the Volta Review (Journal). He holds an MS in Special Education and an MA in Language Disorders / Neurolinguistics (Essex University, UK). His Ph.D. thesis was about Phonoprosodic Features of infants wearing Cochlear Implants and he received a research award by the European Social Fund for studying Language Development in Cochlear Implants. Dr Paris Binos also holds an FHEQ in Brain and Language from the University of Oxford, and a certificate in Audiology from the Ear Institute of UCL, London. He has published in many International Journals and he has presented his work in many European and International Conferences (ESPCI 2011, 2013; ICED 2015; HEAL 2014 etc). Presently, he is a Research Associate at the European University Cyprus, Cyprus University of Technology and Visiting Lecturer in Dentistry School of Aristotle University, Greece.