

RESEARCH ARTICLE

Correlation between perceptual speech intelligibility and word duration in 4-6 years old children with cochlear implant

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Abstract

Background and Aim: The speech intelligibility is evaluated through the perceptual and acoustic methods. In the perceptual method, the speech intelligibility is investigated using the listener's judgment. On the other hand, in the acoustic method, the acoustic parameters related to speech are studied. This study aimed to evaluate the association between the suprasegmental components and perceptual speech intelligibility through investigating the correlation between the mean duration of speech at the word level with the percentage of speech intelligibility in children with cochlear implant.

Methods: This study was conducted on 18 children with cochlear implant within the age range of 4-6 years. The participants were asked to repeat 30 selected Persian words displayed in a video show while their voices were recorded by a microphone. The evaluation of perceptual speech intelligibility was performed using the judgment of three listeners who were unfamiliar with the speech of the hearing impaired children. The speech duration was calculated

through the Praat software version 5.2.25.

Results: According to the results, the mean of words duration was 0.5140 ± 0.098 seconds and the mean percentage of the perceptual intelligibility of the selected words was 47.78%. Furthermore, the speech duration was significantly correlated with perceptual speech intelligibility ($p < 0.001$).

Conclusion: The speech duration plays a prominent role in determining the speech intelligibility in the children with cochlear implant at the word level. Therefore, this method can be applied in the clinical rehabilitation programs implemented for these children to increase their speech intelligibility in an appropriate manner.

Keywords: Duration; perceptual intelligibility; cochlear implant

Introduction

Speech intelligibility is defined as the amount or degree of a specific message comprehended by a listener, depending on various segmental and suprasegmental speech components [1]. Several factors can affect the clarity of speech. Permanent hearing loss as the most important factor is significantly affects the development of speech and language of an individual [2,3]. Hearing loss can lead to many errors in the speech units

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in these children, which could have an impact on the vocal acoustic properties and speech intelligibility [4-6].

In case of the early detection of the hearing loss, through the prescription of the hearing aids, and performing the required educational and treatment programs, these children could reach to the normal speech condition until the age of three [7]. Cochlear implantation is an effective strategy used for patients with severe to profound bilateral hearing loss. It has been documented that this approach has positive effects on the language and speech growth [2,8].

Speech intelligibility is speech intelligibility evaluation is the gold standard and a comprehensive tool for assessing the effectiveness of the cochlear implant on the development of speech skills. This measure is directly associated with the verbal communication performance and regarded as the only applied technique for the assessment of the verbal communication [1,9]. Various studies have evaluated the speech intelligibility using the perceptual and acoustic techniques.

In the perceptual method, the intelligibility score is obtained based on the perceptual judgment of the listeners regarding the percentage of the clarity of words or syllables in the speech samples of a child [1,8,10]. On the other hand, the acoustic properties of speech sounds are assessed in the acoustic technique. Prosody is one of the components associated with perceptual intelligibility of speech, which is evaluated acoustically [1,11]. The duration of speech sound production and pauses are other important parameters that determine the prosody and speech intelligibility [1].

Although, there are many studies evaluating the speech intelligibility in the children with cochlear implant and its effective factors, in the majority of these studies, the investigated children did not receive the same rehabilitation approach. Furthermore, the perceptual judgment of the speech clarity in these children was mainly performed by individuals who were familiar with speech of hearing impaired children. Therefore, the scores and results of these studies cannot be compared with one another. In other words, in

these studies, the final results cannot be generalized [10,12,13].

Nevertheless, these drawbacks were considered in the present study. In this regard, children were evaluated using similar rehabilitation approach. In addition, the perceptual speech intelligibility of the subjects was assessed by the listeners who were unfamiliar with the speech of these children. Based on the available evidence and studies, the speech duration was one of the suprasegmental parameters, selected to be determined in the acoustic analysis performed in this study.

Although speech intelligibility is affected by such segmental components as production accuracy, this is not the only factor that determines the intelligibility. This is to the fact that occasionally an individual have a low production accuracy, however his/her speech intelligibility is at an acceptable level, since errors can be expected in articulation disorders. Therefore, despite the production errors, the listener can detect the speech of the person and comprehend it because of the predictability of speech errors [1].

With the above mentioned background, this study aimed to evaluate the association between the suprasegmental components and perceptual speech intelligibility through investigating the correlation between the mean duration of speech at the word level with the percentage of speech intelligibility in children with cochlear implant.

Methods

This analytical and cross-sectional study was conducted on 18 children (8 males and 10 females) within the age range of 49-67 months with severe to profound hearing loss having undergone cochlear implantation. The participants were selected through the purposeful simple sampling method. The present study was approved by the Ethics Committee of Jundishapur University of Medical Sciences, Ahvaz, Iran, with the ethical code of IR.AJUMS.REC.1394.491. The sample selection was based on the medical records of the children, who had undergone cochlear implantation in the Cochlear Implant Center of Imam Khomeini Hospital in Ahvaz.

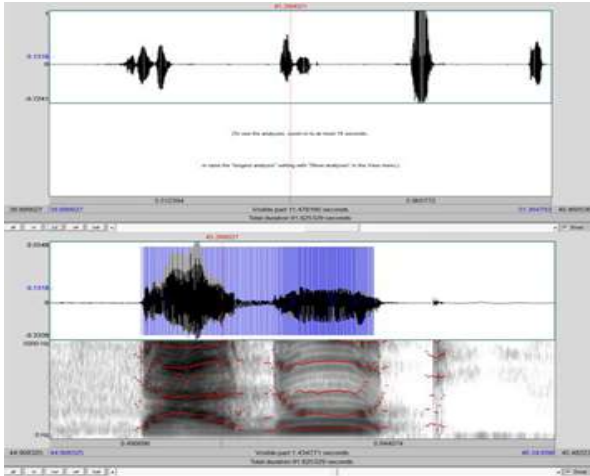


Fig. 1. An example of measuring word duration in Praat.

The inclusion criteria were: 1) age range of 4-6 years, 2) complete participation in the required rehabilitation sessions after receiving the cochlear implant, 3) the use of auditory-verbal therapy in the rehabilitation program, 4) an overall elapsed time of at least one year from the surgery, and 5) no mental disorders or other language and speech impairments. On the other hand, the exclusion criteria included the unwillingness of the family to participate in the study, participation in the rehabilitation sessions more than required within the first year after implantation surgery, and lack of the children's cooperation during the tests. The written informed consents were completed by the parents prior to the study.

To collect the speech samples of the children, 30 words were selected from the Persian speech intelligibility test [14]. In the acoustic room, the process was explained to the child based on the guidelines of the test. In addition, the participant was asked to pay attention and listen to the displayed video and repeat the presented words. Subsequently, the child's voice was recorded by a microphone (C410; AKG Acoustics, Vienna, Austria). The microphone was placed 6 cm away from the speaker's lips and the voice was recorded with the sampling rate of 44.1, using an external audio interface (US-122mkII,

TASCAM, China). The recorded files were saved in a specific hard disc. However, the sound recording was initiated two seconds before the expression of the words in order to monitor the ambient noise [15].

In line with the study objectives, the recorded samples were evaluated through the application of the perceptual and acoustic methods. In the perceptual method, the recorded samples were played for three Persian-speaking individuals, who were unfamiliar with the speech of the hearing impaired children and unaware of the selected words expressed by the participants. Then, they scored the expressed words based on their levels of clarity. Accordingly, those words which were clearly heard were assigned one score, and the unclear words were allocated zero point. The speech intelligibility score of the participants was estimated based on the following formula (in percentage):

$$\frac{\text{number of clearly heard words}}{\text{total spoken words}} \times 100$$

The inter-rater reliability of the test was confirmed using the intra-class correlation coefficient (ICC). Subsequently, the mean of the scores given by the three listeners was calculated for each of the participants and considered as the percentage of their perceptual intelligibility. The acoustic analysis of the recorded samples was carried out using the Praat software version 5.2.25. This software facilitated the determination of the border of the beginning and end of each word based on its waveform and spectrogram (Fig. 1). In addition, each word was evaluated through the auditory test for several times in order to confirm the accuracy of the determined boarder. Subsequently, the duration of all words was recorded and the mean was estimated based on the mentioned method.

The data were analyzed using the descriptive statistics (i.e. mean, standard deviation, minimum, and maximum). Normal distribution of data was confirmed by Kolmogorov-Smirnov test at a significance level of 0.05. The Pearson's correlation coefficient was employed for the correlational analysis.

Table 1. The demographic characteristics of the children with cochlear implant

Case	Sex	Age (month)	Duration of cochlear implant use (month)
1	boy	67	48
2	girl	54	21
3	boy	62	30
4	girl	51	28
5	girl	49	32
6	boy	63	25
7	girl	50	19
8	boy	56	18
9	boy	62	21
10	girl	49	35
11	boy	65	38
12	girl	59	37
13	girl	53	30
14	girl	49	17
15	girl	61	29
16	boy	64	22
17	boy	66	30
18	girl	56	38
Mean (SD)	-	57.55 (6.40)	28.77 (8.37)

Results

According to the results of the study, the mean age of the participants was 57.55 ± 6.40 months. The mean duration of cochlear implant use in the children was 28.77 months. The demographic characteristics and duration of cochlear implant use in all of the participants are separately presented in Table 1.

Based on the results of the acoustic analysis, the mean duration of words was 0.51 ± 0.09 seconds (Table 2). Moreover, high stability was found among the three listeners ($ICC=0.93$, $p<0.001$). The mean perceptual intelligibility was found to be 47.78%. There was a strong correlation

between the perceptual intelligibility and word duration ($r=0.91$, $p<0.001$; Fig. 2).

Discussion

Prosody, which is defined as the tune and rhythm of speech, is one of the suprasegmental parameters related to speech intelligibility [1]. Speech duration as one of the major primary in determining the prosody, was evaluated as an acoustic parameter on the word level in this study. According to the results of the present study, the mean duration of the word was 0.51 ± 0.098 seconds, which was significantly correlated with the percentage of perceptual intelligibility ($r=0.90$, $p<0.001$). In other words, increased duration of words was associated with elevated perceptual intelligibility (Fig. 1).

In a study conducted by Kord et al., the mean duration of the sentence was 2.79 seconds [10]. The results of our correlational analysis was in line with those obtained in the mentioned study, which investigated the association between speech duration and prosody in declarative sentences ($p=0.001$) and questions ($p=0.002$). Moreover, in other studies, such as those carried out by Kent and Read or Monsen and Shaughnessy, a positive relationship was reported between speech duration and perceptual intelligibility [11,16].

Nonetheless, there are several studies which rejected the direct relationship between increased duration and higher speech intelligibility. For instance, Nejime and Moore stated that the increase of word duration that is disproportionate to other respective time dimensions could not improve the speech intelligibility [17]. In another study, Tanaka et al. indicated that the increased intelligibility of speech would

Table 2. Perceptual intelligibility and duration in children with cochlear implant

	Mean (SD)	Min	Max
Duration (ms)	0.5140 (0.013481)	0.35	0.76
Perceptual intelligibility (%)	47.78.7 (20.33834)	21.11	85.55

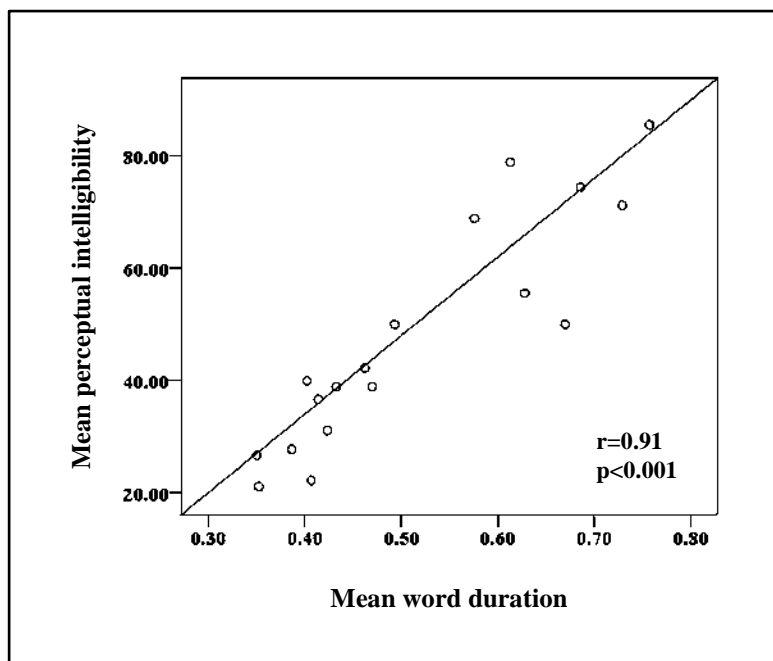


Fig. 2. Correlation of perceptual speech intelligibility with the word duration in children with cochlear implant.

improve provided that there was a coordination between the speech duration and the pauses between words and phrases [18].

Given the significant association between speech duration and intelligibility on the word level and significantly higher mean duration in the children with cochlear implant in comparison to their normed counterparts, the increase of speech duration can be concluded as one of the strategies that can be applied by these children to increase the speech intelligibility. This finding is consistent with the results obtained by Girgin and Ozsoy regarding the increased speech duration in children with cochlear implant [19]. Therefore, this parameter can be taken into consideration in the rehabilitation programs, which are implemented after cochlear implantation activation or prescription of hearing aids, especially those executed during the first year after these interventional procedures, to increase the perceptual intelligibility of speech in these children. However, to improve the perceptual intelligibility, this parameter should be emphasized along with other prosodic features of speech production in these programs.

In this study, a direct relationship was observed between the increased speech duration and intelligibility on the word level; however, this may not be the case for other speech units. The most practical context to evaluate the intelligibility is conversational speech, which usually includes longer speech units. In this regard, increased abnormal and disproportionate duration (e.g. duration of vowels and pauses) in the language levels longer than words (e.g. phrase or sentence) might lead to the loss of listener's concentration, which may result in the reduction of the speech intelligibility [20]. Therefore, further studies are recommended to investigate the association between intelligibility and duration of sentences and conversational speech in children with cochlear implant. Moreover, while different suprasegmental parameters have been examined in various studies, no specific relationship has been identified between these parameters and speech intelligibility [12]. Consequently, further studies are required to evaluate the correlation between the suprasegmental parameters and perceptual intelligibility. It is also suggested investigating the association of other

suprasegmental components on word, sentence, and conversational speech levels with perceptual intelligibility in children with cochlear implant using similar educational features and instruments.

Conclusion

As the results of the present study indicated, there was a significant and direct relationship between the duration and perceptual intelligibility of speech on the word level. Given the longer mean duration of speech in children with cochlear implant, compared to their normal counterparts, this parameter could be regarded as a compensatory method applied by these children to increase the speech intelligibility. Therefore, this method can be utilized in the clinical rehabilitation program held for these children in order to increase their speech intelligibility in an appropriate manner.

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