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Effects of Vowel and Consonant Duration Transformation on the Speech Intelligibility in Children with Hearing Loss

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Abstract

The present study aimed at investigating the effects of transformation of vowel and consonant duration on the intelligibility of speech in children with hearing loss. Sixteen bisyllabic words with stop consonants and vowels, uttered by participants with severe sensorineural hearing loss and normal hearing participants in the age range of eight to ten years were recorded, and the vowel duration and consonant duration were analysed acoustically. Results of statistical analyses revealed that there were significant differences in both the vowel duration and consonant duration between the participants of two groups. The mean values of both vowel duration and consonant duration of the participants with normal hearing were used to transform (to approximate the normal values) the vowel and consonant duration (individually and in combination) in the speech of the participants with hearing loss. The results of perceptual analysis showed significantly higher speech intelligibility scores for the transformed words compared to the unaltered words spoken by the children with hearing loss. Combined transformations resulted in the highest improvement in speech intelligibility compared to the individual transformations of vowel duration and consonant duration.

Keywords: Vowel duration, Consonant duration, Acoustic analysis, Hearing loss, Transformation of speech

Introduction

Normal hearing is essential for typical speech development. Hearing monitors speech acquisition and production[1–3]. Verbal language perception, development, and production are strongly related to the auditory sense[4,5]. Auditory stimulation enables the development of speech perception in infants, and speech perception facilitates early speech and language development[6]. Therefore, hearing loss can negatively affect the development of speech and language in children[7–9].

Past researchers have reported the impact of hearing loss on the acquisition and development of speech[3,10–13]. Children with hearing loss (CHL) encounter severe communication problems – normal speech is unintelligible to the child with hearing loss, and due to the lack of auditory feedback, the child encounters difficulty in speech production[14] – leading to both segmental and suprasegmental errors[15]. These errors in the segmental and suprasegmental aspects contribute to the poor intelligibility of speech in CHL[7]. Therefore, to develop more effective methods of speech training for the CHL, it is necessary to study the deviation in their speech from that of the CNH and hence, the analysis of acoustic parameters in the speech of the CHL becomes essential.

Vowel duration is one such important acoustic (temporal) parameter of speech that has been studied by various investigators, under different conditions. Vowel duration refers to the duration from the onset to the offset of the vowel[16], measured in terms of milliseconds[17]. Studies on acoustic analyses of speech in children with normal hearing (CNH) have reported that the vowel duration is influenced by effects operating at the level of phonetic segments[18]. Duration of any particular vowel depends on its height, the position in the word, accentual or tonal characteristics, rate of speech, grammatical complexity, adjacent segments, word length and the physical and psychological state of the individual[16,19]. These differences in vowel duration have considerable impacts both on the production and perception of segmental aspects, as vowels form the nuclei of the larger segments of speech. Several past studies that have investigated vowel duration in the utterances of the CHL and CNH and have reported significantly longer vowel durations in the utterances of the CHL compared to the speech of the CNH[18–26].

Consonant duration is one of the several temporal parameters of speech related to the production of the consonant. Studies have revealed that, in general, the speech of the CHL have longer consonant durations than the CNH[17,20,27,28]. Researchers have also documented higher standard deviation values of the consonant duration in the speech of the CHL compared to that of CNH[28]. Longer segmental durations in the speech of the CHL have been found by a large number of studies[27,29,31–36]. Thus, studies have revealed significant differences in the duration of both vowels and consonants between the CHL and CNH.

Errors in vowel and consonant production can negatively affect the speech intelligibility of the CHL[18,37–41]. Past researchers have attempted to identify the factors affecting the speech intelligibility in CHL and have reported that the errors in the production of consonants affected speech intelligibility more than the errors in vowel production and both consonant and vowel errors together were the best predictors of speech intelligibility of the CHL[37].

Research to determine the factors responsible for poor intelligibility of speech in CHL has been ongoing. Several efforts have been carried out to determine the factors and their importance in correcting the speech of the CHL to improve the intelligibility of speech[29–32]. Several methods of speech corrections – including the training studies and the computer transformation of speech – have been used to determine the factors, the correction of which would improve the intelligibility of speech in CHL.

Osberger and Mc Garr[33] pointed out that the trouble with the training studies was that the training often resulted in changes in speech other than those of interest. The effects of phoneme and prosodic feature production on speech intelligibility have also not been separated in these studies. Recent investigators have attempted to eliminate these confounding variables by using computer speech processing techniques. Some studies have used these computer processing techniques, and the speech of the individuals with hearing loss have been transformed or modified to correct the segmental and suprasegmental errors selectively, to determine the effect of correction of each type of error on the intelligibility of speech[17,31,32,34–36]. Studies that have carried out the correction of timing errors via speech synthesis have reported improvement of intelligibility in speech of the CHL[31,48].

The use of transformation of speech of the CHL offers several advantages over the traditional speech correction studies. Transformation of speech permit manipulation of a specific acoustic parameter to the desired manner, without modifying other parameters and thus helps to determine the effect of transformation of a specific parameter on the speech intelligibility of CHL[29,35]. Speech correction of CHL using transformation may be helpful to identify the acoustic parameters that contribute most to improve the intelligibility of speech. Once identified, these parameters may be given particular focus during therapy for CHL.

Several investigators have attempted to analyse and transform the acoustic, spectral and temporal parameters in the speech of the CHL to find out the possible improvement in the intelligibility of speech[17,24,36–39]. However, most of these studies have only documented the effect of the transformation of individual parameters on the intelligibility of speech in CHL. Further, studies have involved the transformation of specific acoustic parameters related to either consonant or vowel production in the speech of the CHL. A limited number of studies have investigated the improvement in the intelligibility of speech following the transformation of both consonant duration and vowel duration in the speech of the CHL. Thus, the present study aimed at investigating the effects of the transformation of vowel and consonant duration individually and in combination, on the intelligibility of speech, in the CHL.

Method

Participants

The present study included two groups of participants. Group 1 consisted of ten male CHL with a mean age of 10.5 $\pm$ 1.1 years (range 9 to 11 years). All the participants of group 1 had congenital bilateral sensorineural hearing loss with a pure tone average greater than 70 dBHL in the better ear[40] as per the audiometric testing. All the participants were attending speech and language therapy and using binaural hearing aids regularly at least for the past three years. Group 2 also included ten male CNH with a mean age of 10.4 $\pm$ 0.9 years (range 9 to 11 years). Participants of group 2 had normal hearing sensitivity in both the ears[40] as per the audiometric testing and age-appropriate speech and language skills. Participants of both groups were native speakers of Kannada (an Indian Language spoken in Karnataka state in Southwestern India) and were able to read Kannada words. None of the participants had a history of neurological, psychological or other problems. Participants of both groups belonged to middle socio-economic status as per socioeconomic status scale[41].

The number of participants was determined based on the statistical power analyses using G-Power (ver. 3)[26] using the mean and standard deviation values of the parameters in the speech of CHL reported by earlier investigators[17,39]. The power of the test was assigned a value of 0.8 and the α error probability of 0.05. Convenience and purposive sampling were employed in selecting the participants. The purpose of the voice recording was explained to all the participants, and informed consent was obtained. The institutional ethical committee approval was obtained prior to the study.

Materials

Eighty simple bisyllabic meaningful Kannada words (CVCV) (without geminate clusters) with voiced and unvoiced bilabial (/p/ and /b/), dental (/t/ and /d/), velar (/k/ and /g/) and retroflex (/ṭ/ and /ḍ/) stop consonants in initial and/or medial position and vowels /a/, /i/, /u/, /e/ and /o/ were selected from Kannada textbooks meant for children studying in the first, second and third standard. In order to select the words that were most familiar to the children aged eight to ten years, three primary school teachers, who were native speakers of Kannada, were instructed in Kannada, to rate each word based on the familiarity to the children of eight to ten years. They were as to rate the word as "not familiar", if the word was used by the children in the class less than 50% of the time, as "familiar", if the word was used approximately 50% to 75% of the time by the children in the class, and "most familiar" if the word was used approximately more than 75% of the time by the children in the class. Sixteen of forty words which were rated as "most familiar" by all the teachers were selected. The words were selected such that there met the following criteria, i.e., two words in each with the voiced bilabial, dental, velar, retroflex stop consonants and the unvoiced bilabial, dental, velar, retroflex stop consonants in the initial and medial position.

Data collection

The recording was carried out in a sound-treated room used for audiometry which met the ANSI specifications prescribed for hearing evaluation[42]. The room was free from distraction and had a comfortable temperature and well lit. Each participant was seated comfortably in a chair in front of the laptop during the recording. Each target word typed on the card (6"x 4" size) was presented to the participants. The CNH were instructed in Kannada to read the word written on the card. Similar instructions were given to CHL in the auditory and visual modality (using gestures). Each CHL wore the hearing aids suitable for his/her hearing loss during the evaluation. All the participant were asked to repeat the word three times, and the speech samples were recorded using a dynamic microphone onto the Praat software (version 6.0.56)[43]. The microphone was placed at a distance of 15 cm from the participant's mouth. All the samples were digitised at a sampling frequency of 44.1 Hz and 16 bits/sample quantisation. Thus, 16 words, uttered three times each, yielding 48 utterances were recorded from each participant and were stored on the hard disk for analyses. Out of the three recordings of each word, the most stable recording was chosen for analysis.

Acoustic analysis

The vowel duration of the vowels /a/, /i/, /e/, /u/, /a:/, /o:/ and /e:/ and the consonant duration of the voiced and unvoiced bilabial (/p/ and /b/), dental (/t/ and /d/), velar (/k/ and /g/) and retroflex (/ṭ/ and /ḍ/) stop consonants in medial position were measured using Praat software in the utterances of the participants of both the groups. Vowel duration (in ms) and consonant duration (in ms) were measured from all the words through Praat software. Vowel duration and consonant duration values extracted from all the words uttered by the participants of both the groups were tabulated and statistically analysed.

Transformation of acoustic parameters

Transformation involved the modification of the vowel duration and consonant duration individually and in combination in the speech of the CHL to approximate the normal values as in the speech of the CNH. Transformation of vowel and consonant durations in the speech of the CHL were carried out by reducing the vowel, and consonant durations in the speech of the CHL, as the vowel and consonant duration values were significantly higher in the speech of the CHL. The vowel and consonant durations were modified using the Praat vocal toolkit – a free plugin for Praat with automated scripts for voice processing. Thus, the vowel duration values of both medial and final vowels in all the sixteen words uttered by all the CHL were modified to approximate the normal mean vowel duration values and saved on the hard disk of the computer for perceptual analysis. The consonant duration values of both initial and medial consonants in all the sixteen words uttered by all the CHL were modified to approximate the normal mean consonant duration values and were saved on the hard disk of the computer for perceptual analysis. Further, the combined modifications of vowel duration and consonant duration were carried out in the utterances of the CHL. To carry out the combined modification of vowel duration and consonant duration, the utterances in which the consonant duration had already been transformed were used, and the vowel duration was transformed and was saved as separate files. Thus, the transformation of the words spoken by the CHL was carried out in three different ways: vowel duration was transformed alone; consonant duration was transformed alone; the combination of both vowel duration and consonant duration were also transformed.

Perceptual analysis

Three qualified female speech-language pathologists and three female naïve listeners were selected to carry out the perceptual evaluation of the unaltered and the transformed utterances of the CHL. A sound-treated room used for audiometry which met the ANSI specifications prescribed for hearing evaluation[42] was used. The room was free from distraction and had a comfortable temperature and well lit. The perceptual analysis was carried out individually by all the six listeners. Each listener was seated comfortably, and the loudspeakers (Zebronic SW1000 2.1 multimedia speakers with a frequency response of 40Hz – 20kHz) connected to the laptop were placed in front of the listener. Each listener was presented the original unaltered, vowel duration transformed and consonant duration transformed utterances of CHL through the loudspeaker and was asked to rate the intelligibility of the words on a 3-point rating scale where "1" referred to "unintelligible", "2" referred to "partially intelligible" and "3" referred to "highly intelligible speech". The ratings were tabulated and were statistically analysed. Intralistener reliability was obtained by presenting the twenty percent of samples after one week. Interlistener reliability was also calculated.

Results and discussion

Acoustic analysis

The analysed acoustic parameters were subjected to statistical analyses using SPSS (Version 24). As a part of the descriptive statistics, mean, standard deviation values and range of vowel and consonant duration were determined for the participants of both the groups. The mean, standard deviation and range of vowel duration of each vowel were calculated and are presented in **Table 1**. As can be evidenced from the table and graph, vowel /o:/ had shown the highest mean and the vowel /e:/ had shown the lowest mean values in group 1. Vowels /i/ and /e:/ had the highest and lowest standard deviation values. The duration of vowel /e:/ showed the highest range of vowel duration. The vowel /e:/ and vowel /e/ had the highest and lowest mean and standard deviation values of vowel durations, respectively, in the utterances of participants of group 2. The range of the vowel duration was lowest for the vowel /a/ and the highest range was noticed for the vowel /o:/. The mean vowel durations of group 1 were higher than group 2 except for the vowel /e:/. Group 1 showed higher variability in the vowel durations than that of group 2. The range of the vowel duration was also higher in group 1 compared to that of group 2.

Independent sample t-test was carried out using an alpha level of 0.05 (95% confidence interval) to determine the significant differences in each of the acoustic parameters between the utterances of the participants of both the groups. The results revealed that there were significant differences in the vowel duration between the participants of both groups in all the vowels, except for /i/, /u/, and /o:/. Thus, it was concluded that the CHL showed a significantly longer duration for the vowels compared to the CNH (**Table 2**).

Inspection of table 2 shows that the consonant /b/ had the highest values and /ḍ/ had the lowest values of consonant duration in the utterances of the participants of group 1. Stop consonant /t/ had the lowest standard deviation, and /g/ showed the highest standard deviation values. The range of consonant duration was highest for the stop consonant /g/ and lowest for the consonant /t/. The stop consonant /p/ showed the highest values of consonant duration in words uttered by the participants of group 2, and the lowest mean consonant duration was observed for the stop consonant /ḍ/. Lowest standard deviation value was found for /t/ and the highest standard deviation value was noted for /p/. The range of consonant duration values varied from 139.59 ms for /p/ to 29.43 ms for /t/. The mean duration values of for all the stop consonants in the utterances of the participants of group 1 were higher than that of group 2. The consonant duration in the utterances of the participants of group 1 showed larger variability than in group 2. The range of the consonant duration was also higher in participants of group 1 than that of group 2.

The results of the independent samples t-test revealed significant differences in consonant duration between both groups for all the consonants except for the stop consonant /g/. It was inferred from the results of the descriptive and inferential statistics that the CHL had significantly longer consonant duration values compared to the CNH.

Thus, the vowel duration and consonant duration were longer in the speech of the CHL compared to that of the CNH. Christy[21] studied the characteristics of vowels in CNH and CHL and found significantly longer vowel duration in the speech of the CHL compared to that of the CNH. Similar results were reported by several past researchers[17–20,22,24,46–48]. Vowel duration has been documented to be longer and also more variable with higher standard deviation values in the speech of the CHL compared to the age-matched CNH[23,25,28]. As the results of the present study also showed that the vowel duration in CHL was longer and variability was also higher compared to the CNH, the results of the present study are in agreement with the findings of the earlier studies.

Calvert[27] had reported that the CHL had longer consonant durations compared to CNH. Several researchers had found that the consonant duration was longer, and the range of consonant duration was higher in the CHL compared to the CNH[17,23,28]. Further, these studies had also revealed that the standard deviation values of the consonant duration were higher in the CHL. Nataraja et al. had documented higher consonant duration of voiceless stop consonants in speech of the CHL and higher consonant duration of voiced stop consonants in speech of the CNH[20]. The study also reported that the increase in consonant duration in CHL was due to exaggerated articulation caused due to excess tension in the articulators and required greater air pressure for the release. The study also postulated that the buildup of greater air pressure behind the articulator might take a long time for the release of the articulator, enhancing the closure duration, burst duration and the voice onset time, which in turn prolonged the consonant duration[20]. The present study had not considered the comparison of consonant duration between the voice and voiceless consonants, however as the results of the present study showed that the consonant duration in the speech of the CHL was significantly higher than that of CNH, the results of the present study support the findings of all the earlier studies.

Perceptual analysis

Interclass correlation coefficient and Cronbach's α analyses were carried out to determine the intralistener and interlistener reliabilities. The Cronbach's alpha values for the intelligibility of speech among all the listeners were greater than 0.7. According to Bland and Altman[44], Cronbach's alpha value of 0.7 or more indicates good intra listener reliability. Thus, it was inferred that the listeners had shown good test re-test reliability in terms of rating the speech intelligibility.

The results of speech intelligibility scores rated by six listeners were subjected to inter listener reliability. The results revealed that the inter-class correlation coefficients for the ratings of intelligibility of speech between the six listeners were greater than 0.75. According to Koo and Li[45], the inter-class correlation coefficient of 0.75 to 0.9 indicates 'good reliability'. Thus, it was inferred that the ratings of speech intelligibility by the listeners had shown high inter listener reliability.

Percentage scores of speech intelligibility were calculated for the transformed and unaltered utterances of the CHL; and the unaltered utterances of the CNH. Differences between the ratings of intelligibility of speech between the speech-language pathologists and naïve listeners were determined using the Mann Whitney U test. The results revealed that there were no significant differences in the ratings of intelligibility of speech between the professional and naïve listeners. Therefore, it was inferred that the rating of speech intelligibility provided by the speech-language pathologists and the naïve listeners were similar, i.e., the naïve listeners were equally good in judging the intelligibility of speech as speech-language pathologists in the present study.

Table 3 shows the percentage scores of speech intelligibility of the unaltered utterances of the CNH and CHL. The listeners had reported higher speech intelligibility scores in participants of group 2 compared to that of group 1. Average speech intelligibility scores of the participants of group 1 were 100%, and group 2 were 68%. Thus, the listeners had rated the speech of CHL as having lower intelligibility of speech compared to the speech of the CNH.

The results of Mann Whitney U test showed that there was a significant difference in speech intelligibility [/z/ = -25.32, $p < 0.05$] between the participants of the two groups. Therefore, it was concluded that the CHL had significantly poor intelligibility of speech compared to that of CNH (**Table 4**).

The percentage of speech intelligibility of the unaltered words, vowel duration transformed words, consonant duration transformed words and the words with the combined transformation of vowel duration and consonant duration in the utterances of the CHL have been presented in Table 4. The results revealed that the listeners had reported higher intelligibility scores for the vowel duration transformed words, consonant duration transformed words and words with the combined transformation of vowel and consonant duration compared to the unaltered words. The average intelligibility scores of the unaltered words were 68%. The intelligibility ratings of vowel duration transformed words were 86%, and the consonant duration transformed words were 74%. However, the combined transformation of vowel and consonant duration resulted in higher speech intelligibility ratings of 89%.

Differences between the ratings of intelligibility of speech between the transformed and untransformed samples were also determined using the Mann Whitney U test. The results showed that there were significant differences in the intelligibility of speech between the unaltered words and the vowel duration transformed words (/z/ = -13.95, $p < 0.05$); significant differences in the intelligibility of speech between the unaltered words and the consonant duration transformed words (/z/ = -5.19, $p < 0.05$); significant differences in the intelligibility of speech between the unaltered words and the words with the combined modification of vowel and consonant duration (/z/ = -15.76, $p < 0.05$). Therefore, it was inferred from the results that the transformation of vowel and consonant duration resulted in improved speech intelligibility in the participants of group 1. Further, it was also noted that the combined modification of vowel duration and consonant duration resulted in greatest improvements in speech intelligibility compared to the words with the individual transformation of vowel duration and consonant duration.

The results of the perceptual analysis also revealed a significantly lower speech intelligibility scores for the speech of the CHL compared to that of the normal controls. Lower intelligibility in the speech of the CHL compared to that of CNH was also documented by several past investigations[17,29–31,36,38,39]. Studies have also reported lower speech intelligibility in hearing-impaired children using hearing aids compared to that of CNH[49,50]. As the results of the present study also revealed that the CHL showed relatively poor intelligibility of speech compared to the CNH, the findings of the study reconfirm the findings of all the mentioned earlier studies.

Transformations of the temporal parameters (vowel duration and consonant duration) in the speech of the CHL resulted in considerable improvement in the intelligibility of speech. Studies have reported that the duration is the primary articulatory feature for contrasts such as voicing in stops[51,52] and contributes as a secondary feature to an accurate expression of contrasts in vowels and other segments[53]. Therefore, the modifications of temporal aspects of speech in the utterances of the CHL have been found to improve the intelligibility of speech[54]. Nataraja et al.[17] had also carried out the transformation of temporal, spectral and prosodic parameters in the speech of the CHL and reported that the transformation of the temporal parameters resulted in maximum improvement in the intelligibility of speech. Therefore, the results of the present study are in accordance with all these earlier mentioned studies.

Further, the results also showed that, among the transformed samples, the words with the combined transformation of the vowel and consonant duration resulted in the highest increase in intelligibility compared to the individual transformation of the vowel and consonant duration. Thus, it was inferred that the transformation of the combination of temporal parameters resulted in greater improvement in intelligibility compared to the transformation of the individual temporal parameters of speech in CHL. In contrast, earlier studies have reported that the transformation of multiple parameters in the speech of the CHL had caused lesser improvements in the intelligibility scores compared to the transformation of a single parameter[17].

It was also noted that the transformation of any individual or multiple temporal parameters in the speech of the CHL did not result in a 100% improvement in speech intelligibility. Therefore, it may be inferred that there might be other additional factors or parameters that contributes to the improvement in the intelligibility of speech.

Conclusion

The study investigated the effects of the transformation of vowel duration and consonant duration (individually and in combination) in the speech of the CHL on the speech intelligibility. Acoustic analysis of vowel duration and consonant duration in words spoken with CHL, and CNH was carried out. Results of the acoustic analyses revealed that both the vowel duration and consonant duration were significantly longer in the speech of the CHL compared to CNH. Based on these results, both vowel duration and consonant duration were transformed in words spoken by the CHL (to approximate the mean values of these parameters to that of CNH) and the perceptual analysis of speech intelligibility was carried out. The results showed significantly higher speech intelligibility scores for the transformed words compared to the unaltered words spoken by the CHL. Combined transformations of vowel duration and consonant duration resulted in the highest improvement in speech intelligibility compared the individual transformation of these temporal parameters. Future studies can throw light on investigating the effects of transformation of several other temporal and spectral parameters in the speech of the CHL on their speech intelligibility. Foraging researches on various other temporal and spectral parameters in the speech of the CHL can be helpful to determine the various acoustic parameters and their importance in correcting the speech of the CHL to improve the intelligibility of speech.

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Table 1: *Mean, Standard Deviation, range of vowel duration and the results of independent t-test between the vowel duration between the participants of both the groups.*

Target vowel	**Group 1**			**Group 2**			**t value**	**df**	***p*-value**
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**			
/a/	246.69	86.45	253.60	192.12	31.65	71.48	-2.70	18	0.01
/i/	276.23	126.59	326.86	221.12	37.32	89.53	-1.91	10.77	0.08
/e/	246.13	92.24	265.54	174.55	30.92	80.42	-2.55	13.13	0.02
/u/	261.42	108.90	272.33	236.33	35.36	85.05	-0.35	18	0.72
/a:/	217.22	66.14	180.98	196.34	32.31	89.81	-2.98	12.07	0.01
/o:/	276.91	121.37	349.78	235.64	43.56	123.45	-1.12	18	0.27
/e:/	206.42	58.87	167.04	298.58	46.75	110.19	-2.80	9.85	0.01

Mean- measured in ms, SD- standard deviation,

Table 2: *Mean, Standard Deviation and range of consonant duration and the results of independent t-test between consonant duration between the participants of both the groups.*

Target Consonant	**Group 1**			**Group 2**			**t value**	**df**	***p*-value**
	Mean	**SD**	**Range**	**Mean**	**SD**	**Range**			
/p/	248.83	95.33	240.03	170.63	41.83	139.59	-2.37	12.34	0.03
/t/	188.50	56.85	145.35	133.60	8.86	29.43	-3.01	9.43	0.01
/k/	250.92	94.12	233.25	156.86	20.07	62.35	-3.09	9.81	0.01
/ṭ/	220.68	59.58	165.87	145.49	18.35	54.81	-3.81	10.69	0.00
/b/	252.76	122.74	349.80	96.54	12.56	44.54	-4.00	9.18	0.00
/d/	211.53	138.90	364.32	77.22	10.89	32.68	-3.04	9.11	0.01
/g/	222.85	203.77	543.56	88.39	11.41	37.35	-2.08	9.05	0.06
/ḍ/	159.34	87.64	232.15	69.53	18.84	60.07	-3.16	9.83	0.01

*Mean- measured in ms, SD- standard deviation, I- Initial position, M- Medial position.

Table 3: *Percentage scores of speech intelligibility of the unaltered utterances of the participants of both groups.*

	roup 1	**roup 2**
1	9%	00%
2	0%	00%
3	0%	00%
4	7%	00%
5	6%	00%
6	5%	00%
verage	**8%**	**00%**

*L- Listener

Table 4: *The percentage of intelligibility of the unaltered words, words with the individual transformation of vowel duration, consonant duration and combined transformation of vowel and consonant duration in the utterances of the CHL.*

	Unaltered	**VD Transformed**	**CD Transformed**	**VD and CD Transformed**
L1	69%	89%	76%	91%
L2	70%	89%	75%	91%
L3	70%	86%	77%	90%
L4	67%	84%	71%	89%
L5	66%	82%	73%	88%
L6	65%	85%	73%	82%
Average	**68%**	**86%**	**74%**	**89%**

* VD- Vowel Duration; CD- Closure Duration, L- Listener