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Vowel Space Areas across Age, Gender and Dialects in Telugu

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Abstract

Vowel space is an acoustic measure for indexing the size of the vowel articulatory working space constructed using F1 and F2 of vowels /i/, /a/ and /u/. Watson et.al., (2004) reported significant differences in the vowel space among different age groups (50s, 70s and 80s). Larger vowel space and area could be indicators of clear speech and used for judging the speech intelligibility (Carrell, 1984; Blomgren, Robb & Chen, 1998; Ferguson & Kewley-Port, 2007).

Though vowel space has been used as a diagnostic tool in Telugu population, no studies on the vowel space across the age, gender and region groups exist in Telugu literature. This justified the current study on obtaining vowel space for different age, gender and region groups of Telugu language. Speech samples consisting of target word in CVCV/CVCCV context with varying preceding consonants were recorded from 72 Telugu speaking normal individuals in age groups (Group I: 06 to 09 years; Group II: 13 – 15 years; Group III: 20 – 30 years) from three different regions (Coastal, Rayalaseema and Telengana).

Analysis of the recorded speech was done using CSL 4500. Formant frequencies F1 and F2 were recorded to draw the vowel triangle and to calculate the vowel space. The results suggest that with age increase the vowel space decreased; females have larger vowel space than males and

samples of Coastal region speaker have larger vowel space followed by Telengana and Rayalaseema regions.

***Keywords**: Formant frequency, Vowels, Telugu, vowel space.*

Abbreviations

F1 and F2 – First and Second Formant frequencies.

Introduction

The vowel space is a graphical method to represent speech sounds, such as vowels, and their location in both "acoustic" and "articulatory" space. The first two formants are used to plot the vowel space, where the vertical axis represents the first formant frequency (F1) and the horizontal axis, the second formant frequency with the lines connecting the points representing the gap between the first two formants (F2-F1). This 2-dimensional representation corresponds, to a certain degree, to tongue body position, in an articulatory space.

The method usually used is to set up an imaginary "vowel space" and define vowels by their position in the space. Vowel space is an acoustic measure for indexing the size of the vowel articulatory working space constructed using F1 and F2 of vowels /i/, /a/ and /u/. Watson et.al., (2004) reported significant differences in the vowel space among different age groups (50s, 70s and 80s). Larger vowel space and area has been considered as an indicator of clear speech and used for judging the speech intelligibility (Carrell, 1984; Blomgren, Robb & Chen, 1998; Ferguson & Kewley-Port, 2007).

Formant Frequency

The formant frequency values differ across individuals, gender and dialects. In spite of these variations, the vowels are perceived and produced in similar manner. To understand how they differ, the vowel space is used. Literature has reported that, in spite of differences in the formant frequency values which influence the phonetic quality of particular vowels, the extended vowel space area is unaffected by dialectal variation. No gender variations in the vowel space used were observed in three distinct regional dialects of American English. (Jacewicz, Allen Fox, & Salmons, 2007).

Formant is defined as a property of the resonating vocal tract (Fant, 1960). However, Monsen & Engebretson (1983) defined formants as the property of the acoustic signal which has concentration of energy along a frequency scale, defined by the prominence of several harmonics. The formants of a speech sound are known as the first formant (F1), second formant (F2), third formant (F3) and so on. The formant frequencies of vowels are affected by the length of the pharyngeal-oral tract, the vocal tract constriction and degree of narrowness of the constriction (Pickett, 1996).

Formant frequencies are related to the volume of the cavities in front of (oral cavity) and behind the constriction (pharyngeal cavity) of the vocal tract. In general, larger vocal tracts with larger volumes will resonate at lower frequencies, while smaller volumes resonate at higher frequencies. Formant frequencies are influenced by the vocal tract configuration. It has been presumed that the 1st formant corresponds to the back cavity and the 2nd formant to the front cavity of the mouth (Joos, 1948). Hasegawa-Johnson et.al., (2003) reported that formant frequencies and log area were independent of vowel place. F2 is maximally sensitive to area changes near the vocal tract constriction. F1 is maximally sensitive to area near the glottis, except for vowel /i/. In the literature, it is proved that, the first two formants, and in some cases, the first three formants are most important for vowel perception. (Monsen & Engebretson, 1983; Carlson & Granström, 1978; Carlson, Granström & Klatt, 1979).

Some Studies

Eguchi and Hirish (1969), Kent (1976), Kent, Weismer and Kent, (1989) and Most. et al.,(2000) reported changes in formant frequencies (F1 and F2) across the age groups in English vowels. This difference in the formant frequencies logically should and will be reflected in the vowel space used by the different age groups. Watson, Palethorpe & Harrington (2004) in their study on vowels in New Zeland English speakers, have reported that, F1 lowering was seen over the age. Cox (2004) in his study on understanding the acoustic characteristics of /hVd/ vowels reported that, gender differences in formant values demonstrate non-linear variation. The open vowels when compared to close vowels had clear gender variations. Man (2007) reported that F1 and F2 formant frequency values for the vowels produced by male speakers were lower than those of female speakers. They also reported that the relative distance between the mid vowels and the high vowels is greater for female speakers than for the male speakers in the vowel ellipses.

Iso vowel lines have been used in different regional languages and pathological cases. Using iso-vowel lines, F1, F2 were plotted in a myositis case, where all the formant frequencies were much lower than the expected normative data. Vowels /i/ and /u/ were distorted and the investigator emphasized the need for periodic spectrographic analysis of speech to monitor the progress made from medical treatment and speech therapy (Duggirala, 1983-1984).

Children with history of tracheotomy presented varied F2 dimension for /i/ and /u/ and F1 dimension for /□/ and /i/. Iso-vowel lines were used to map the results and were found to be dispersed. Based on this, it was stated that children undergoing tracheotomy would experience difficulty with tongue extension and retraction (Kertoy et al., 1999) and the study highlighted the use of iso-vowel lines and formant analysis in describing the speech characteristics in children with history of tracheotomy.

Whitehill, Ciocca, Chan & Samman (2004) analyzed vowel space, formant frequencies (F1 & F2) in glossectomy patients and found that, F1 and its range did not show any significant difference; however, F2 was lower for vowel /i/ and its range was restricted when compared to control speakers. They concluded that, among the parameters studied, F2 range could serve as a sensitive correlate for vowel intelligibility for speakers with partial glossectomy.

F1 and F2 Variance

From the literature it is evident that F1 and F2 of vowels vary based on vowel, age, gender and dialects. Although attempts have been made to study the vowel formants in Telugu, there is no published literature on F1 F2 data, iso-vowel lines, vowel space across the age, gender and regions. Studies on different clinical population have reported that, that iso-vowel lines help in differential diagnosis and in monitoring progress in rehabilitation (Duggirala, 1983-1984; Whiteh ill, Ciocca, Chan & Samman, 2004; Kertoy et al., 1999). The aim of the current study was to study F1, F2 and calculate vowel space for normal individuals in different age, gender and region groups in Telugu.

Method

Material

A list of 60 meaningful words (Krishna, 2009) consisting of all ten short and long vowels present in Telugu, in all possible preceding consonant and semivowel (CVCCV/CVCV) context was used. The target word was embedded in the final position of a carrier sentence "/i: padamu (target word) /" (This word is ______), to obtain reasonable uniform stress and intonation patterns (Bennett, 1981; Most, Amir & Tobin, 2000). The words were grouped based on their manner and place of articulation and voicing features of the preceding consonant.

Participants

A total of 72 Telugu speaking normal individuals from three different regions (Coastal, Rayalaseema and Telengana) in three different age groups (Group I: 06 to 09 years; Group II: 13 – 15 years; Group III: 20 – 30 years) with equal gender ratio participated in the study. The mean age of Group I was 8 years; Group II, 13 years; and Group III 23 years. All the participants were born in Andhra Pradesh and were native Telugu speakers. A qualified Speech-Language Pathologist and Audiologist evaluated and certified their speech, language, and hearing, as being normal at the time of data collection.

Procedure

After an informed consent, the randomly selected participants from the respective groups were comfortably seated in a quiet room and their speech samples were recorded using a condenser microphone and Wave Surfer recording software. The participants were asked to read the sentence presented to them visually. The speech sample was recorded at a sampling rate of 22,050 kHz and bit rate of 256 kbps. A total of 4320 samples were analyzed for the formant frequencies of the target vowel present in the target word using Computerized Speech Lab (CSL) 4500. An anti-aliasing filter with a 10 kHz cutoff frequency was used before A/D conversion and a pre-emphasis factor of 0.8 was applied.

The researcher re-measured 10% of the tokens (random selection) after 6 months of the first measure for intra-judge reliability. Results from the paired *t*-test revealed the two measures as highly reliable ($t_{(431)}$ = 1.026, p = 0.309). An experienced Speech Language Pathologist, unaware of the purpose of the study, measured temporal and spectral characteristics of 10% of the tokens (random selection) for inter-judge reliability. Results from the paired *t*-test suggested high reliability ($t_{(431)}$ = 0.10, p = 0.920).

Mean and standard deviation values were used to summarize the variations in F1 and F2 of the vowel in different age, gender and region groups. To evaluate the effect of covariates (age, gender and region) on formant frequencies, a multilevel approach (Quene & Bergh, 2004) was used. All the statistical analysis was carried out using the SPSS 16 and MlWin 1.1 software.

Results

The current study aimed at studying the First and Second formant frequencies of the vowels in Telugu across regions, gender and age groups and drawing vowel space to understand the acoustic/phonetic characteristics among these groups. Table 1 represents the mean F1 and F2 values obtained for vowels /i/, /a/ and /u/ and their standard deviation.

Table 1: Mean F1 & F2 (Hz) and SD of /i/, /a/ and /u/ vowels in Telugu speakers.

N=4320

Vowel	Format Frequency	Mean	SD
/i/	F1	545.23	81.7
	F2	2494.05	342.14
/a/	F1	809.3	124.26
	F2	1479.72	188.42
/u/	F1	535.38	72.85
	F2	947.08	80.6

Scrutiny of the F1 data revealed that, central low mid vowel /a/ had the highest mean F1 followed by /i/ and back high vowel /u/. Front high vowel /i/ has highest mean F2, followed by central low mid vowel /a/ and high back vowel /u/. Further, the data was analyzed for each age group, children, adolescent and adults. The results are depicted in Table 2.

Table 2: Mean F1 & F2 (Hz) and SD of /i/, /a/ and /u/ vowels in Telugu speakers across different age groups.

N=4320

Vowel		Children		Adolescent		Adult	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
/i/	F1	586.82	82.87	546.66	72.57	502.77	486.98
	F2	2529.8	356.53	2563.53	347.19	2390.78	300.4
/a/	F1	885.76	87.61	811.44	112.63	730.67	713.76
	F2	1569.16	153.47	1490.76	178.18	1378.64	182.41
/u/	F1	572.45	66.48	538.15	69.13	495.7	487.39
	F2	951.12	80.19	947.29	75.14	942.88	86.29

From Table 2 it is observed that, F1 for all vowels (/i/, /a/ and /u/) reduced as the age increased. Except for vowel /i/, F2 decreased as the age progressed. For vowel /i/, F2 had maximum of 2563.53 Hz and reduced in adults. Among all age groups, central low mid vowel /a/ had the highest mean F1 followed by /i/ and back high vowel /u/. Front high vowel /i/ had highest mean F2, followed by central low mid vowel /a/ and high back vowel /u/. The results obtained for both genders for F1 and F2 are presented in Table 3.

Table 3: Mean F1 & F2 (Hz) and SD of /i/, /a/ and /u/ vowels in Telugu speakers across the genders.

N=4320

Vowel	Formants	Female		Male	
		Mean	**SD**	**Mean**	**SD**
/i/	F1	580.56	65.93	509.57	80.8
	F2	2598.3	295.78	2388.82	254.64
/a/	F1	851.47	97.99	766.83	133.29
	F2	1541.05	164.17	1418.79	191.46
/u/	F1	564.08	60.2	506.6	73.16
	F2	947.74	83.26	946.44	77.96

From Table 3 it is observed that, gender differences do exist for both formant frequencies across the vowels. Females showed higher values compared to males for all formant frequencies and for all vowels compared. Here too, central low mid vowel /a/ had the highest mean F1 followed by /i/ and back high vowel /u/. Front high vowel /i/ had highest mean F2, followed by central low mid vowel /a/ and high back vowel /u/. F1 and F2 values were compared for the three vowels /i/, /a/ and /u/ across the three dialects. The results are given in Table 4.

Table 4: Mean F1 & F2 (Hz) and SD of /i/, /a/ and /u/ vowels in Telugu speakers across the three dialects.

N=4320

Vowels		Coastal		Rayalseema		Telengana	
		Mean	SD	Mean	SD	Mean	SD
/i/	F1	530.87	81.55	552.71	88.38	552.2	73.58
	F2	2501.67	326.23	2522.93	367.55	2457.85	333.45
/a/	F1	797.83	129.67	795.29	117.13	834.84	122.36
	F2	1477.67	185.51	1482.04	188.77	1479.42	192.06
/u/	F1	525.92	77.27	542.56	71.97	537.59	68.43
	F2	947.61	86.75	942.92	81.87	950.66	72.88

From Table 4, it is evident that, formant frequencies F1 and F2 varied between vowels studied across the regions. Vowel /i/ and /u/ had higher F1 in speakears of Rayalaseema followed by Telengana and Coastal region while for vowel /a/, speakers from Telengana had higher F1 followed by Coastal and Rayalseema. A similar pattern was observed for F2 formant among all the vowels. Central low mid vowel /a/ had the highest mean F1 followed by /i/ and back high vowel /u/ among the regions. Front high vowel /i/ had highest mean F2, followed by central low mid vowel /a/ and high back vowel /u/.

The vowel space in the current study was drawn using PRAAT software considering F1 and F2 values of /i/, /a/ and /u/ of the overall data across different groups (age, gender and region) as depicted in Figures 1, 2, 3 and 4 respectively. Vowel space area was calculated by using the model of Blomgren et.al., (1998), for the different groups of the current study and presented in Table 5

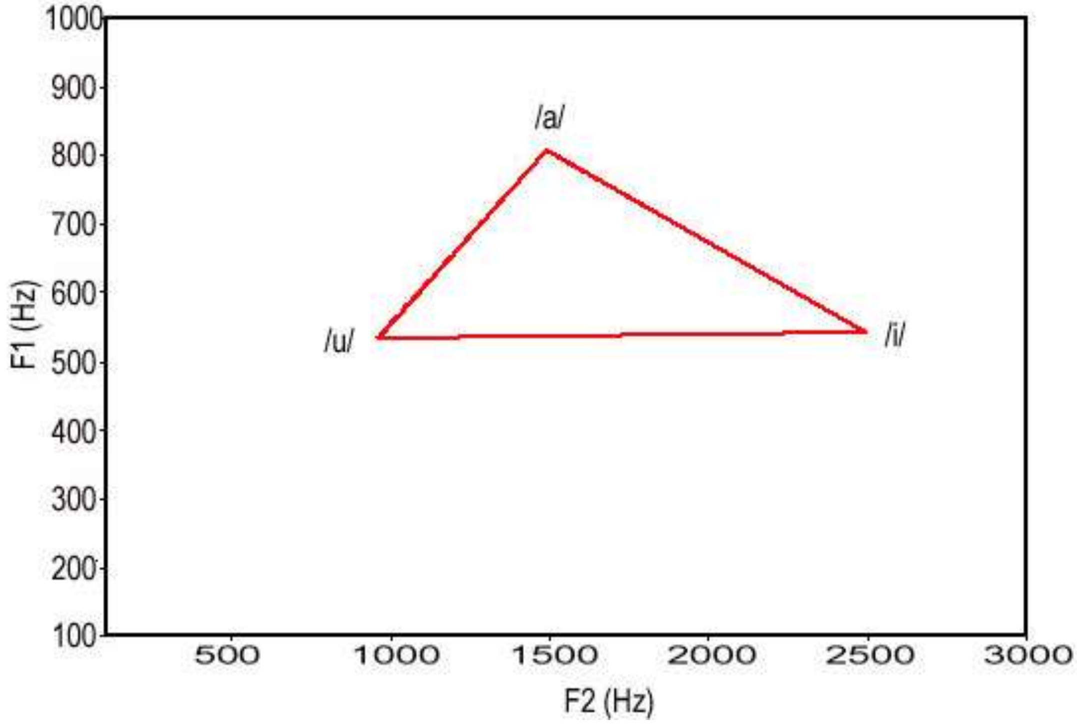

Figure 4.3.1: Vowel space for vowel /a/, /i/ and /u/

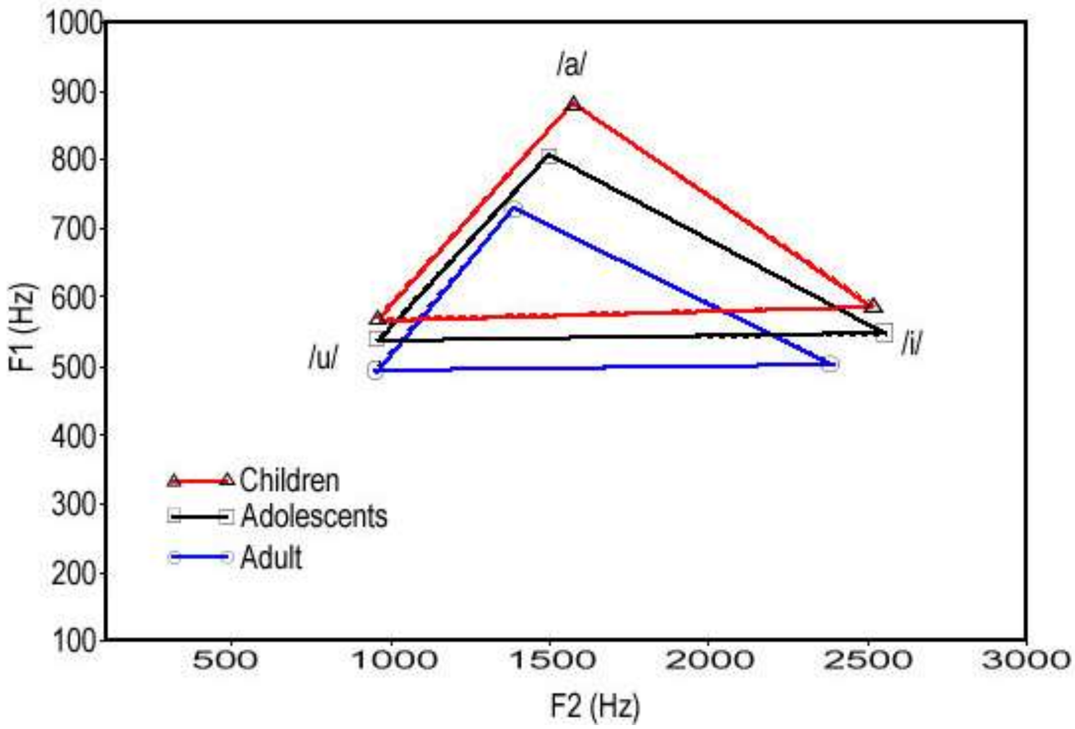

Figure 4.3.2: Vowel space for age categories

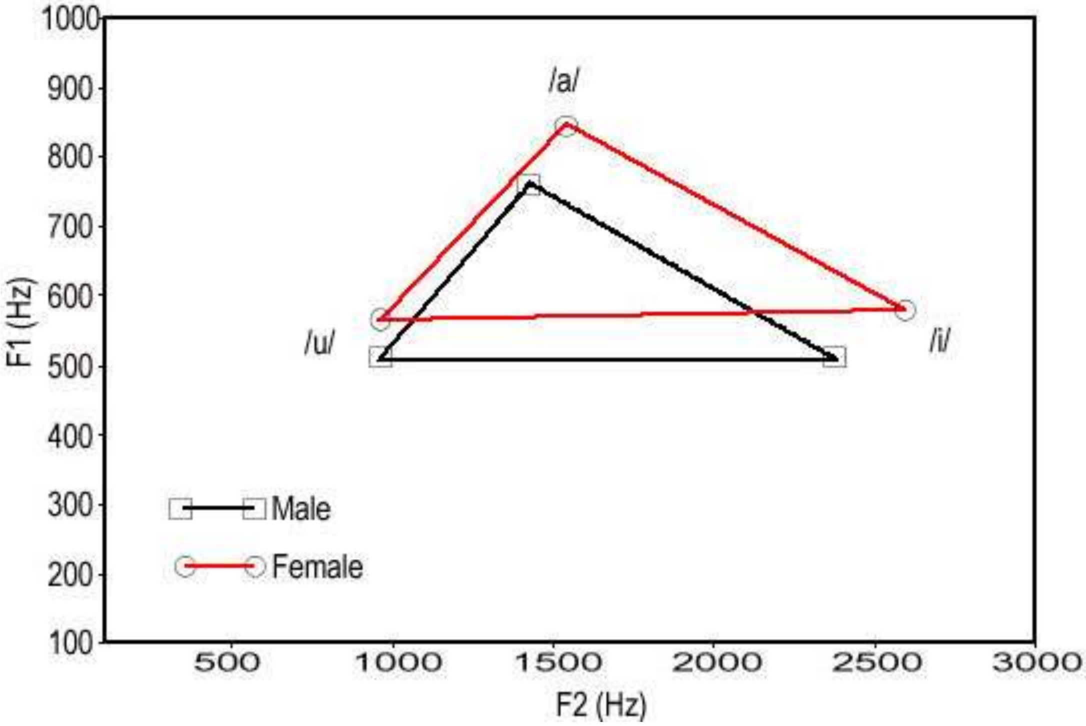

Figure 4.3.3: Vowel space for gender categories

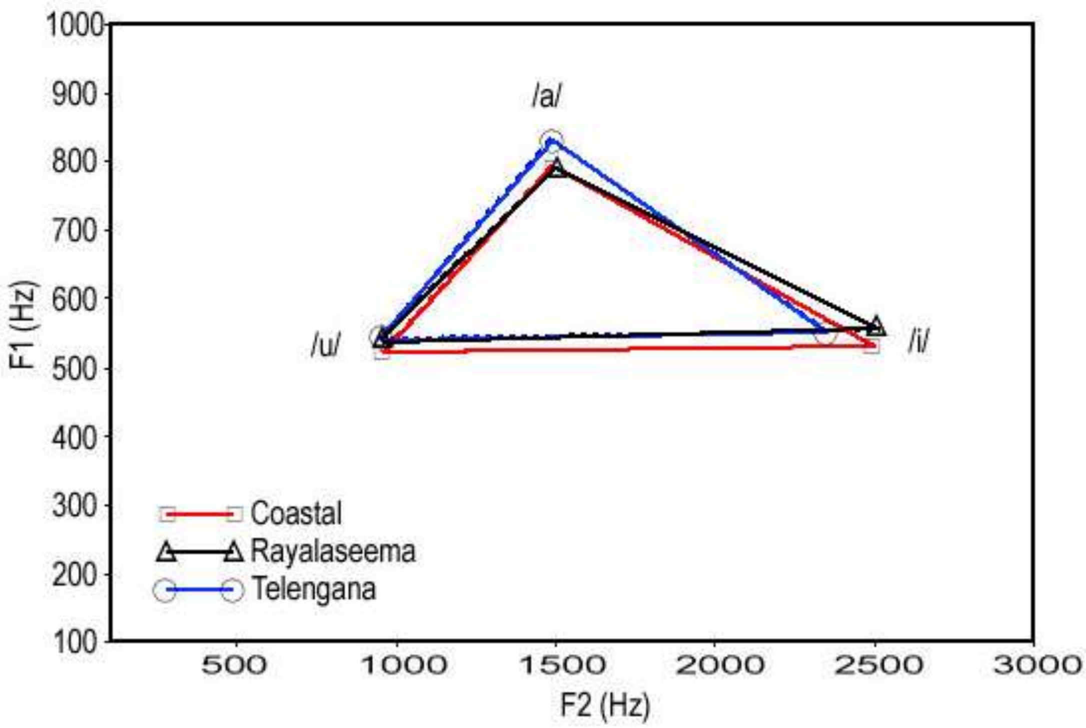

Figure 4.3.4: Vowel space for region categories

Table 5: Vowel space area in different groups

	Overall	Age			Gender		Region		
		Children	Adolescents	Adult	Female	Male	Coastal	Rayalaseema	Telengana
Area (Mz^2)	209279	242631	218412	168614	232167	186752	210019	197170	219822

On scrutiny of the data in Table 5 and Figures 1, 2, 3 and 4, it is observed that vowel space is different between the groups. Though the age groups considered in the current study are not the same as in literature (Watson et.al.,2004), age related changes in the vowel space did emerge.

Conclusion

In the current study, smaller vowel space is noted for adults as compared to children, for males as compared to females and for speakers from Rayalaseema region as compared to Coastal or Telengana. The presence of the larger vowel space and area could be indicators of clear speech and could be used for judging the intelligibility of speech (Carrell, 1984; Blomgren, Robb & Chen, 1998; Ferguson & Kewley-Port, 2007).

In the current study Telegana region had larger vowel space which could be interpreted as speakers from Telengana have more clear speech. This is not true as per literature, which reports that speakers from Coastal region have more clear speech. Female having higher vowels space as compared to males indicates females having clearer speech than males. Blomgren et.al., (1998), Klich & May (1982), Duggirala (1983-1984) and Turner, Tjaden & Weismer (1995) have used vowel space in differential diagnosis. The data obtained in this study could be used by the clinicians in differential diagnosis of various communication disorders. With contradictory reports on association between vowel space and vowel intelligibility (Ferguson & Kewley-Port, 2007) more studies on its clinical utility are warranted.

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