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Vowel Duration across Age and Dialects of Telugu Language

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Abstract

Vowel duration, one of the important acoustic characteristics, is important in vowel perception. Vowel duration varies based on individual, linguistic and non-linguistic characteristics. This study was to study vowel duration in all Telugu vowels across different gender, region and age groups. Using cross sectional study design, a total of 4320 tokens from 72 randomly selected Telugu speaking participants from three age groups, two gender and three region groups were analyzed. Vowel duration of the target vowel was extracted and analyzed using spectrogram. From the results it is interpreted that significant variations in vowel duration of vowels in Telugu exist between children, adolescents and adults; Coastal, Rayalaseema and Telengana speakers. Vowels /e/ and /a:/ had longest vowel duration, while short and long vowels /i/ have shortest vowel duration. Children found to have longer vowel duration as compared to adolescents or adults. Regional influences are seen on vowel duration. Rayalaseema speakers

have longer vowel duration as compared to Coastal or Telengana speakers. Hence, it is essential for speech language pathologists to apply the age, gender and region appropriate normative data to achieve appropriate speech output.

Keywords: Vowel duration, Vowels, Telugu.

Introduction

Speech sounds consist of vowels and consonants. Vowels carry maximum energy and play a major role in speech understanding. Consonants carry less energy but have meaningful message in speech communication. "Vowel is a conventional vocal sound in the production of which the speech organs offer little obstruction to the air stream and form a series of resonators above the level of the larynx" (Mosby, 2008). The organs involved in the production of speech sounds develop over the period of life span, and there are structural variations among genders and races, which contribute in producing different vocal quality. Linguistic, syntactic and phonological rules of each language further contribute to the complexity of the speech sound. Ladefoged's (1975) comments that the vowels of different languages though perceived as same, with subtle acoustic differences between them, have relevance to the study of their acoustic and temporal characteristics in different languages and age groups. Information on acoustic characteristics of speech sounds will further enable understanding their articulatory nature and their perception (Pickett, 1980). Analysis of the acoustic characteristics of speech sounds of Indian languages is needed to understand their production and perception (Savithri, 1989). It will further be useful in perceptual studies, speech processing strategies, diagnosis and rehabilitation of various communication disorders.

Telugu Language

Telugu belongs to the Dravidian family of languages (Krishnamurti, 2003) and is the second most widely spoken language in India (Hussain, Durrani & Gul, 2005). Telengana, Coastal Andhra and Rayalaseema are the major dialect regions of Telugu. (Prahallad & Patel, 2006; Wikimedia Foundation, 2008d). According to Nagamma Reddy (1986), ten vowels (long and short: i, e, a, o, u) represent the common core of Telugu language.

Acoustic Theory and Vowels

The acoustic theory of speech production proposed and expounded by Fant (1960) views speech as the product of source and filter or transmission function. Vowels are produced by voiced excitation of the open vocal tract. Mastery of the speech sounds, especially vowels occurs during the first six months of life (Irwin, 1943). Acoustically, vowels are characterized by changing formant pattern, formant bandwidth, duration, amplitude and fundamental frequency. Among these, it is believed that formant pattern, duration and fundamental frequency play a major role in vowel perception (Pickett, 1980). In certain Indian languages, the phonological contrast between the pairs of vowels has distinguishing features in quality and quantity or both (Nagamma Reddy, 1998).

Literature survey also reveals that, vowels are the significant components of human speech and are influenced by developmental, linguistic, cultural, social and emotional factors (Kent & Read, 1995; Klatt, 1976; Ladefoged, 1975; Nagamma Reddy, 1998; Prahallad & Patel, 2006; Savithri, 1989; Sreenivasa Rao & Yegnanarayana, 2004). These features are also reported to play a major role in assessment, differential diagnosis and rehabilitation of communication disorders (Duggirala, 1983-1984, 1995, 2005; Edward & Valter, 2006, 2007; Hoasjoe, Martin, Doyle & Wong, 1992; Premalatha, Shenoy & Anantha, 2007). Analysis of speech sounds is increasingly used in recent years to assess the anatomical and neuro-muscular maturation of speech mechanism (Duggirala, 1983-1984).

Vowel Duration

The vowel duration is an important parameter which provides information on the prosodic as well as linguistic aspects of speech. Vowel duration may be taken as the difference in time between the onset of the first identifiable period and the offset of the last identifiable period in the vocalic segment which can be better identified by wideband spectrograms using a resolving filter of 293 Hz bandwidth (Manwal, Gilbert & Lerman, 2001). Gopal (1987) defines vowel duration as the duration from the onset of the vowel to the offset of the vowel. The onset and the offset of a vowel are determined by the presence and absence of clearly visible first two

formants on the spectrogram respectively. He also commented that describing and quantifying the effects of various factors of vowel duration leads to predictive rules that could be effectively used in speech recognition and in speech synthesis. Krause (1982) defines vowel duration as the difference between the vowel onset and vowel offset, where vowel onset is defined by the initiation of formant structure coincident with periodic energy and vowel offset defined by the end of second formant energy.

Vowel duration can be used to signal the stressed syllable (Fry, 1955), mark the word boundaries (Lehiste, 1959), identify the syntactic units (Gaitenby, 1965), to distinguish between similar phonetic segments (Denes, 1955; Lisker & Abramson, 1964) and determine phonetic quality (Lehiste, 1970). Vowel duration and intonation play an important prosodic feature in the quality of synthesized speech (Sreenivasa Rao & Yegnanarayana, 2004). The duration of the vowel is influenced by the position, phonological and contextual factors. Other factors such as gender, psychological state, age, relative novelty in the words affect its duration.

Vowel Duration in Telugu

Vowel duration in Telugu is subject to a number of contextual effects (Duggirala, 2005). Nagamma Reddy (1986) reported that, the ratio of short and long vowel duration in word-initial to word-medial vowels of Telugu is more than 1:2. In a single case study, on the duration of vowels in Telugu in different consonant environments, Girija and Sridevi (1995) reported that the duration of a long vowel is approximately twice the duration of a short vowel and the ratio between the short and long vowels is 1:2.1. The longest among short vowels is /o/ and the shortest is /u/ and the longest among long vowels is /a:/ and the shortest is /e:/. These studies do not reflect the vowel duration in different age groups, gender variations and dialectal variations.

Tense and Lax Vowels

The approximate configuration for tense vowels is said to require a longer period than that for lax vowels, which results in relatively longer vowel duration for tense vowels as compared to lax vowels (Mitleb, 1984). In English language, lax/short vowels have much shorter vowel duration than long/tense vowels. It is also reported that, the discrepancy between the

longest of the short vowel (/ɛ/, 185 ms) and the shortest of the long vowel (/u:/, 225 ms) is 40 ms (Hongyan, 2007).

Effect of Dialectal Variations on Vowels

Dialectal or regional variations have an effect on acoustic characteristics of vowels. Study of acoustic measures (duration, first and second formant frequencies) from six regional varieties of American English, revealed a consistent variation due to region of origin, particularly with respect to the production of low vowels and high back vowels. Vowel system of American English is better characterized by the region of origin than in terms of single set (Clopper, Pisoni, & de Jong, 2005).

Studies on Telugu Vowels

Most of the studies on acoustic analysis of Telugu vowels in the literature (Kostić, Mitter & Krishnamurti, 1977; Nagamma Reddy, 1998, 1999; Prabhavathi Devi, 1990; Girija & Sridevi, 1995; Sreenivasa Rao, Suryakanth, Gangashetty, & Yegnanarayana, 2001) have been done only on adults or children, in limited consonant contexts, in limited sample size, selected from one region/dialect, with no comment on gender variations. With recent advances in the rehabilitation of communication disorders, knowledge on acoustic characteristics of speech sounds in each age group, language, dialects, and gender will assist the clinician in assessing, diagnosing and rehabilitating communication impaired individuals. The paucity of comprehensive data on the vowel duration of vowels in Telugu across different age group, has prompted the current study.

Method

Material

A list of 100 meaningful disyllabic words consisting of CVCCV and CVCV syllables were selected from Telugu magazines and dictionary (Sitaramacharyulu, 2005) and given to age appropriate normals across the three different regions (Coastal, Rayalaseema and Telengana) for familiarity rating. Words that were rated as familiar and most familiar across all the regions and age groups were selected for compilation of the final word list. Final list of 60 words (Appendix I) consisting of all ten short and long vowels present in Telugu, in all possible consonant and

semivowel context was prepared. The target word was embedded in the final position of a carrier sentence "/i: padamu (target word) /" (This word is _____), so as to obtain reasonable uniform stress and intonation patterns (Bennett, 1981; Most, Amir & Tobin, 2000).

A total of 4320 tokens of vowels from 72 participants served as the initial sample size. 21 tokens were eliminated owing to poor acoustic features, bringing down the final sample size to 4299.

Participants

A total of 72 Telugu speaking normals 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. Selection of age criteria for Group I was to avoid the effect of pubertal changes among the participants. Both genders were included in this group, as children below this age group generally don't demonstrate any significant differences in their vocal characteristics (Most, Amir & Tobin, 2000). The mean age across each group that participated in the study is Group I – 8.5 years, Group II – 13.42 years and Group III – 23.42 years. Each age group was further divided into equal number of males and females. Further, three subgroups were made based on each region (Coastal, Rayalaseema and Telengana) of the language usage. A total of 18 subgroups were formed. All the participants were born in Andhra Pradesh and were native Telugu speakers. A qualified Audiologist and Speech-Language Pathologist evaluated and certified their speech, language, and hearing, as being normal at the time of data collection.

Procedure

The randomly selected participants from the respective groups were comfortably seated in a sound treated chamber. With the condenser microphone to mouth distance kept constant at 2 centimeters, the recording was done on to the hard disk of a personal laptop computer (IBM ThinkPad, with Genuine Inter(R) CPU, T2300 @ 1.66GHz, 504 MB of RAM and with a built-in audio interface card) installed with the Wave Surfer recording software. The speech sample was recorded at a sampling rate of 22,050 kHz and bit rate of 256 kbps.

The tokens were presented on the computer screen to the participant one at a time. The participant was instructed to read the target embedded sentence twice as it appeared on the screen. All recordings were stored in Microsoft Windows wave format (*.wav) for future retrieval and analysis. From the two thus recorded sentences, the perceptually correct target word was extracted using Adobe Audition (version 3.0) software. The extracted sound was saved in *.wav format. The target words were presented to one Telugu speaking adult Speech Language Pathologist to perceptually judge the correct pronunciation of the target word. Computerized Speech Lab (CSL) 4500 was used for temporal and spectral analysis of the target vowel present in the target word. 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.

10% of the sample was randomly selected and given to an experienced Speech Language Pathologist for reliability. Results from the paired t-test suggest that the two measures are highly reliable. ($t_{(431)} = 0.10$, $p = 0.920$). 10% of the sample was randomly selected and re-analyzed by the researcher to test the test-retest reliability. Results from the paired t-test suggest that the two measures are highly reliable ($t_{(431)} = 1.026$, $p = 0.309$).

Results

The mean and 1 standard deviation (1 SD) bars of all vowels' vowel duration are depicted in Figure 1 and Table 1. Scrutiny of the vowel duration data revealed that the mid high vowel /e/ and low mid vowel /a:/ were the longest and the high front vowels /i/ and /i:/ were the shortest. Central vowels were longer followed by front and back vowels. It was also observed that, the mean vowel duration of the short vowel was shorter followed by long vowel.

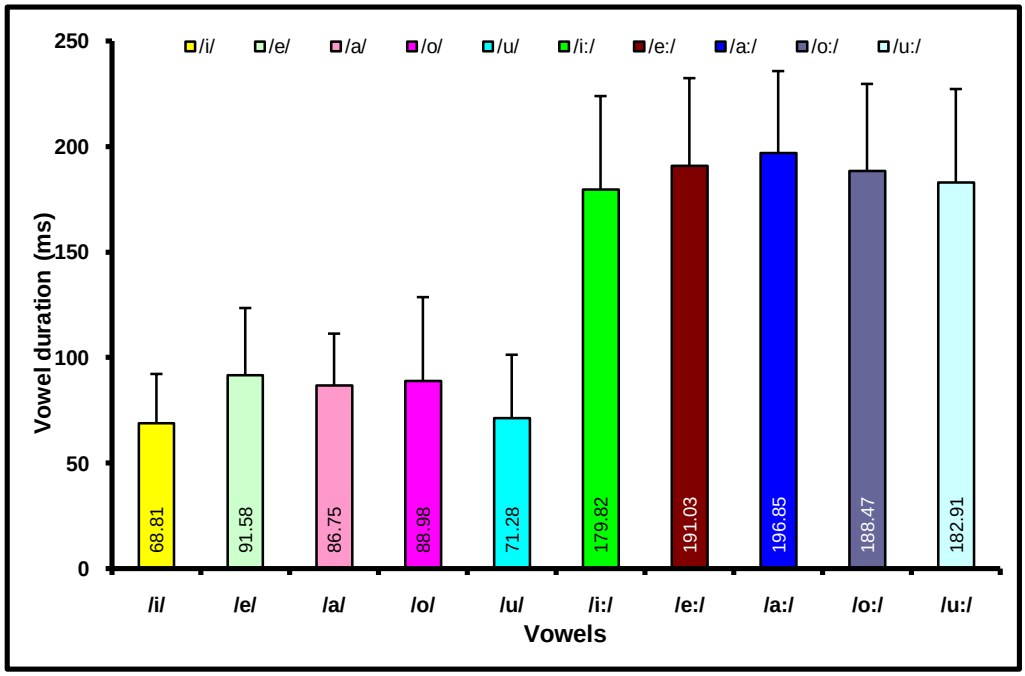

Figure 1: Mean vowel duration (ms) and 1 SD bars of all vowels

The mean vowel duration was also longer in children followed by adults and adolescents in all long vowels. The means with 1 SD bars of vowel duration across the age groups are depicted in Figure 2 and Table 1.

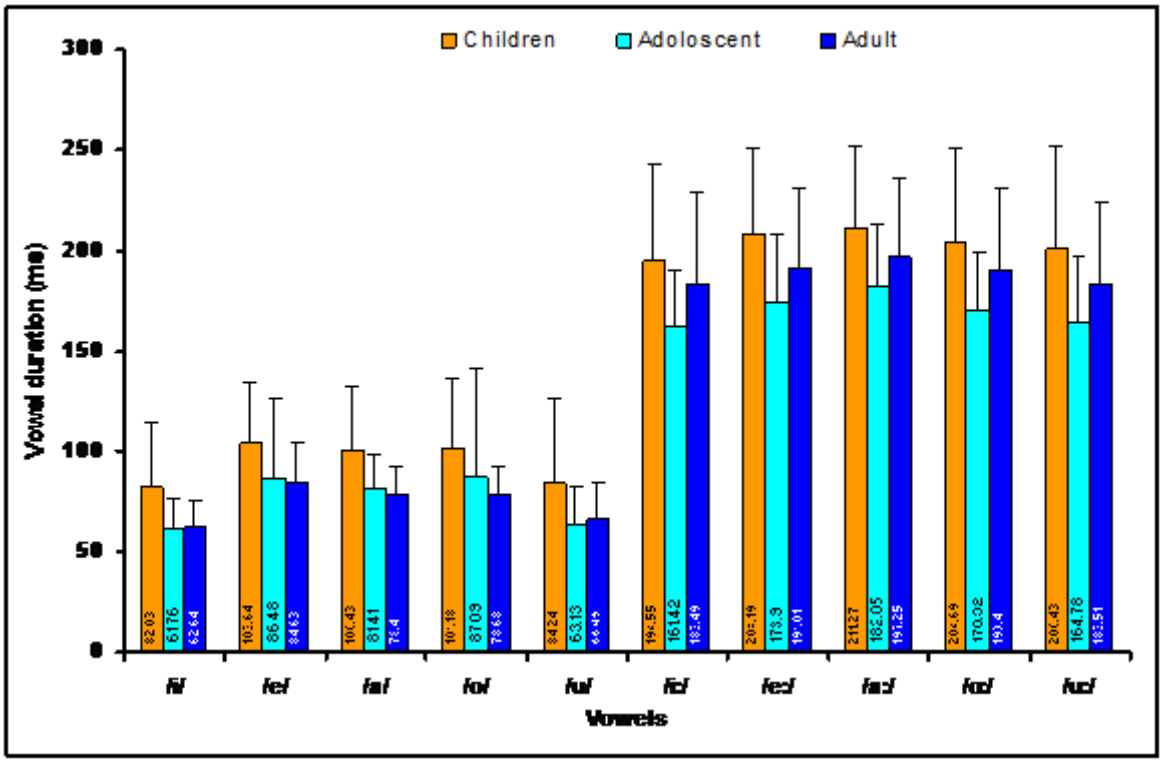

Figure 2: Mean vowel duration (ms) and 1 SD bars across age groups

Region wise, speakers from Rayalaseema region had longer mean vowel duration for all short and long vowels followed by Telengana and Coastal speakers. Among short vowels, front mid vowel /e/ had the longest mean vowel duration for Coastal, Rayalaseema and Telengana speakers. Short front high vowel /i/ had the shortest mean vowel duration for Coastal, Rayalaseema and Telengana speakers. Among long vowels, low mid vowel /a:/ had the longest mean vowel duration in Coastal, Rayalaseema and Telengana speakers respectively. Long vowel /i:/ had the shortest vowel duration for Coastal, Rayalaseema and Telengana speakers respectively. The means with 1 SD bars of vowels duration across region groups are given in Figure 3 and Table 1.

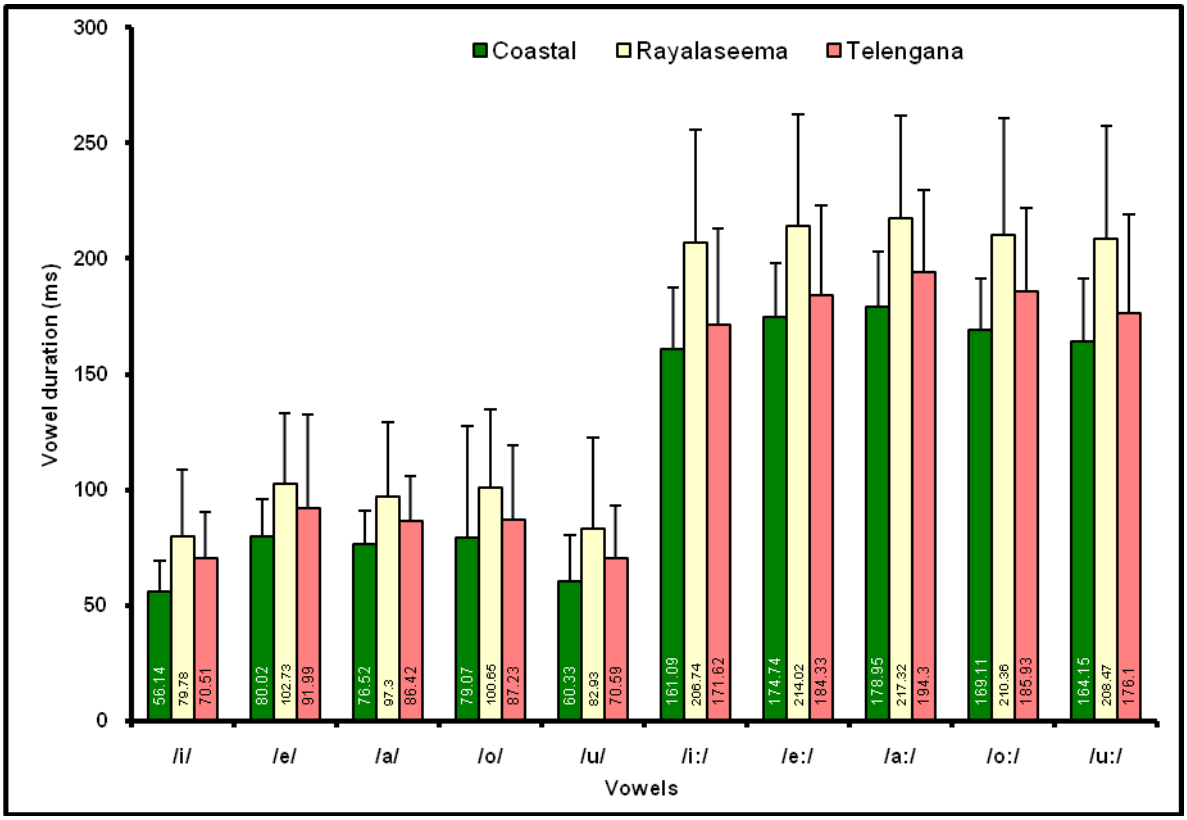

Figure 4: Mean vowel duration (ms) and 1 SD bars across region groups

In order to understand the associations of age, gender and region with vowel duration and which of the vowels studied have significant difference in vowel duration among the age and region groups, a random intercept model was used. The results are given in Table 2.

From Table 2 it is observed that, there is a significant association of vowel duration with age and region with, age having negative association. Further to study which of the vowels differed significantly among the age and region groups, Tukey HSD was done and the results suggested that vowel duration of all short vowels (/i/, /e/, /a/, /o/ and /u/) did not show statistically significant difference between adolescents and adults and for /i:/ between children and adults (Table 3). Within the region groups, vowel duration of vowels /o/, /i:/, /e:/ and /u:/ did not show statistically significant difference between Coastal speakers and Telengana speakers (Table 4).

Table 2: Statistical analysis using random intercept model for VD

N=4320

Covariates	Estimate	Std. Error	Wald ratio	P value*
Constant (β_{0ij})	137.08	9.58	14.31	< 0.01
Age (β_{1ijk})	-0.82	0.08	-10.25	< 0.01
Gender (β_{2ijk})	-2.57	1.07	-2.40	0.01
Region (β_{3ijk})	5.69	0.65	8.75	< 0.01
Variance components				
Random Error:	1207.54			
Consonant Level:	42.28			
Individual level:	2970.79			
Total variation:	4220.6			
*-2*loglikelihood(IGLS) = 43190.59*				

**significant at 0.05 level*

Table 3: Post hoc results for each vowel between age groups for VD

N=4320

Vowel	(I) Age Group	(J) Age Group	Mean Difference (I-J)	Sig.
	Children	Adolescent	20.26(*)	< 0.01
/i/	Children	Adult	19.39(*)	< 0.01
	Adolescent	Adult	-.88	0.968
	Children	Adolescent	17.16(*)	< 0.01
/e/	Children	Adult	19.01(*)	< 0.01
	Adolescent	Adult	1.85	0.847
	Children	Adolescent	19.02(*)	< 0.01
/a/	Children	Adult	22.03(*)	< 0.01
	Adolescent	Adult	3.01	0.392
/o/	Children	Adolescent	14.08(*)	0.014

Vowel	(I) Age Group	(J) Age Group	Mean Difference (I-J)	Sig.
	Children	Adult	22.49(*)	< 0.01
	Adolescent	Adult	8.41	0.211
	Children	Adolescent	21.11(*)	< 0.01
/u/	Children	Adult	17.75(*)	< 0.01
	Adolescent	Adult	-3.36	0.443
	Children	Adolescent	33.14(*)	< 0.01
/i:/	Children	Adult	11.06	0.166
	Adolescent	Adult	-22.07(*)	0.001
	Children	Adolescent	34.28(*)	< 0.01
/e:/	Children	Adult	17.18(*)	0.001
	Adolescent	Adult	-17.10(*)	0.001
	Children	Adolescent	29.22(*)	< 0.01
/a:/	Children	Adult	14.02(*)	< 0.01
	Adolescent	Adult	-15.20(*)	< 0.01
	Children	Adolescent	34.36(*)	< 0.01
/o:/	Children	Adult	14.29(*)	0.031
	Adolescent	Adult	-20.07(*)	0.001
	Children	Adolescent	35.65(*)	< 0.01
/u:/	Children	Adult	16.92(*)	0.016
	Adolescent	Adult	-18.73(*)	0.006

*significant at 0.05 level

Table 4: Post hoc results for each vowel between region groups for VD

N=4320

Vowel	(I) Age Group	(J) Age Group	Mean Difference (I-J)	Sig
/i/	Coastal	Rayalaseema	-23.64(*)	< 0.01

Vowel	(I) Age Group	(J) Age Group	Mean Difference (I-J)	Sig
	Coastal	Telengana	-14.38(*)	< 0.01
	Rayalaseema	Telengana	9.26(*)	0.029
	Coastal	Rayalaseema	-22.71(*)	< 0.01
/e/	Coastal	Telengana	-11.96(*)	0.001
	Rayalaseema	Telengana	10.74(*)	0.004
	Coastal	Rayalaseema	-20.78(*)	< 0.01
/a/	Coastal	Telengana	-9.90(*)	< 0.01
	Rayalaseema	Telengana	10.88(*)	< 0.01
	Coastal	Rayalaseema	-21.58(*)	< 0.01
/o/	Coastal	Telengana	-8.17	0.232
	Rayalaseema	Telengana	13.42(*)	0.021
	Coastal	Rayalaseema	-22.60(*)	< 0.01
/u/	Coastal	Telengana	-10.25(*)	0.001
	Rayalaseema	Telengana	12.34(*)	< 0.01
	Coastal	Rayalaseema	-45.65(*)	< 0.01
/i:/	Coastal	Telengana	-10.53	0.161
	Rayalaseema	Telengana	35.11(*)	< 0.01
	Coastal	Rayalaseema	-39.28(*)	< 0.01
/e:/	Coastal	Telengana	-9.59	0.084
	Rayalaseema	Telengana	29.69(*)	< 0.01
	Coastal	Rayalaseema	-38.38(*)	< 0.01
/a:/	Coastal	Telengana	-15.35(*)	< 0.01
	Rayalaseema	Telengana	23.03(*)	< 0.01
	Coastal	Rayalaseema	-41.25(*)	< 0.01
/o:/	Coastal	Telengana	-16.81(*)	0.006
	Rayalaseema	Telengana	24.44(*)	< 0.01
/u:/	Coastal	Rayalaseema	-44.32(*)	< 0.01

Vowel	(I) Age Group	(J) Age Group	Mean Difference (I-J)	Sig
	Coastal	Telengana	-11.96	0.103
	Rayalaseema	Telengana	32.36(*)	< 0.01

*significant at 0.05 level

Discussion

From the results, it is inferred that there is a significant association between age and region with respect to vowel duration. As age increased, there was a significant decrease in vowel duration. From the analysis it is inferred that, vowel duration is influenced more by the individual variations as compared to preceding consonants.

The finding of reduced vowel duration for vowel /i/ in this study is similar to the findings of Nagamma Reddy (1998) and Prabhavathi Devi (1990) in Telugu and Sreedevi (2000), Venkatesh (1995) in Kannada. Similar findings have also been reported in English by Lisker (1974). The findings of the present study further support the report of Maddieson (1993) that vowel duration depends on the height of the tongue.

Central vowels having longer vowel duration followed by front and back vowels have been reported in most of the languages *viz.*, English (Clopper, Pisoni & de Jong, 2005; Hunyady, 2006), Hebrew (Most, Amir & Tobin, 2000), Greek (Daver, 1980), Telugu (Girija & Sridevi, 1995; Prabhavathi, 1990; Sreenivasa Rao, Suryakanth, Gangashetty & Yegnanarayana, 2001), and other Indian languages (Riyamol, 2007; Savithri, 1984; Venkatesh, 1995). Based on the aforesaid studies, it may be appropriate to conclude that vowel duration due to place of constriction is an universal phenomenon irrespective of language. This could probably be attributed to the anatomical and physiological aspects of the articulators involved in the production of these vowels.

It can thus be concluded from the current study that, as the age increases, vowel duration reduces. The reduction in vowel duration as the age progresses is reported in English (Eguchi & Hirish, 1969; Kent & Burkhard, 1981; Kent & Forner, 1979; Krause, 1982; Smith, 1978), Hebrew (Most et.al., 2000) and in all Indian languages studied (Rashmi, 1985; Samuel, 1973; Sreedevi, 2000; Usha, 1978) excepting in Malayalam (Ampathu, 1998). Such a reduction in vowel duration could be attributed to neuromuscular changes that occur over the age (Eguchi & Hirish, 1969; Kent & Burkhard, 1981) and as an index of deterioration of vowel precision in various adult speakers (Strom, Thomson, Boutsen & Pentz, 2005).

Regional variations or dialectal variations in vowel duration as observed in the present study for Telugu have also been reported for American English (Clopper, Pisoni & de Jong, 2005; Gendrot & Adda-Decker, 2007).

Conclusion

Vowels are produced by voiced excitation of the open vocal tract. Vowels are classified based on the tongue height, position of the tongue, lip position, soft palate position, phonemic length, articulators' tension and pitch. Acoustically, vowels are characterized by changing formant pattern, formant bandwidth, duration, amplitude and fundamental frequency.

Acoustic characteristics of vowels are generally studied based on their Fundamental Frequency, Formant Frequencies, Vowel Duration and Intensity. Acoustic studies illuminate the subtle differences in the production problems experienced not only by the hearing impaired but also in normal individuals and in different languages (Edward & Valter, 2006 & 2007; Duggirala, 1995; Ladefoged, 1975).

Telugu belongs to the Dravidian family of languages (Krishnamurti, 2003) and is the second most widely spoken language in India (Hussain, Durrani & Gul, 2005). It has ten vowels (long and short: i, e, a, o, u) and seventeen consonants (six plosives: p, b, t, d, k, g; two retroflex stops: t%, d%; two affricates: tΣ, dZ; two fricatives: s, Σ; two nasals: m and n; one lateral: l; and

two semi-vowels: /w/ and /y/) (Nagamma Reddy, 1986). Most of the studies on acoustic analysis of Telugu vowels in the literature (Kostić, Mitter & Krishnamurti, 1977; Nagamma Reddy, 1998, 1999; Prabhavathi Devi, 1990; Sreenivasa Rao, Suryakanth, Gangashetty, & Yegnanarayana, 2001) have been done only on adults or children, in limited consonant contexts, in limited sample size, selected from one region/dialect, with no comment on gender variations. However, these factors (age, dialectal variations, and consonant context) play significant role on the acoustic characteristic of vowels. The paucity of comprehensive data on the acoustic characteristics of vowels in Telugu across different age group and regions on the most essential features (vowel duration, formant frequencies, and bandwidth), has prompted the current study.

The aim of the current study was to investigate the vowel duration of vowels in Telugu language across different age groups, and different regions in Andhra Pradesh. A list of 60 words consisting of ten vowels eighteen consonant and semivowel present in Telugu were used to analyze the temporal and spectral characteristics of the first vowel occurring in CVC/CVCCV context. A total of 72 randomly selected, Telugu speaking normal participants 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.

A total of 4320 tokens of vowels from 72 participants served as the sample size for analysis. Descriptive analysis of the data was performed using SPSS 16. A three-level model was constructed with individuals as first level, consonants context as second level and vowels as third level, to evaluate the effect of age and region on the response variables (vowel duration,), a multi-level approach (Quene & Bergh, 2004) was used in MlWin 1.1. Significance levels were determined with Wald test. Further to estimate the significant mean difference of each vowel between the age and region groups for each response variables, one way ANOVA with Tukey HSD post hoc test were used respectively using SPSS 16.

From the current study, it can be concluded that, in Telugu:

- Vowels /e/ and /a:/ have longest vowel duration.

- Short and long vowels /i/ have shortest vowel duration.
- Children have longer vowel duration as compared to adolescents or adults.
- Regional influences are seen on vowel duration. Rayalaseema speakers have longer vowel duration as compared to Coastal or Telengana speakers.

From the current study it is inferred that, vowels in Telugu follow universal criteria of vocal tract constriction and resonance characteristics, especially spectral parameters. As reported, significant variations in vowel duration of vowels in Telugu exist between children, adolescents and adults; Coastal, Rayalaseema and Telengana speakers. Hence, it is essential for speech language pathologists to apply the age, gender and region appropriate normative data to achieve appropriate speech output. From the multilevel statistical analysis, it is observed that consonants have higher contribution to the changes in formant frequencies and hence consonant contexts of the words with the target vowel should be carefully selected during comparisons of speech samples.

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