

Acoustic Correlates of Emphatic Stress in Tulu: A Preliminary Study

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Abstract Stress is an extra effort given on a syllable/word/phrase to emphasize special meaning. The acoustic cues for stress include increased fundamental frequency, amplitude, duration and vowel quality. These cues vary depending upon the structure of languages. The acoustic correlates of emphatic stress in Tulu language are not well understood. Hence the aim of the present study was to investigate the acoustic correlates of emphatic stress in Tulu language. A total of 20 female native speakers of Tulu language within the age range of 18-25 years were selected for the study. Ten bisyllabic words consisting of an adjective and a verb were chosen. The subjects were asked to read the two word phrases with and without stress on the adjectives, to note the variations in stressed and unstressed conditions. The peak fundamental frequency (f0), peak intensity (dB) and duration (msec) were extracted from the adjectives of ten phrases using the praat software. Paired t test was employed to note the significance of difference between the stressed and unstressed conditions. Statistical analysis revealed significant increase in word duration and peak intensity in stressed conditions. It can be concluded that the Tulu speakers use duration and intensity as a cue to indicate emphatic stress. Additional research is warranted to confirm these findings, using larger population and by controlling the variables that affect the acoustic cues for stress in Tulu language.

Keywords Stress, Fundamental Frequency, Intensity, Duration

1. Introduction

Stress is used to emphasize a word and to bring about difference in meaning. Stress is defined as an utterance of syllable with greater effort than other neighbouring syllables in a word or words in a sentence ([1]). There are many categories of stress in literature. The present study focuses on the acoustic correlates of emphatic stress. "Emphatic stress in a phrase or sentence is used to indicate the word, which needs to be focused to indicate the syntactic relationships between words or parts of word, and has a linguistic function in distinguishing between a compound and a noun([2])." Earlier studies have shown that the acoustic correlates of stress vary from language to language and stressed syllables are associated with one or more of the following properties i.e., raised fundamental frequency, increased loudness, greater duration, and different vowel qualities ([3],[4]). In languages such as English ([5],[6]), Polish ([7]) and French ([4]), fundamental frequency was observed as the primary acoustic correlate of emphatic stress, whereas duration was reported to be major correlate in languages such as Swedish ([8]), Italian ([9]) and Estonian ([10]). Thus, there is a need to expand the breadth of our phonetic knowledge about the

manifestations of stress in Indian languages too. Given India's multiple language environments, with 22 constitutionally accepted languages, four classical languages and about 1652 mother tongues ([11]) spoken in and around the country, it offers a fertile experimental ground for phonetic research. Though India is a land of many languages, it has not been subjected to the instrumental studies of stress. Only a few studies have been carried out in Indian languages to measure emphatic stress. Among Dravidian languages, duration and intensity were found to contribute significantly towards perception of stress ([12]). Other studies reported that duration alone is indicated to be the major cue in Kannada ([13],[14],[15],[16]), Konkani ([17]) and Tamil ([18]). According to Sitapati ([19]) and Srinivas ([20]), intensity has been reported as a reliable acoustic correlate of stress in Telugu. In Indo Aryan language Hindi, duration and fundamental frequency were observed as the major acoustic correlates of stress ([21]). However, the acoustic correlates that signal emphatic stress has not been explored in many Indian languages. One such language which has not been focused till date is the Tulu language.

Tulu is a most highly developed Dravidian language spoken in Dakshina Kannada district of Karnataka state as well as in the northern part of Kerala by around 25 lakh people. The word Tulu implies 'related to water'. Thus Tulu means the 'language of waters'([22]). It is considered as one of the five major Dravidian languages; the other four being Telugu, Kannada, Tamil and Malayalam. It has retained

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several characteristic features of the original Dravidian tongue and made certain innovations that are not noticed in other Dravidian languages. The paucity of literary works has rendered the precise dating of the origin of this language very difficult. A claim is that it predates Tamil, but has lot in common with Kannada and also has some relation with Malayalam and Tamil. Tulu has a rich vocabulary and has been considered as a highly developed language by the linguists. The overall phonemic system of Tulu includes 14 vowels (7 short, 7 long) and 34 consonants with 8 stops and 2 affricates. Though Tulu is spoken in a limited geographical area, it has its own phonemes, vocabulary and syntax ([23]).

From the literature, it seems that the stress patterns in various Indian languages have been studied, but there is no published quantitative research in Tulu language. Thus, there is a need to enrich our knowledge about the manifestations of emphasis in Tulu language in the field of speech synthesis, text to speech analysis, second language teaching and correction of speech in clinical population with prosodic disorders. The present study was proposed with the aim of analyzing the acoustic correlates of emphasis in Tulu language.

2. Method

2.1. Subjects

A total of twenty adult females in the age range of 18 to 25 years (mean age 21.5 years) were included in the study. The mother tongue of all the subjects was Tulu. The subjects were non-smokers and had normal hearing and oro-facial structures. Those who had a history of vocal abuse or misuse, exposure to toxic chemicals, or any upper respiratory tract infection were excluded from the study.

2.2. Test Material

The test material consisted of ten two-word Tulu phrases. In each phrase, first word was an adjective and the second a verb. It was ensured that all adjectives selected were bisyllabic and none of the syllables were aspirated or had geminate clusters. Familiarity was checked by three Tulu native speakers and finally a set of ten phrases were selected for the study. A list of ten phrases are appended in Appendix-1.

2.3. Instrumentation

The subject's speech samples were recorded through the SONY digital recorder ICD-U60 and the same was loaded onto the Praat software ([24]) and stored on computer hard disk. The recordings were done digitally and sampled at 22 kHz, 12 bit quantization. All the recordings were obtained with the microphone position fixed at a constant distance of 6 cm.

2.4. Procedure

Each subject was tested individually. They were seated comfortably in a quiet room, with minimum interference from the background noise. They were instructed to read the given written material in two conditions, first without stressing the phrases (speaking as naturally as possible) and then by stressing the adjective in each of the phrases. Before recording the samples, the subjects were allowed to practice the phrases. Praat software was used for the extraction of fundamental frequency, duration and intensity in both unstressed and stressed conditions from the adjectives under study. The definitions of the terms are appended in Appendix-2. Mean peak intensity was corrected with the correction factor as per the calibration procedures of the Praat software.

2.5. Statistical Analysis

Mean and standard deviation (SD) values for each acoustic parameter in stressed and unstressed conditions were tabulated. Paired t-test was used to find out the significant difference between both conditions for peak fundamental frequency, peak intensity and duration using SPSS 17.0 (Statistical Package for Social Sciences 17.0).

3. Results

3.1. Peak Fundamental Frequency (F0)

Table 1 and Figure 1 display the mean and SD values of peak fundamental frequency obtained for all the ten adjectives in the two conditions. The mean fundamental frequency obtained for all the ten adjectives under study in unstressed condition was 235.82 Hz (SD = 22.09) and in stressed conditions, it was 236.32 Hz (SD = 41.96). On statistical analysis, paired t-test revealed no significant difference ($t = 0.122$; $p = 0.903$) between unstressed and stressed conditions. Overall, out of ten analyzed words, only one adjective /malla/ was significantly different ($p = 0.034$).

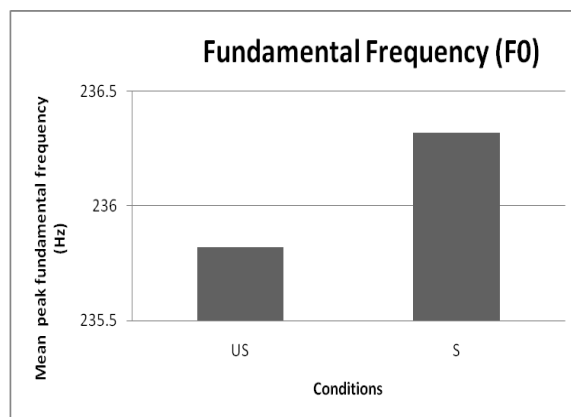


Figure 1. Mean fundamental frequency in Hz for unstressed (US) and stressed (S) conditions

3.2. Peak intensity (Io)

The mean and SD values of peak intensity obtained for all the ten adjectives in the two conditions are presented in

Table 2 and Figure 2. The mean peak intensity obtained for all the ten adjectives included in the study was 68.20 dB (SD = 3.59) in unstressed condition and in stressed conditions, it was 70.11 dB (SD = 2.94). From Table 1, it is clear that the peak intensity in the stressed condition was higher compared to that of unstressed condition. The statistical analysis results showed a significant difference between unstressed and stressed conditions at 0.05 level ($t = -7.8$; $p = 0.000$). However, the results showed that two of the adjectives were not statistically different (/medu/ ; $p = 0.44$ and /ellya/ ; $p = 0.247$).

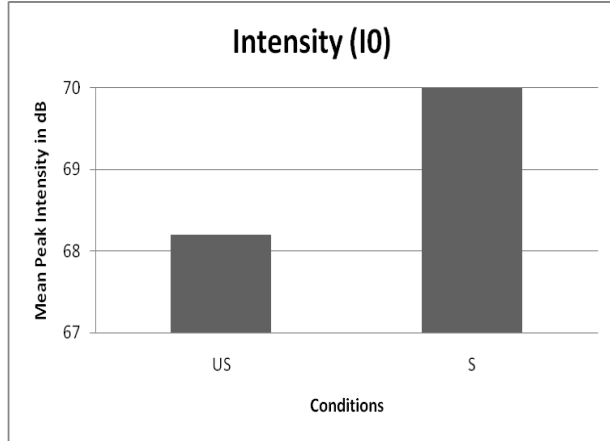


Figure 2. Mean peak intensity in dB for unstressed (US) and stressed (S) conditions

Table 1. Mean, standard deviation and t test values of peak fundamental frequency for all the ten adjectives in unstressed (US) and stressed (S) condition.

Words	Peak fundamental frequency (Hz)		
	US	S	t-value
/medu/	233.19 (17.65)	226.14 (27.03)	-0.958 (0.363)
/ellya/	232.82 (22.99)	228.24 (11.19)	-0.955 (0.365)
/kundyā/	228.82 (18.20)	236.82 (30.64)	0.884 (0.400)
/sipe/	246.30 (23.96)	243.98 (16.07)	-0.308 (0.756)
/red/	229.66 (34.58)	222.14 (26.11)	-2.051 (0.071)
/tora/	235.90 (21.03)	230.59 (15.30)	-1.216 (0.256)
/puli/	249.53 (16.66)	259.95 (70.96)	0.428 (0.679)
/malla/	233.82 (27.20)	222.32 (16.82)	-2.490 (0.034)
/kara/	230.67 (13.97)	226.79 (12.88)	-1.779 (0.113)
/boldu/	235.57 (16.94)	245.83 (64.62)	0.544 (0.600)
Mean	235.82 (22.09)	236.32 (41.96)	0.122 (0.903)

3.3. Duration (D0)

Table 3 and Figure 3 show the mean and SD values of duration obtained for all the ten adjectives in both the

conditions. The mean word duration obtained for all ten adjectives selected in unstressed condition was 412.23 msec (SD=102.6) and in stressed condition, it was 501.75 msec (SD=128.5). The mean duration was higher in stressed condition compared to that of unstressed condition. The results of statistical analysis showed a significant difference between unstressed and stressed conditions ($t = -10.67$; $p = 0.000$). The results were consistent except for the word /medu/ ($p = 0.152$).

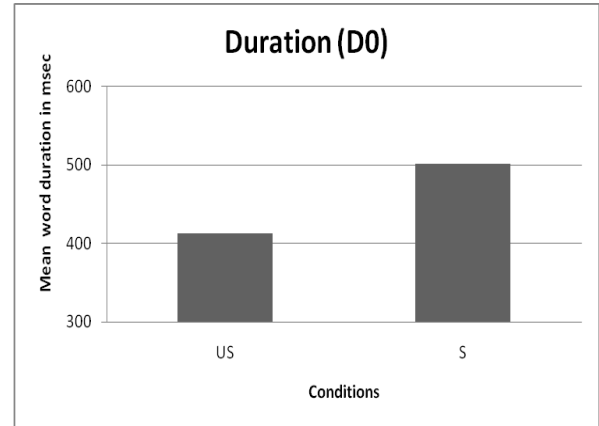


Figure 3. Mean duration in msec for unstressed (US) and stressed (S) conditions

Table 2. Mean, standard deviation and t test values of peak intensity for all the ten adjectives in unstressed (US) and stressed (S) condition.

Words	Peak Intensity (dB)		
	US	S	t-value
/medu/	68.67 (3.54)	69.14 (2.49)	-0.807 (0.441)
/ellya/	69.39 (3.36)	70.14 (1.94)	-1.239 (0.247)
/kundyā/	67.22 (3.28)	68.64 (2.56)	-3.714 (0.005)
/sipe/	66.92 (3.99)	68.94 (2.71)	-2.42 (0.039)
/red/	66.94 (3.33)	68.75 (2.16)	-2.382 (0.041)
/tora/	69.27 (4.44)	73.21 (3.17)	3.381 (0.01)
/puli/	68.04 (2.96)	70.01 (3.02)	-2.865 (0.019)
/malla/	68.77 (4.18)	70.89 (3.11)	-2.495 (0.034)
/kara/	69.28 (3.11)	70.88 (3.06)	-5.447 (0.000)
/boldu/	67.54 (8.81)	70.51 (3.07)	-3.742 (0.005)
Mean	68.20 (3.59)	70.11 (2.94)	-7.851 (0.000)

3.4. S-ratio

The S-ratio was calculated by obtaining the difference between stressed and unstressed conditions for peak fundamental frequency (f_0), peak intensity (I_0) and duration. The values obtained were 0.5 Hz, 1.91 dB and 89.52 msec for peak fundamental frequency (f_0), peak intensity (I_0) and

duration respectively. There was a slight difference in peak fundamental frequency between stressed and unstressed condition.

4. Discussion

The present study is one of the first to investigate the acoustic correlates of emphatic stress in Tulu language. For this, a set of ten phrases were recorded from the native speakers of Tulu language in unstressed and stressed conditions. The peak fundamental frequency (f_0), peak intensity (dB) and duration (msec) were extracted from the adjectives of ten phrases and both conditions were compared. The results revealed higher peak fundamental frequency, peak intensity and duration in stressed condition than in unstressed condition. The S-ratio was 0.5 Hz, 1.91 dB and 89.52 msec for peak fundamental frequency, peak intensity and word duration respectively.

Table 3. Mean, standard deviation and t test values of duration for all the ten adjectives in unstressed (US) and stressed (S) condition

Words	Duration (msec)		
	US	S	t-value
/medu/-	375.62 (93.45)	431.20 (83.18)	-1.567 (0.152)
/ellya/	390.33 (56.58)	477.03 (100.1)	-4.853 (0.001)
/kundya/	434.48 (113.7)	545.69 (120.4)	-3.341 (0.009)
/sipe/	580.88 (80.69)	659.42 (164.3)	-2.039 (0.072)
/red/	413.27 (77.35)	483.79 (62.36)	-6.563 (0.000)
/tora/	363.90 (58.86)	446.16 (87.77)	-3.518 (0.007)
/puli/	334.00 (79.74)	432.67 (136.4)	-4.929 (0.001)
/malla/	382.89 (64.30)	481.13 (111.8)	-4.516 (0.001)
/kara/	402.83 (79.00)	517.62 (147.6)	-3.263 (0.010)
/boldu/	444.12 (112.1)	542.79 (105.1)	-4.610 (0.001)
Mean	412.23 (102.6)	501.75 (128.5)	-10.67 (0.000)

The results of the present study revealed no significant difference in fundamental frequency between unstressed and stressed conditions. In contrast to this, fundamental frequency was the primary acoustic correlate of emphasis in languages such as Polish, English, and French ([4],[5],[6],[7]). Thus this data supports the notion that acoustic correlates of emphasis differ across languages and depends upon the structure of language. On the contrary, peak intensity showed a significant difference between unstressed and stressed conditions. These results are in consonance with the findings reported in Kannada language ([12]), where they obtained intensity as an acoustic correlate of emphasis along with duration. However, results of

intensity measure should be considered with the following limitations. There are many factors that affect the intensity parameter such as intrinsic properties of the speech sound in the words selected for the analysis, interaction between fundamental frequency and first formant frequency, co-articulatory factors, recording variables and calibration ([25]). Further studies are warranted to include perceptual analysis and correlate it with acoustic findings for a better clinical picture of emphatic stress in Tulu language.

The mean duration was higher for the words in stressed condition compared to that of unstressed condition. The results are in agreement with the findings reported in several other Indian languages like Kannada ([12],[13],[14],[15],[16]), Telugu ([20]), Tamil ([18]), Hindi ([21]) and Konkani ([16]), where they reported duration measure as a major cue for emphasis. Studies have also reported that duration is a major acoustic correlate of emphasis in Swedish ([8]), Estonian ([10]) and Italian ([9]) languages. The increase in duration in stressed condition may be hypothesized to the differences in the phonetic structure of long and short vowels in Tulu language. Hence, lengthening of duration was used consistently by all the speakers to cue emphasis. The present study was conducted in an area where Kannada language was spoken predominantly; this might have also influenced the results. Further studies can be carried out by controlling the influence of Kannada language to note emphasis in Tulu language.

5. Conclusions

In the present study, acoustic correlates of emphasis were studied in Tulu speaking female subjects. The results showed that there is a significant increase in word duration and peak intensity consistently, in stressed condition. Therefore, it is possible that a Tulu speaker uses duration and intensity as a cue to indicate emphasis. This information would enable us to understand acoustic correlates of emphasis in Tulu language as well as in the assessment and treatment of prosodic disorders in Tulu speakers. However, in the present study sample size is comparatively small, includes only female subjects and makes use of only bisyllabic phrases for the analysis. Further studies should be carried out using larger population, both males and female respondents, and data at sentence level to validate the results.

Appendix 1. Ten Tulu Phrases

Sl.no	Ten Phrases
1	meddu kudzal
2	ellyja ba:le
3	kuddja a:n
4	si:pe per
5	red ka:dzi:
6	to:ra manushja
7	pu:li sa:r
8	malla mara
9	ka:ra kadzippu
10	boldu ku:li

Appendix 2. Acoustic parameters

1. Peak fundamental frequency (fo) was measured as the maximum pitch in the utterance in Hertz (Hz)
2. Peak Intensity (Io) was measured as the maximum intensity in the utterance in dB.
3. Duration (Do) was measured as the time difference between the starting and end point of the utterance in milliseconds.
4. S-ratio was measured by taking the difference between stressed and unstressed conditions for all the above mentioned acoustic parameters.

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