Acoustic Correlates of Stress in Nepali Language

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Abstract- Stress provides an acoustic cue to a syllable, word or a part of a sentence to convey different intents without changing the meaning. The acoustic correlates of stress comprises of increased fundamental frequency, intensity, duration and vowel quality. These acoustic measures vary according to the structure of the language. There are no reports on the acoustic correlates of stress in Nepali. Hence, the present study aims to investigate the acoustic correlates of stress in Nepali language. A total of 20 native speakers of Nepali language in the age range of 18 to 30 years participated in the study. Ten bi-syllabic words consisting of an adjective and a noun were chosen. The participants were asked to read the two word phrases with and without stress on the adjectives that were marked in italics. The variations in stressed and unstressed conditions were analyzed for the marked adjectives. The peak fundamental frequencies (Fo), peak intensity (dB), duration (msec) were extracted from the adjectives of the 10 phrases using PRAAT (Version 5.3.17) software. S-ratio was also computed for the acoustic measures of stress for both the stressed and unstressed conditions. Descriptive analysis revealed increase in the Means of peak fundamental frequency (Fo), peak intensity (Io) and duration (Do) and t-test revealed significant increase in Fo and Io in both conditions. However, Do revealed no statistical significance in stressed and unstressed conditions.

Index Terms- Stress, Fundamental frequency, Intensity, Duration, Nepali.

I. 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 neighboring syllables in a word or words in a sentence (Jones, 1950). Stress in literature is seen in many categories. Acoustic correlates of emphatic stress were focused in recent studies. "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" (Savithri, Rohini & Sairam, 2003). Studies done earlier has shown that, the acoustic correlates of stress vary from language to language and stressed syllables are usually associated with one or more of the following properties i.e., raised fundamental frequency, increased loudness, greater duration, and different vowel qualities (Liberman, 1960). In languages such as English (Bolinger, 1958), Polish (Jassem, Morton, Steffen, 1968) and French (Rigault, 1968), 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 (Westin, 1966), Italian (Bertinetto, 1980) and Estonian (Lehiste, 1968). In the Indian context, research on acoustic correlates of stress in words were carried out in Kannada (Savithri, 1999), Konkani (Kumar, 2009), Tamil (Balasubramanian, 1981) which indicated increased duration in stressed conditions. In addition, peak intensity was the major cue for stress in languages such as Telugu (Sitapati, 1936 and Srinivas, 1992) and Tulu (Manjunath, Teja, Sneha, Dattatreya, 2012). Among Indo-Aryan languages Hindi, duration and fundamental frequency was observed as the major acoustic correlates of stress.

Nepal is a country enriched with many languages, however not much has been explored on the acoustical characteristics of stress Hence, there is a need to enlighten and research about the acoustic characteristics of stress in Nepali language too. Given Nepal's multiple language environments, with 4 constitutionally accepted languages, about 126 mother tongues spoken in and around the country. Nepali language is a well developed Eastern Pahari group of Indo- Aryan language spoken in East and adjacent south central regions. It is considered as one of the Eastern Pahari group of Indo-Aryan language. Nepali has a rich vocabulary and has been considered as a highly developed language by the linguists (Nakkeerar, 2010). With a rich grammatical structure, the present study aimed at analyzing the acoustic correlates of stress in Nepali language.

II. Method

2.1. Participants

The participants taken in the study were 20 young adults (10 males and 10 females) in the age range of 20-30 years. The native language of the subjects was Nepali. Participants included in the study were non-smokers having no oro-facial anomalies and neurological related issues.

2.2. Test Materials

Ten two-word Nepali phrases were provided to the participants. The first word in each phrase was an adjective and the second word was a noun. The adjectives were bi-syllabic. A list of the ten phrases is provided in Appendix- A.

2.3. Instrumentation

Audio recordings were carried out using the Praat software (Version 2.3) installed on a laptop. The speech sample were then stored in the computer hard disk. The sampling rate was at 22 kHz, 12 bit quantization. The speech samples were recorded with

the microphone placed about 10 cm from the mouth and was connected to the laptop.

2.4. Procedure

Speech samples recorded for each participant were carried out in a quiet room. The participants were instructed to read each of the ten phrases in two conditions i.e., Unstressed (US) and Stressed(S) condition. The 10 phrases were read in 2 conditions. First, the participants read it as naturally as possible and then stressing the adjective in each of the phrases. Before the start of the recording, the participants practiced the phrases. Fundamental Frequency (F0), Intensity (I0) and Duration (D0) were extracted using Praat software. Table 1 shows the ten two-word phrases in Nepali provided to the participants for both the conditions.

Table 1: Ten Nepali phrases

SL.No	Ten Phrases
1	dherailuga:
2	ra:mrotaSbir
3	mi:thomasu:
4	ra;totSura
5	chokhopani:
6	Thulogadi
7	ta:jakha:na
8	Khalijhola
9	Sunsandarbar
10	sojhi a:ma

2.5. Statistical Analysis

Paired t-test was used to find out Mean and Standard Deviation (SD) values for each acoustic parameter in stressed and unstressed condition. Peak fundamental frequency, peak intensity and duration were calculated using SSPS (Statistical Package for Social Sciences) version 17.0.

III. RESULTS AND DISCUSSION

3.1. Peak Fundamental Frequency (F0)

Table 2 shows the Mean and SD values obtained for the 10 phrases in stressed and unstressed conditions. As shown in Figure 1, the mean fundamental frequency obtained for all the ten adjectives under study in unstressed condition was 245.083 Hz (SD=84.28) and in stressed conditions, it was 302.32 Hz (SD=120.69). On statistical analysis, paired t-test revealed no significant difference (t=-4.97; p=0.0004) between unstressed and stressed conditions. Overall, there was an increase in peak fundamental frequency (F0) for Stressed (S) condition compared to Unstressed (US) condition.
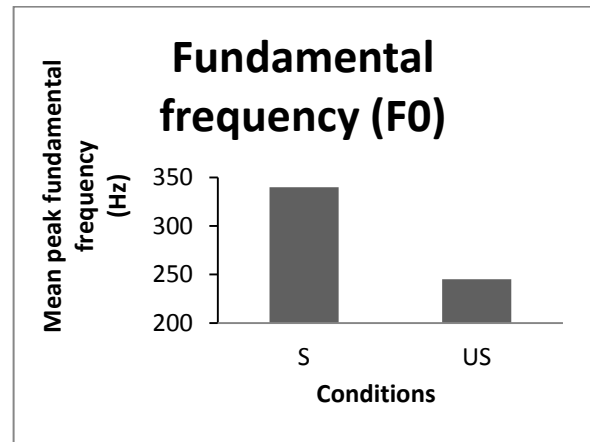

Fig 1. Mean fundamental frequency in Hz unstressed (US) and stressed (S) conditions

Table 2. 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
/dherai/	221.39 (57.49)	321.17 (118.89)	-5.411 (0.000)
/ra:mro/	238.56 (67.90)	331.79 (122.03)	-5.735 (0.000)
/mi:tho/	252.83 (95.837)	319.71 (115.70)	-4.372 (0.000)
/ra;to/	235.01 (66.34)	345.15 (105.95)	-7.509 (0.000)
/chokho/	267.44 (88.15)	375.96 (127.41)	-5.141 (0.000)
/thulo/	249.95 (101.91)	341.41 (128.39)	-4.337 (0.000)
/ta:ja/	227.45 (76.03)	284.44 (99.81)	-3.939 (0.001)
/khali/	226.65 (79.10)	358.23 (131.02)	-5.825 (0.000)
/sunsan/	256.47 (105.14)	354.03 (132.30)	-4.128 (0.001)
/sojhi/	275.08 (104.92)	366.48 (125.37)	-3.349 (0.003)
Mean	**245.08 (84.28)**	**302.31 (120.69)**	**-4.975 (0.0005)**

3.2. Peak intensity (I0)

Table 3 displays the mean and SD values of peak intensity obtained for all the ten adjectives in the two conditions. The mean peak intensity obtained for all the ten adjectives included in the study was73.71 dB (SD=3.96) in unstressed conditions and in stressed conditions, it was 79.98 dB (SD=4.33) as shown in Figure 2. The statistical analysis is results showed a significant difference between unstressed and stressed conditions (-7.72; p= 0.000). Overall there was an increase in peak intensity (I0) for Stressed (S) condition compared to Unstressed (US) condition.
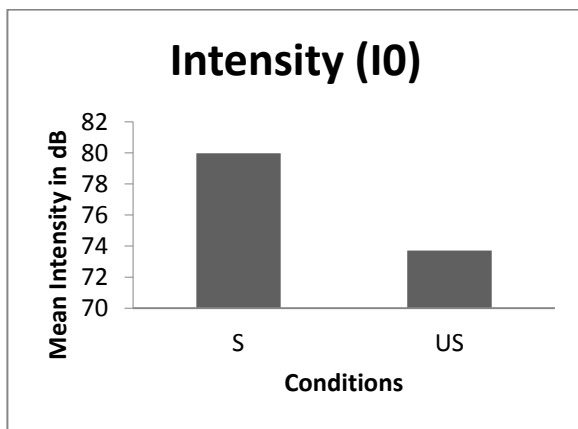
Fig 2. Mean peak intensity in dB for unstressed (US) and stressed (S) conditions

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

Words	Duration (msec)		
	US	S	t-value
/dherai/	473 (117.07)	511 (172.47)	-1.357 (0.191)
/ra:mro/	521.5 (119.26)	590.5 (161.85)	-1.832 (0.083)
/mi:tho/	515 (127.05)	559 (147.14)	-1.936 (0.068)
/ra:to/	531 (137.45)	550 (102.91)	-0.937 (0.361)
/chokho/	505.5 (138.85)	517.5 (83.85)	-0.459 (0.652)
/thulo/	453.30 (130.15)	474.5 (98.06)	-0.832 (0.416)
/ta:ja/	477 (124.73)	512.5 (68.97)	-1.550 (0.138)
/khali/	479.5 (126.88)	487.5 (77.93)	-0.348 (0.732)
/sunsan/	695 (147.34)	639.8 (103.96)	1.535 (0.141)
/sojhi/	578 (139.87)	593.5 (89.28)	-0.627 (0.538)
Mean	**470.78 (130.87)**	**543.58 (110.64)**	**-0.8343 (0.332)**

3.3. Duration (D0)

The mean and SD values of duration obtained for all the ten adjectives in both the conditions as shown in Table 4 and Figure 3. The mean word duration obtained for the ten adjectives selected in unstressed condition was 470.78 msec (SD=130.87) and in stressed condition, it was 543.58 msec (SD=110.64). The mean duration was higher in stressed condition compared to that of unstressed condition. The results of statistical analysis showed no significant difference between stressed and unstressed condition (t=-0.8343; p=0.332). Overall there was an increase in duration (D0) for Stressed (S) condition compared to Unstressed (US) condition.
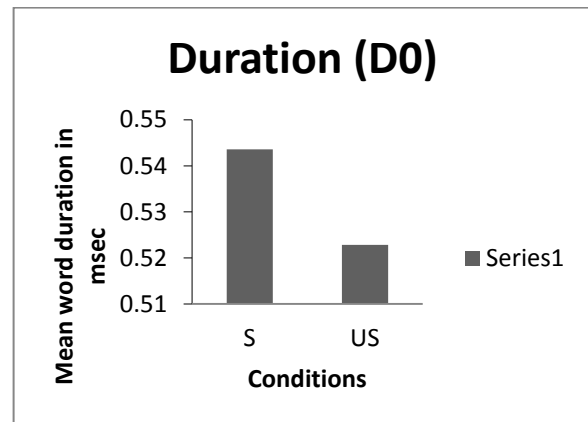

Fig 3. Mean duration in msec for unstressed (US) and stressed (S) conditions

Table 4. Mean, standard deviation and test values of duration for all the ten adjectives in unstressed (US) and stressed (S) condition

Words	Peak Intensity (dB)		
	US	S	t-value
/dherai/	73.94 (3.60)	79.59 (4.25)	-7.28 (0.000)
/ra:mro/	73.67 (4.41)	80.46 (4.23)	-9.407 (0.000)
/mi:tho/	74.86 (4.31)	80.47 (4.01)	-5.858 (0.000)
/ra:to/	73.56 (4.20)	79.12 (4.21)	-9.513 (0.000)
/chokho/	74.27 (4.72)	80.28 (4.83)	-6.835 (0.000)
/thulo/	76.65 (4.11)	82.07 (3.44)	-5.450 (0.000)
/ta:ja/	72.61 (3.63)	80.42 (4.17)	-10.431 (0.000)
/khali/	72.46 (3.14)	78.83 (4.03)	-8.212 (0.000)
/sunsan/	71.42 (3.41)	78.45 (5.44)	-7.045 (0.000)
/sojhi/	73.70 (4.01)	80.07 (4.80)	-7.139 (0.000)
Mean	**73.71 (3.96)**	**79.98 (4.34)**	**-7.72 (0.000)**

3.4 **S-Ratio**

S-Ratio was calculated as the difference between Stressed and Unstressed conditions for Peak fundamental frequency, peak intensity and duration. The values obtained for (Fo) was 99.95Hz, (Io) was 6.68 dB and (Do) was 0.03 msec. There was a

trivial difference observed in the fundamental frequency of Stressed and Unstressed conditions.

IV. DISCUSSION

The finding for the acoustic correlates of stress in Nepali language is one of the first attempts. The peak fundamental frequency (f0), peak intensity (dB) and duration (msec) were extracted from the adjectives and both conditions were compared. The results concluded fundamental frequency, peak intensity and duration is higher in stressed than in unstressed condition. The S-ratio for peak fundamental frequency, peak intensity, and duration of words was 99.95 Hz, 6.68 dB and 0.03 msec respectively.

The results of the study concluded that there is significant difference between fundamental frequency and intensity and no significant difference in duration of words. The primary acoustic correlates of stress in various language such as Polish (Jassem et al, 1968), English (Bolinger,1958) and French (Rigault, 1962) is different in fundamental frequency where as for Swedish (Westin, Buddenhagen & Obrecht 1966), Italian (Bertinetto, 1980), and Estonian (Lehiste,1968) had duration as the major correlates. Recent studies also show that, Kannada (Savithri, 1999), Konkani (Kumar & Bhat 2009), Tamil (Balasubramanian, 1981), had duration as the major correlates for acoustic stress, whereas according to Sitapati (1936) and Srinivas (1992), intensity was reliable acoustic correlate of stress in Telugu language.

In the present study, peak fundamental frequency and peak intensity show significant difference between unstressed and stressed conditions which correlates with the study done by Manjunath et.al (2012). Hence, these literature reviews support the concept that an acoustic correlate of stress differ across language and depends upon the structure of language.

V. CONCLUSIONS

The recent study of acoustic correlates of stress was studied in Nepali speaking of both male and female subjects. The results visualize that there is a significant increase in peak fundamental frequency and peak intensity repeatedly, in stress condition. Thus, it is possible that a Nepali speaker uses peak fundamental frequency and peak intensity as a cue to indicate stress.

Acoustic parameters
1. Peak fundamental frequency (o) 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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