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Phonetic Analysis of Lexical Stress in Sindhi

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Abstract: Investigation of acoustic correlates of lexical stress tests the hypothesis that lexical stress modifies acoustic properties of sounds in Sindhi. The experiment was carefully designed in order to examine the phonetic exponents of lexical stress. The analysis is based on the voice samples of recorded 10 Sindhi word stress pairs, and they were similar however, they just differ in terms of assignment of primary stress. A total 2000 voice samples (10×10×20=2000) were analyzed in a fixed carrier phrase. The data consists of Sindhi stressed and unstressed vowels /i, ɪ, e, ɛ, ə, ɑ, ɔ, o, ʊ/ and ɯ/, from ten native speakers of [1]*Utradi (Northern)* dialect recorded on Praat speech processing tool, and a high quality microphone. Four parameters were considered for an acoustic analysis of lexical stress i.e., duration, fundamental frequency (F0), vowel quality (F1-F2) and the stop closure. The acoustic examination of the voice samples provides evidence for higher frequency of stressed vowels and lower frequency for unstressed vowels relatively. In addition, the data analysis reveals that there were statistically significant differences in the values of short and long vowels referencing to the stressed and unstressed syllables. Similarly, the frequency values of the duration and stop closure of stressed vowels were also greater than the unstressed, while F0 and F1-F2 values were higher in stressed and lower in unstressed vowels which explicitly provides a strong evidence that phonetic correlates of lexical stress in Sindhi.

Keywords: Phonetic, Acoustic, Analysis, Lexical Stress, Sindhi

1. INTRODUCTION

This study is based on 2000 voice samples (10×10×20=2000) which were analyzed in a fixed carrier phrase. The experiment was designed to examine the impact of lexical stress in Sindhi by analyzing four phonetic exponents of stress (parameters) e.g., duration, fundamental frequency, first and second formant frequency, and stop closure. Intensity was not included in the present study as a potential correlate of stress since it is often cited as a reliable correlate of stress cross-linguistically. Intensity was not examined on account of variation in the distance between the microphone and the speaker's mouth, variation (particularly intra-recording) in gain settings. The study focuses on the acoustic realizations of prominent syllable and non-prominent syllable on lexical level by the analysis of four aforementioned factors. Bolinger (1981) argues that lexically unstressed vowels are reduced in languages e.g., English, German and Russain. Phonological reduction may cause neutralization of some vowel contrasts, e.g., British etc., whereas, Lindblom (1963) argues that the vowel reduction is a process, which results in a reduced vowel space.

This present paper provides evidence of lexical stress in Sindhi through examination of greater duration in stressed and shorter duration in unstressed, F0 and F1-F2 stressed vowel values are also higher whereas, in unstressed vowels, values are shorter. These acoustic aspects are correlated of lexical stress in Sindhi. **(Table-A)** (in Appendix-A) illustrates that the words with HL[1] (heavy light) syllable pattern are in the third column and the fourth column contains words with an HS[2] (heavy super heavy) syllable pattern. One exception to this is the word in row 8, where the word in the fourth column has the LS[3] (light super heavy) syllable pattern. This pattern is also expected to have stress on the second syllable, as with the HS pattern.

Fry (1955, 1958) was a pioneering figure and his first ever seminal work on the acoustic correlates of stress in English where Fry applied these factors like duration, intensity, and fundamental frequency. In addition, Gordon's work is merely one of many that explore the phonetic exponents of stress. For instance Gordon *et al.* (2004) investigated the phonetic study of stress in Chickasaw through acoustic data from eight speakers of Chickasaw.

The study examined duration, fundamental frequency, intensity, and vowel quality as evidence for lexical level stress to determine how primary stress, secondary, and stressed syllables are phonetically distinguished from each other and from unstressed syllables.

[1] HL heavy light syllable
[2] HS heavy super heavy
[3] LS light super heavy

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Basic articulatory characteristics of the first two formants are: the tongue body displacement in mouth (the height and back-ness) and the lip rounding (Ladefoged, 1993; Pfitzinger, 2003). The first and second formants frequencies are regarded as enough for acoustic-phonetic analysis, although for speech recognition and synthesis F3, F4, and F5 are needed (Parsons, 1987). For male adult speakers, the formants can be described in terms of their range of frequencies, for example, F1 ranges between 200-800 Hz, F2 ranges between 600-2800 Hz, and F3 ranges between 1300-3400 Hz (Parsons, 1987). The phoneticians argue the vowel quality can be quantified acoustically by examining F1 and F2 of the vocal tract. Reetz and Jongman, (2009) state that in English, disyllabic nouns are often stressed on the first and verbs are stressed on the second, e.g., the minimal stress pairs: (n) record [ɹɛ.kə͡d] and (v) record [ɹə.kɔɹd]. When the stressed syllables are compared to the unstressed syllables, it causes an increase in fundamental frequency, longer duration, and increase in intensity, and a change of formant frequency pattern in English.

1.1 Sindhi Vowel Inventory

There is a vowel contrast in Sindhi vowel system which can be categorized as short and long vowels. A vowel contrast does not apply to all ten vowels in Sindhi. There are three pairs of short and long vowels as also noted by Keerio (2010) and also in this study. Short and long vowels are illustrated in **(Table 1)** and vowel contrast shown in **(Table 2)** as follows:

Table 1. Short and long vowels

Long vowels	/i/	/e/	/ɛ/	/ɑ/	/ɔ/	/o/	/u/
Short vowels	/ɪ/			/ə/			/ʊ/

Table 2. Vowel contrast

SN	Vowels contrast		Sindhi in IPA	English Glossary	Sindhi in [4]IPA	English Glossary
1	/i/	/ɪ/	siːrə	Water flow	sɪrə	Brick
2	/u/	/ʊ/	surə	Pain	sʊrə	Music
3	/ɑ/	/ə/	sɑrə	Miss	sərə	reeds

2. METHOD

2.1 Data Collection

The data were obtained from 10 subjects through recordings with neutral focus. These individuals were identified by their initials: The males AM, MR, LM, MK, and NM and females SJ, SM, NT, AK, and MQ adults who self-reported with no speech impairment. Their ages ranged between 17 to 40 years with an average age of 27. Sampling was randomly selected from *Utradi (Northern)* dialect of Sindhi, spoken in upper Sindh, Pakistan. All subjects had sixteen years of education along with formal education in Sindhi as a major in school. They all spoke Sindhi as a native language at home and at their work place. Many of the speakers could also speak Urdu and English. Speakers were naive about the task of recording, with the exception of the author.

2.2 Recording

Subjects were provided with a set of 10 cards with two carrier phrases written on each card in Sindhi script. Twenty words comprising ten near-minimal stress pairs were picked from the *New Comprehensive Sindhi dictionary* (Baloch, 2005). All of the token words embedded in carrier phrases were written on a set of cards. The paired words had the same [5]CV (onset-vowel) as the first syllable, but with stress (expected to be) realized on the first syllable of one word in the pair, and on the second syllable in the other word in the pair. Each word was embedded in identical carrier phrases and presented in Sindhi script on each card.

There were a total of 10 cards, i.e., one card for each pair of words, containing stressed and unstressed tokens in carrier phrases, where the paired words were matched in their first syllable and differed in the weight of the second syllable. The hypothesis tested here is that stress assignment will be different for the paired words, with stress attracted to the heavier of the two syllables: H in HL and S in HS. In addition, the set of 10 cards was read with 10 repetitions by each subject. The cards were reshuffled after each repetition in a block randomized design, and subjects read aloud the phrases on each card in sequence with a short break between repetition blocks. In addition, the participants were provided a quiet and calm environment, with no background noise, in a closed room far from the noise of city traffic. The microphone used faced them at a distance of around six inches. They were instructed to maintain a normal speech rate and to read the phrases using a neutral focus, as in ordinary talking conditions. Subjects were recorded directly onto a laptop computer *Acer Travel mate* Core i3 system using the Praat speech processing tool (Boersma & Weenink, 2014) and a high quality microphone.

2.3 Speech Material

Twenty disyllabic words were chosen as the words for this experiment. The words were selected in order to keep any effects unrelated to stress from influencing the acoustic measurements. Therefore, mostly highly familiar words were picked up from the Sindhi lexicon,

[4] IPA International Phonetic Association

[5] CV (consonant vowel) consonant followed by stressed vowel (syllable) in first word and in second pair of word consonant is followed by unstressed vowel.

and the words in each pair were matched as closely as possible for segmental context, with labio-dental and bi-labial stops as the onset consonants in the first syllable of each word. The vowel of the first syllable of each word was analyzed by measuring four phonetic properties: F0, duration, F1, and F2 the latter two representing vowel quality. Highly frequent words of *Utradi (Northern)* dialect were selected; however, a few less frequent words were also selected to achieve greater phonological similarity between the two words of the pair. Table-A (Appendix-A) contains the near-minimal stress pairs of words.

2.4 Measurements

All measurements of duration of the stressed and unstressed vowels were taken manually by visual inspection of wideband spectrographic display on computer screen. Start and end points of the target vowels were measured in milliseconds on the spectrographic displays. Both beginning and ending points were measured using the speech processing tool Praat (Boersma & Weenink, 2014). All formant measures for the lowest two formants, F1 and F2, were taken manually based on formant tracks at the visually located mid-point of the target vowel in stressed and unstressed tokens. Whenever a mismatch between the tracks and the visually apparent formant band in the spectrogram was detected, the formants were checked by visual inspection of wideband spectrographic display on computer screen. The pitch contours were manually extracted using the Praat autocorrelation method. Measurements were taken at the visually located mid-point of each target vowel in stressed and unstressed tokens. Closure duration was measured in milliseconds from the end of the preceding vowel to the beginning of the release burst.

3. RESULTS

The results show explicit impact of the phonetic exponents of lexical stress in Sindhi. Many phoneticians agree that phonetic correlates of stress include vowel quality as measured through duration, F1, F2, and F0 as discussed in introduction section also. In addition, the stop consonants in onset position of the target syllable were analyzed for stress effects on stop closure duration. Durational data were collected from the matched initial syllables of each word in the word pair. The segments preceding and following the word-initial syllable were identical for each word in the pair. For example, the duration of /di:/ was taken from the initial stressed syllable of [di:də] (eyesight) and from the initial unstressed syllable of [di:dɑ:r] (glimpse). The long and short vowels were separately analyzed statistically. Statistical analyses were conducted using the SPSS statistics package. The statistical results are reported as significant with $p< 0.05$.

3.1 Durational Values

The duration of vocalic sounds is the strong cue of stress distinctions in some languages as also noted by many phoneticians. The vocalic analysis illustrates that there were statistically significant effects on vowel duration. The present study analyzed the duration of lexically stressed vowels and found stressed vowels were longer in duration, whereas, the duration of unstressed vowels were shorter in duration relatively.

A separate *t* test for short vowels were significantly longer than the unstressed short vowels (t= 5.629, df=9, p < .01). Whereas, a separate paired *t* test for long vowels on the mean durations of all subjects showed that the stressed long vowels were significantly longer than the unstressed long vowels (t=6.59, df=9, p <.01). **(Fig. 1)** illustrates two different voice samples spliced from the stressed and unstressed vowels which were assembled together in a single spectrogram in order to make its view more vivid. Figure 1 illustrates quite a large difference in the duration of stressed and unstressed vowels in spectrogram. The spectrogram shows the production of male speaker voice samples as follows: [bɛtə] (poem) in stressed syllable and [bɛtɑ:b] (anxious) in unstressed syllable. The spectrographic view of tokens was analyzed as greater duration in terms of stressed syllables and relatively shorter in unstressed syllables. The greater duration of Figure 1 clearly indicates that the vowel /ɛ/ in stressed syllable is larger while unstressed syllable is shorter relatively as illustrated in **(Fig.1).** In addition, Fig. 1 illustrates two different environments of stressed and unstressed vowels extracted from two different words and spliced side by side as follows:

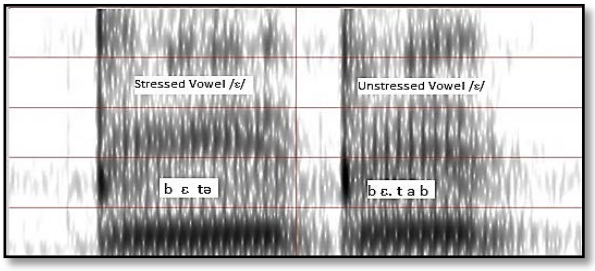


Fig. 1. Vowel duration contrast in length by a male speaker

Statistical test results show that female value for stressed short vowel was 70 milliseconds and for unstressed 64 milliseconds, whereas male speakers duration value for stressed vowel was 65 milliseconds and for unstressed vowel 59 milliseconds. The value for short vowels is a statistically significant difference within the group and between the groups. The short vowels of the stressed syllables are longer in duration by each speaker. In addition, statistical test results show that the female speakers' duration of stressed first

syllable for long vowels was 181 milliseconds and for unstressed syllable 148 milliseconds, whereas male speakers' duration value for stressed long vowel was 163 milliseconds and for unstressed vowel was 121 milliseconds. These values are statistically significant as the values differ for stressed versus unstressed syllables within a group and between the groups for long vowels. Overall analyses of duration values of all 10 vowels show a highly significant effect of stress on duration of long vowels in particular, as compared to short vowels. Individual speakers showed a significant overall effect of stress on duration; for instance, primary stressed vowels were longest (e.g., 150 milliseconds) averaged over all speakers, and unstressed vowels were shortest (e.g., 110 milliseconds). This significant difference of stressed and unstressed syllables indicates that there is greater inter-speaker variability relative to primary stressed and unstressed vowels. **(Fig. 2)** illustrates the short vowels duration by speaker. Each bar represents a different speaker, whereas **(Fig. 3)** illustrates long vowels duration by speaker. Each bar represents the mean vowel duration for one speaker.

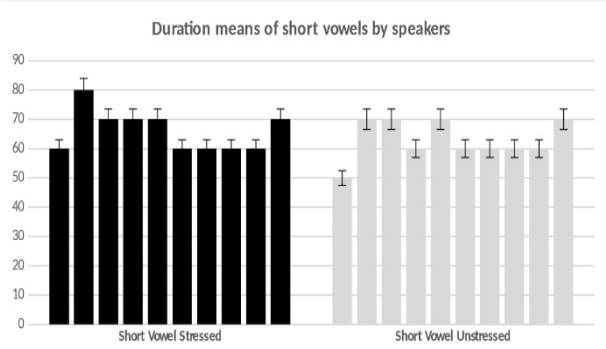


Fig. 2. Short vowel duration by speaker. Each bar represents a different speaker

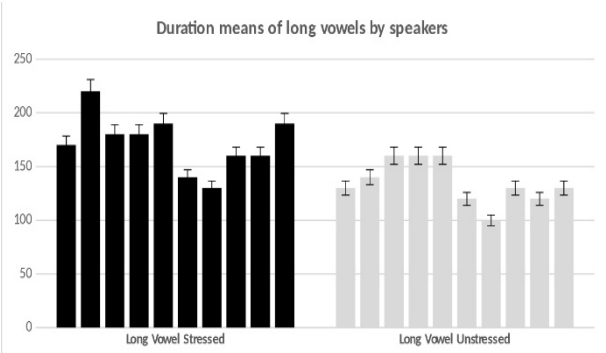


Fig. 3. Long vowel duration by speaker. Each bar represents the mean vowel duration for one speaker.

The light grey-shaded bars are displayed as unstressed syllables, whereas black-shaded bars represent stressed syllables in (**Figs. 2.3.4)**. illustrates ten Sindhi vowel duration voice samples across speakers.

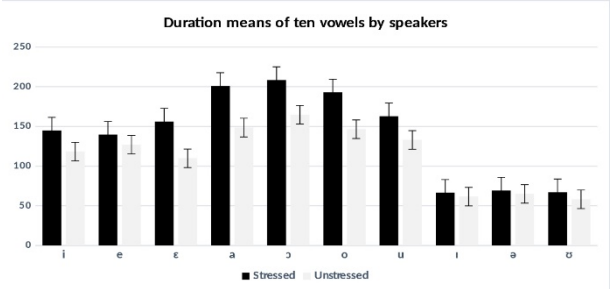


Fig. 4. Mean each vowel duration, data pooled across speakers

The overall mean of short vowels duration was 75 milliseconds for stressed and 66 milliseconds for unstressed. The mean difference between stressed and unstressed was 40 milliseconds for long vowels and 9 milliseconds for short vowels. Fig. 4 clearly shows that unstressed duration of vowel sounds is shorter as compared to stressed syllable. Thus, the data in this study provide strong evidence that unstressed vowels are shorter and stressed vowels are longer in duration. Similar results are also noted by researchers measuring the acoustic properties of lexical stress in various languages.

The paired-sample *t* test reports *df* =9, which suggests that a single mean value was compared for stressed vs. unstressed vowels for each of 10 speakers (or, for each of five speakers if the *df* =4). *T* tests were run on the mean values of acoustic measures, pooling together all repetitions and all the distinct vowels that belong to the comparison groups. The results show that the *df*=9, comparing the stressed-unstressed differences across the speakers. So, the dependent variable is the average duration for all long or short stressed (or all unstressed) vowels for a given speaker. In summary, mean durational values of stressed and unstressed syllables indicate that the phonetic properties of vocalic sounds change with the lexical stress since stressed duration values were significantly higher than unstressed values for these phonetic exponents of stress. Primary stress was duration-ally distinguished across speakers. Therefore, the statistically significant results indicate evidence of increased duration, which may be considered to be a reliable property associated with the phonetic exponents of lexical stress in Sindhi.

3.2 Fundamental Frequency (F0)

All values have been taken from the same context of minimal stress pairs occurring in first syllable of all token words. The data indicate that there is no difference in F0 values found between speakers of the same gender, however, there is a relatively significant difference between male and female speakers. The average F0 values were obtained from 10 speakers for all ten vowels. The recorded voice samples are represented in Fig. 5. The graph shows that overall means of F0 in stressed syllables are higher relatively in

all ten voice sample sounds. Similar results were also found by other researchers for the stressed syllables F0 values as analyzed in this study. Whereas, Fig.5 shows F0 values for unstressed syllable are lower in all ten vowels, relatively as found in acoustic results of F0 values.

Paired sample *t* tests were carried out to test the effects of stress on F0. Among males, F0 values were not significantly different for stressed and unstressed vowels with stressed short vowels (t=2.3, df=4, p<.05) as illustrated in **(Fig. 5)** nor with long vowels (t=2.2, df=4, p<.05) whereas **(Fig. 6,7)** illustrates overall F0 mean of all vowels.

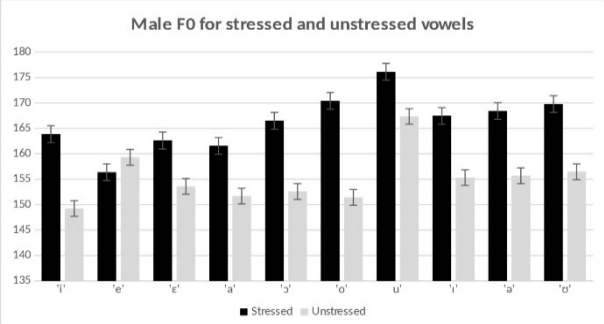


Fig. 5. Means of F0 of stressed and unstressed vowels for each vowel

Paired sample *t* tests were carried out to test the effects of stress on F0. Among female speakers, F0 was significantly higher for both stressed short vowels (t=6.97, df=4, p<0.5) and stressed long vowels (t=5.97, df=4, p<.05) as shown in Figure 6. Whereas Figure 7 illustrates overall means by speakers.

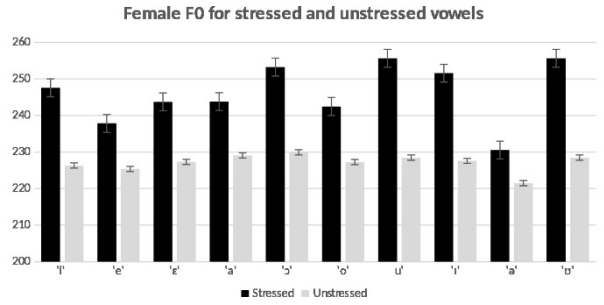


Fig. 6. Means of female F0 of stressed and unstressed vowels for each vowel

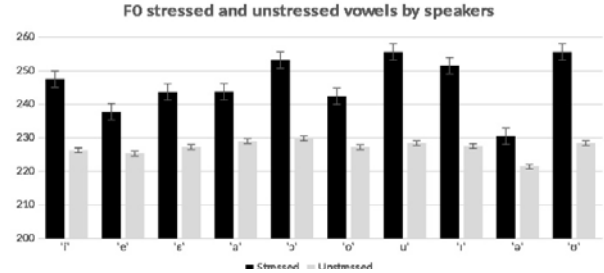


Fig. 7. Means of F0 of stressed and unstressed vowels by speakers

In addition, the results show that the five male speakers' average F0 was 165 Hz for stressed long vowels and 155 Hz for unstressed. For the five male speakers, the average F0 was 165 Hz for stressed short vowels and 154 Hz for unstressed. In this context, the average F0 values of male speakers for stressed long vowels was 10 Hz higher than for the unstressed long vowels, while F0 values for the stressed short vowels was 8 Hz higher than the unstressed vowels. In contrast, the five female speakers' F0 was 246 Hz for stressed long vowels and 228 Hz for unstressed measured. The average F0 for the stressed short vowels among the females was 246 Hz, whereas for the unstressed vowels it was 226 Hz. In addition, F0 values for stressed long vowels of the female speakers' were 20 Hz higher than the unstressed; whereas, F0 values for the short vowels was 20 Hz higher than the unstressed short vowels. The data showed that the female participants' F0 values fell between 200-280 Hz, while male participants between 120-200 Hz. In summary, F0 was higher on the word-level stressed syllable, while unstressed syllables showed lower F0 values. The results were statistically significant for female for both long and short vowels however, mean values of male speakers for long and short vowels were not significant.

3.3 Vowel Quality (F1-F2)

Overall mean F1 values of all ten stressed vowels were higher, whereas, unstressed vowels were lower relatively. Similarly, other researchers also show F1 lower values for unstressed vowels as also noted in this study. Paired sample *t* tests were run on F1 means of stressed and unstressed vocalic sounds; statistical results show that the F1 for female speakers was significantly higher for both the stressed long vowels (t=5.539, df=4, p <.01) and the stressed short vowels (t=7.053, df=4, p <.01). For male speakers, there were also statistically significant differences between F1 values for stressed vowels for both long and short vowels when compared to the unstressed vowels (t=4.183, df=4, p <.01) and short vowels (t=6.120, df=4, p <.01).

Overall average values of F2 for stressed vowels were higher; whereas, mean values of F2 for unstressed were lower relatively. Paired *t* tests were run on F2 means for female speakers, the F2 values were significantly higher for front long stressed vowels (t=3.297, df=4, p<.05) and stressed front short vowels (t=5.933, df=4, p<.05), while back vowels had lower F2. For male speakers, F2 values were not significantly different for front and back stressed and unstressed long vowels (t=0.127, df=4, p<.05), however, front and back short vowels were statistically significant different (t=3.535, df=4, p<.05).

Mean F1 and F2 values were higher for stressed long vowels and short vowels, while F1 and F2 values

were lower for unstressed long and short vowels. Overall average of F1 and F2 values were statistically significant difference within the group and between the groups. However, within the group of male data for long vowels stressed vs- unstressed syllables values were not significant as illustrated in paired sample test. The study utilized formant-plotting software (J-Plot-Formants) (2002) for plotting Sindhi stressed and unstressed vowels as illustrated in **(Fig. 8).** The stressed vowels are displayed by filled circles and unstressed syllables represent unfilled circles on J-plot-formant as follows:

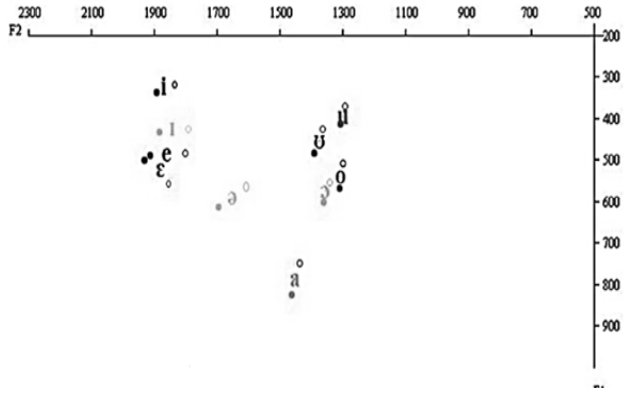


Fig. 8. J-Formant plot of stressed and unstressed Sindhi vowels

The schwa vowel in both stressed and unstressed positions behaves more front or more backward. The front unstressed vowels (unfilled circles in acoustic vowel space) are more backward positioned vs. filled stressed vowels, whereas, back unstressed vowels are higher in acoustic vowel space. Epsilon, the low-mid front unrounded vowel differs its position of unstressed vowel which is more forward in acoustic vowel space while stressed vowel is lower positioned as compared to other vowels. In addition, Figure 8 illustrates that the front stressed vowels become decentralized, going to the left corner, whereas, back vowels to the right corner and slightly lowering from the acoustic space. It is a very interesting result for back vowels in Sindhi, because stressed vowels become more centralized instead of going to the right corner, whereas, the unstressed back vowels were more decentralized relatively; however, positions of Urdu back vowels were centralized for stressed while decentralized for unstressed as noted by Hussain (2010). The lowering effect on the back vowels under stress could be interpreted as sonority-increasing effect as noted by Crosswhite and Padgett & Tabain (2001 and 2005). In addition, the unstressed vowels are shorter than stressed vowels, and they are also centralized relative to stressed vowels. Consequently, the unstressed vowels are less distinct from one another in the acoustic vowel space, while the stressed vowels are more distinctive (Flemming, 2005). Thus, the vowel quality changes with lexical stress in Sindhi.

To find out the distances (in Hz), F1-F2 were calculated between stressed and unstressed vowels for a quantitative comparison of change in vowel quality with stress. A formula was run on the calculations of distances as follows:

Distance $=\sqrt{[(F1 \text{ stressed} - F1 \text{ unstressed})^2 + (F2 \text{ stressed} - F2 \text{ unstressed})^2]}$

Table 3. Average distance of stressed and unstressed vowels for each speaker

Speaker	Sindhi Vowels	Stressed		Unstressed		Distance
		Avg. F1	Avg. F2	Avg. F1	Avg. F2	
1	i	337	1897	315	1845	56
2	e	499	1935	474	1790	147
3	ɛ	554	1852	490	1915	90
4	ɑ	823	1467	749	1449	77
5	ɔ	600	1363	550	1351	52
6	o	569	1313	510	1309	59
7	u	412	1309	380	1293	36
8	ɪ	433	1888	416	1802	87
9	ə	612	1698	566	1610	99
10	ʊ	483	1393	428	1361	63
Means		554	1580	507	1542	77

The shortest distance in Hertz between stressed and unstressed vowels in F1-F2 acoustic space is calculated by the formula illustrated in Table 3. The distance provides a tool to compare stress impact on different vowels. **(Table 3)** shows that the distance between stressed and unstressed vowels was greater for low vowels than for high vowels. On average, the distances between stressed and unstressed long vowels were higher than the distances between stressed and unstressed short vowels. Thus, quality of long-short and high-low vocalic sounds were most affected by lexical stress. Therefore, the quality of stress was affected for high and low vowels and distance between stressed and unstressed vowels was calculated to be 77 Hz on average. The data analysis shows that there were statistically significant differences between short vowel values of stressed and unstressed syllables. The F1 of long and short vowels were higher in stressed syllables in comparison to unstressed syllables in Sindhi. F2 was similarly higher for stressed vowels than for unstressed vowels, though this result is surprising for back vowels; which could be interpreted as sonority-increasing effect as noted by Crosswhite and Padgett & Tabain (2001 and 2005). In addition, the results demonstrated that vowel quality (F1 and F2 frequencies) of females was higher than the male vowel quality values.

3.4 Stop Closure

There were only two stop closures in carrier phrases occurring word-initially, bilabial and alveolar stops, which were calculated. The words were chosen to include only two stops: labial and dental, /b/ and /d/. The measurement of stop closure was calculated in milliseconds from the end of the preceding vowel to the beginning of the release of burst. Across the speakers, the mean duration of onset stop closure was 99 milliseconds and of unstressed onset stop closure was 79 milliseconds. Hence, with lexical stress, onset duration increased by 20 milliseconds over the unstressed duration, whereas, the place of articulation shows that closure durations were ranked as follows: labial > alveolar (98 milliseconds and 100 milliseconds respectively for stressed duration, and 78 milliseconds and 79 milliseconds for unstressed syllables respectively).

A paired samples *t* test was run on means of stop closures to compare the stressed and unstressed closure duration of onset stops. The average analysis for stop closures in stressed syllables were significantly longer than closure durations for the stops in unstressed syllables (t=8.06, df=9, p <.05). The separate analysis for the closures showed that closure duration for stops in stressed syllables were also significantly longer than closure duration for stops in unstressed syllables for voiced bilabial stop /b/ (t=11.56, df=9, p <.05) and for voiced alveolar /d/ (/d/ t=4.56, df=9, p <.05). **(Fig. 9)** illustrates overall means across speakers for distinct CV (onset-vowel) syllables with /b/ and /d/ onsets.



Fig.9. Means of stop closures across speakers

Stress significantly affected the duration of stop closure, as analyzed in this paper. The results show that duration of onset stop stressed syllables increased by stress. This is a quite strong evidence of lexical stress in Sindhi.

4. DISCUSSION

Beckman (1986) differentiates between stress accent and non-stress accent or in other words pitch-accent languages. Languages with stress accent are those which show accentual prominence in terms of phonetic factors, e.g., pitch, intensity, and duration, versus the phonetic cue, i.e., pitch correlates of accent, in non-stress accent languages. Sindhi also seems to be a stress accent language as discussed by Beckman (1986) regarding pitch-accent vs stress-accent language. The exponents of stress can be determined as reported in the present data, the quality of vowels is affected by lexical stress, since the distances were calculated between each vowel. Vowel quality (F1 and F2) frequencies of vowels are the strong cues for stress in Sindhi, as noted in the present study. In addition, the average F0 values of male speakers for stressed long vowels was 10 Hz higher than for the unstressed long vowels, while F0 values for the stressed short vowels was 8 Hz higher than the unstressed vowels. While, F0 values for stressed long vowels of the female speakers' was 20 Hz higher than the unstressed; whereas, F0 values for the short vowels was 20 Hz higher than the unstressed short vowels. The phonetic differences of values analyzed for Sindhi are smaller than those described by Sluijter and van Heuven (1996). Similarly, the stressed and unstressed vowels in context, i.e., [bezɑ] (eggs) vs. [bezɑr] (unhappy), for /e/ vowel, analyzed in Sindhi showed a difference in value of only 47 milliseconds. While the maximum difference between stressed and unstressed /o/ vowel is 50 milliseconds, furthermore the difference between stressed and unstressed /e/ vowel is 10 milliseconds. Thus, the phonetic exponents of stress which were investigated, show strong evidence for Sindhi, through which Sindhi seems to be a stress accent language as also noted by Abbasi and Hussain (2015).

5. CONCLUSION

The present research paper documented the phonetic exponents of lexical stress in Sindhi, how it is realized phonetically phonologically. By documenting stress patterns, the analysis discovered the phonetic properties that are modified by lexical stress in Sindhi. Four parameters were considered for acoustic analysis of lexical stress e.g., duration, fundamental frequency, vowel quality (F1-F2) and the stop closure. Findings of the experimental analysis provide evidence for higher frequencies of stressed vowels and lower for unstressed vowels. In addition, the study found that there were statistically significant differences between short and long vowel values of stressed and unstressed syllables. The duration and stop closure of stressed vowels were greater than the unstressed, while F1-F2 and F0 values were higher in stressed and lower in unstressed vowels which is a quite evident that phonetic correlates of lexical stress in Sindhi. Thus, the phonetic analysis of lexical stress discovered strong evidence of modification of all phonetic exponents of stress which seems to demonstrate that Sindhi is a stress accent language.

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Appendix-A
Table A. Minimal stress pairs used in the study

Vowel	1st Syllable Stressed	English Glossary	1st Syllable Unstressed	English Glossary
i	diː.də	Eyesight	diː.dɑːr	Glimpse
e	beː.zɑ	Eggs	beː.zɑːr	Unhappy
ɛ	bɛ.tə	Poem	bɛ.tɑːb	Anxious
ɑ	bɑː.zə	Falcon	bɑ.zɑːr	Market
ɔ	dɔ.rə	Time	dɔ.rɑːn	Duration
o	doː.ɣʊ	curd	doː.ɣɑːb	Leg flesh
u	buː.zə	Animal	buː.zɑːn	Crazy
ə	bədʒ.dʒɑ	Right	bə.dʒɑːdʒ	Cloth merchant
ɪ	dɪl.lɪ	Heart	dɪl.dɑːr	Beloved
ʊ	bʊs.sə	Chaff	bʊs.tɑːn	Garden

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