An Acoustic Investigation of Primary and Secondary Lexical Stress of Urdu

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ABSTRACT

This paper investigated acoustic correlates of primary and secondary stress in Urdu language. Urdu is not a sufficiently researched language in the context of lexical stress. A few researches (Mehrotra, 1965; Hussain, 1997; Nair, 1999; Mumtaz, 2014, and Qurrat-Ul-Ain & Mahmood (2017) discussed stress in Urdu/Hindi language. Perhaps, Qurrat-Ul-Ain & Mahmood (2017) study is the first to phonetically document the presence of secondary stress in Urdu using the cue of duration. The present study focused on the four popular acoustic cues of lexical stress to see how Urdu lexical stress (primary as well as secondary) behaves against these cues. The stimuli of the study consist of six tri-syllabic words (embedded with low-back-long vowel /a:/ in all syllables) uttered by nine female Urdu speakers from Lahore. Four popular stress cues (duration, vowel quality, pitch, and intensity) have been analyzed to see their correlation with Urdu lexical stress. The analysis reveals three levels of lexical stress: primary, secondary, and unstressed. Vowel duration is the strongest cue to correlate with the levels of stress in Urdu while stressed segments prone to have higher values of intensity. Overall, a trend of lower F0 and higher formant values could be seen against stressed syllables. The study, however, needs to be expanded further by using words having other vowel sounds. Moreover, the phenomenon of word final lengthening can be taken into account in the potential researches.

Keywords: secondary Urdu stress; vowel duration; vowel quality; pitch; intensity

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INTRODUCTION

Urdu is the lingua franca of Pakistan (Bashir, 2010) used to link all the provinces and is one of the binding forces of the nation. However, it is quite regretting that Urdu could not get due importance in research especially with reference to linguistics. In the field of linguistics, only a few works study Urdu and this number becomes even less when we limit the researches to the area of phonetics and phonology. In the recent past, however, we see that the researchers are paying more attention to Urdu. A few of such research studies include Hussain, (1997), Lodhi (2004) and Rizvi (2007). Some more recent studies include Kiani & Khan (2011) and Bilal et al. (2021), and Nawaz et al. (2020). Nawaz et al. (2020) discussed and compared lexical stress variations in the English words spoken by the Urdu and the native English speakers. If we specifically talk about the studies on Urdu lexical stress, very few studies (Hussain, 1997 & 2005; Mumtaz, 2014 and Qurrat-Ul-Ain & Mahmood (2017) come forth with comprehensive accounts of Urdu lexical stress. Moreover, these studies differ in results. Perhaps, Qurrat-Ul-Ain & Mahmood (2017) study was the first to acoustically analyze and discussed the secondary stress of Urdu language but was also limited in some ways. For example, it studied only the 'duration' cues. The present study comprehensively utilizes all the four popular stress cues (vowel duration, intensity, F0, and vowel quality). Precisely, the present work focuses on the acoustic investigation of primary and secondary stress patterns of Urdu.

LITERATURE REVIEW

Phoneticians generally find four acoustic cues (i.e., duration, intensity, pitch, and vowel quality) helpful in the detection and measurement of lexical stress. These four cues are basically the four measuring criteria that assist in the realization of lexical stress. Early traces of researches on the acoustic analysis of lexical stress are suggesting that mostly languages remain restricted to the above mentioned four acoustic cues; however, there can be difference on the use of these cues.

Fry's (1955, 1958) study on English lexical stress motivated many studies on lexical stress of several world languages. Among the initial works include Lieberman 1960, Lehiste 1970, Beckman and Pierrehumbert 1986, Sereno 1986, Beckman & Edwards 1994, Turk & Sawusch 1996, Recasens & Espinosa 2006, Zhang, Nissen & Francis 2008 and Ortega-Llebaria & Prieto 2011. Initially studied languages include English, Polish, French, Spanish, and Swedish. These studies suggest that different stress cues work differently in different languages. For example, studies on German, Spanish and Polish languages suggest that stressed segments have longer vowel duration (Dogil, 1995 and Dogil and Williams, 1999). Anderson and Port (1994), Crystal and House (1988), Klatt (1976), Morton &Jassem (1965), Rigault (1962), including many others, find stressed segments with increased vowel duration. Ladefoged and Johnson (2012) also find the length as the strongest cue for a listener to capture a stressed segment. While the above mentioned studies (including many others) suggest vowel duration a reliable cue for the lexical stress, it goes contrary in some languages. A study on Finnish language (Carlson, 1980), for example, registers quite opposite results, i.e., stressed syllables with decreased vowel duration. Similarly, studies on lexical stress vary on the F0 cue as well. Fry (1958) finds English disyllabic stressed segments with higher pitch values. On the contrary, Sluijter and van Heuven (1996) find F0 as the least reliable cue for the lexical stress. Then, stressed segments have higher intensity values than their unstressed counterparts (Beckman, 1986; Fry, 1955; Lieberman, 1960). However, intensity may behave quite opposite in some other studies. For example, Sluijter and van Hueven (1996) and

Turk & Sawush (1996) suggest that the stressed vowels are not always louder. They also discuss intensity from the point-of-view of the listener's perception. They suggest that increase in the amplitude of a vowel does not always make it prominent for the listener. Lastly, different studies (de Jong *et al*. 1993; Lindblom, 1963; Beckman & Edwards, 1994; Campbell & Beckman, 1997; Fry, 1955) suggest that co-articulation is likely to affect the unstressed or weekly stressed segments and thus the stressed syllables have more vivid vowel quality. However, factors other than stress can have their impact on the vowel quality. Some vowels, e.g. /i:/ and /u:/, exhibit very distinctive vowel quality when they are stressed and vice versa (Rosner & Pickering, 1994). Then, grammatical functions and forms of the words can have their impact on the quality of the vowels. For example, compare the noun 'separate' and the verb 'separate'. Discussion upon the stress cues reveals that although the languages do not have uniformity in the use of stress cues yet these cues work in one way or the other.

Phonetically speaking, Urdu language does not have a rich number of research works. Only a few studies discuss Urdu lexical stress acoustically. Perhaps, Mehrotra's (1965) work is the first to discuss acoustic cues of Hindi lexical stress. Although, Mehrotra's (1965) study is impressionistic in nature, as it does not provide acoustic analysis on the recorded data, yet it is considered to be the first to discuss Hindi/Urdu lexical stress in terms of acoustic cues: stressed vowels have longer duration, higher values of intensity, more vivid vowel quality and lower pitch. Mehrotra (1965) also discusses stress effects on consonants: consonants at the onset position show stronger aspiration; moreover, a consonant may be doubled in order to show vividness. Mehrotra's (1965) work, an impressionistic study though, gets ascertained by the later works like Hussain (1997), especially in terms of stress effects on vowels.

An overview of the studies on acoustic correlates of the Urdu/Hindi lexical stress studies (Mehrotra, 1965; Hussain, 1997; Nair, 1999; Mumtaz, 2014, and Qurrat-Ul-Ain & Mahmood, 2017) revealed that these studies (Ohala, 1977) have consensus on the use of stress cues. These studies agree upon the main stress cue, i.e., vowel duration, means that, stressed segments have longer vowel duration. As far as other stress cues are concerned, these studies differed in one way or other. Mehrotra (1965) and Hussain (1997) have agreement on the pitch cue as well finding it low for the stressed segments. Mumtaz (2014) uses 'pitch stylizing method' and sees abrupt slope of pitch contours against the stressed syllables. Mehrotra (1965), Hussain (1997) and Nair (1999) suggested that the stressed syllables had more vivid vowel formants. Similarly, the cue of intensity behaved almost identically in these studies. Mehrotra (1965) observed stressed vowels more intense. Hussain (1997) documented higher intensity values of the vowels in the stressed syllables; however, he recorded exceptions of individual differences on the same cue.

After Hussain (1997), we found a chain of studies on the phonetic and phonological analysis of the Urdu lexical stress. Nayyar's work (2000) discussed the applicability of Hussain's (1997) stress algorithm on a considerable number of Urdu words. In an impressionistic study, Hussain (2005), for the first time, documented the presence of secondary stress in Urdu. Qurrat-Ul-Ain & Mahmood (2017) present acoustic and phonological analysis of primary and secondary lexical stress of Urdu. The analysis is confined to the cue of vowel duration only. The study discusses patterns of stress in disyllabic and tri-syllabic words of Urdu and finds multiple levels of stress in Urdu.

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DATA COLLECTION

In the present study six tri-syllabic Urdu words have been acoustically analysed to see primary and secondary stress patterns. To control the extraneous factors that may affect the analysis of data (like speech rate across different utterances and differences of vowel quality across various vowels), uniformity of vowel in the words has been ensured.

STIMULI

Vowels differ from each other according to their characteristics. Different researches on English (Heffner, 1937; House & Fairbanks, 1953 and Peterson & Lehiste, 1960) documented that vowel height correlated with the pitch: the higher vowel has lower pitch. The height of vowels (low/high vowels) also correlated with vowel duration. Lower vowels have longer duration (Lehiste & Peterson, 1961). Keeping in view these differences, words carrying same vowel in all syllables were selected. Six tri-syllabic words have been selected. All these words have low-back-long vowel /a:/ in all syllable. The words have been presented in Table 1:

TABLE 1. Target words with IPA transcription, meaning, and syllabification

Sr. No.	Words in Urdu	Transliteration	IPA (Phonemic transcription)	Meaning	Syllabification
1	پاجامہ	Pajama (N)	/pa:'dʒa:ˌma:/	Trousers	/pa:.'dʒa:.ˌma:./ (CVV.CVV.CVV)
2	کارخانہ	Karkhana (N)	/'ka:rˌxa:na:/	Factory	/'ka:rˌxa:na:./ (CVVC.CVV.CVV)
3	ناسازگار	Nasazgar (Adj.)	/na:ˌsa:z'ga:r/	Unfavorable	/na:.ˌsa:z'.ga:r./ (CVV.CVVC.CVVC)
4	مالامال	Malamal (Adj.)	/ˌma:la:'ma:l/	Replete with something	/ˌma:.la:.'ma:l./ (CVV.CVV.CVVC)
5	آماجگاہ	Amajgah (N)	/a:'ma:dʒˌga:/	Target shelter	/a:.'ma:dʒ.ˌga:h./ (VV.CVVC.CVV)
6	خاکساران	khaksaran (Adj)	/ˌxa:ksa:'ra:n/	Humble (out of courtesy)	/ˌxa:k.sa:.'ra:n./ (CVVC.CVV.CVVC)

The target words were embedded in a carrier phrase to ensure natural utterance.
'میں نےاب----- کہا' (Urdu script)
'main nei ab ------- kaha' (Transliteration)
/mæ̃: ne: əb ------- kəha:/ (IPA transcription)
I said ------- now. (Translation)

PARTICIPANTS

Urdu is the national language of Pakistan. The constitution of 1973 documents Urdu as Pakistan's only national language (Kamran 2019 as cited in Begum, 2022). Mostly, people speak Urdu as a second language while their first language is one of the provincial or regional languages of Pakistan like Punjabi, Pashto, Sindhi, Balochi, Persian, Hindko, Pahari, etc. and this makes Pakistan a very rich multiligual society (Begum, 2022). This is the reason that Urdu accent gets affected by the accents of the regional languages. Hayes (1995) also points out the sociolinguistic problem that becomes the main reason of disparities in the results of lexical stress studies on

Urdu/Hindi. Qurrat-Ul-Ain & Mahmood (2017) also observe that speakers with different L1 backgrounds cause discrepancies in the measurements of the stress cues and results stay invalid. Keeping the sociolinguistic issues in mind, certain criteria were set for the selection of the participants. Speakers were required to match on region, linguistic background, education, gender, and age. Total 9 female Lahore based speakers (age: 20-30) were selected having Punjabi as their mother tongue but Urdu as their active language with M.A. in English as their minimum education. It is very important to note that Punjabi as well as Urdu have many accents depending upon the different regions of the Punjab province (Khan, 2015). The selected participants have Lahori-Punjabi accent as their linguistic background (spoken by their parents and grandparents), while they use Urdu as their active conversational language. Also, the participants of the study were born in Lahore. It was important to match the speakers on the linguistic background that they carry along. If an Urdu speaker has a Multani-Punjabi accent as her linguistic background, she is likely to stress alternative segments of the target words when compared to the ones uttered by a Lahori Urdu speaker with a Lahori-Punjabi background. This was observed by Qurrat-Ul-Ain & Mahmood (2017). Therefore, it was very important that the speakers strictly match on all the set variables; i.e., area, linguistic background, education, gender, and age.

The six target words (in a carrier phrase) were recorded in an anechoic room using PRAAT software (Boersma & Weenink, 2019) at the sampling rate of 44.1 kHz. Each speaker was supposed to record each sentence for three times and in this way 162 speech tokens were collected for analysis. Each PRAAT file was saved using specific codes like 'Sp1_1'. In order to segment and label the files, text grids were generated. The basic analysis of this study depends upon the measurements of vowels, therefore, vowel boundaries were carefully marked. Markers were placed around the vocalic boundaries as well as the central point of the vowel. The central point of vowel is considered good for the measurements of different acoustic cues because it is considered the stable part of the vowel under observation.

As this study mainly identified modification in the vowels of the target words due to stress, therefore, vocalic boundaries were very carefully marked. Text grids were generated for each wave file and the segments were labelled. Vocalic context was carefully observed keeping in view the clear visibility of the second formant. Special care was taken while placing the text grid markers around the vocal areas. By zooming out the whole target word, the text grid markers were placed around the darker areas then the boundaries were refined by zooming in.

To maintain reliability of segmentation, the sound files were sent to another annotator who randomly marked some files which were then compared to the previously annotated file. No major difference could be seen in the marking. After the segmentation was complete, the measurements were taken to verify the four stress cues (i.e., vowel duration, intensity, F0 and vowel quality). Entropics Signal Processing System (ESPS) was used (Shore, 1989) on Ubuntu, Linux in the Phonetics Laboratory of the University of Oxford, 41 Wellington Square, Oxford. ESPS contains a number of speech analysis and processing tools that have compatibility with UNIX environment. This software contains a signal labelling utility that allows fast and multiple feature labelling that is specifically useful for large speech data (http://www.entropic.com/).

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DATA ANALYSIS

Six tri-syllabic words having different syllabic templates with same vowel (/a:/) in all syllables were analyzed using four stress cues, i.e., vowel duration, pitch, intensity, and vowel quality. Same vowel in all the syllables allows us to control the effects that are not related to stress while different syllabic templates indicated changes in the stress patterns, therefore, we can possibly determine the types of templates that attract primary and secondary stress. Detailed phonetic and statistical analyses are given in the successive sections.

VOWEL DURATION

Each word has been presented using a separate graph in order to facilitate easy identification of stress levels in each word. The figure distinctly shows that how duration goes along the three stress levels; the longer the duration identified the higher stress level. Figure 1 presented the duration values of different segments across the target words.

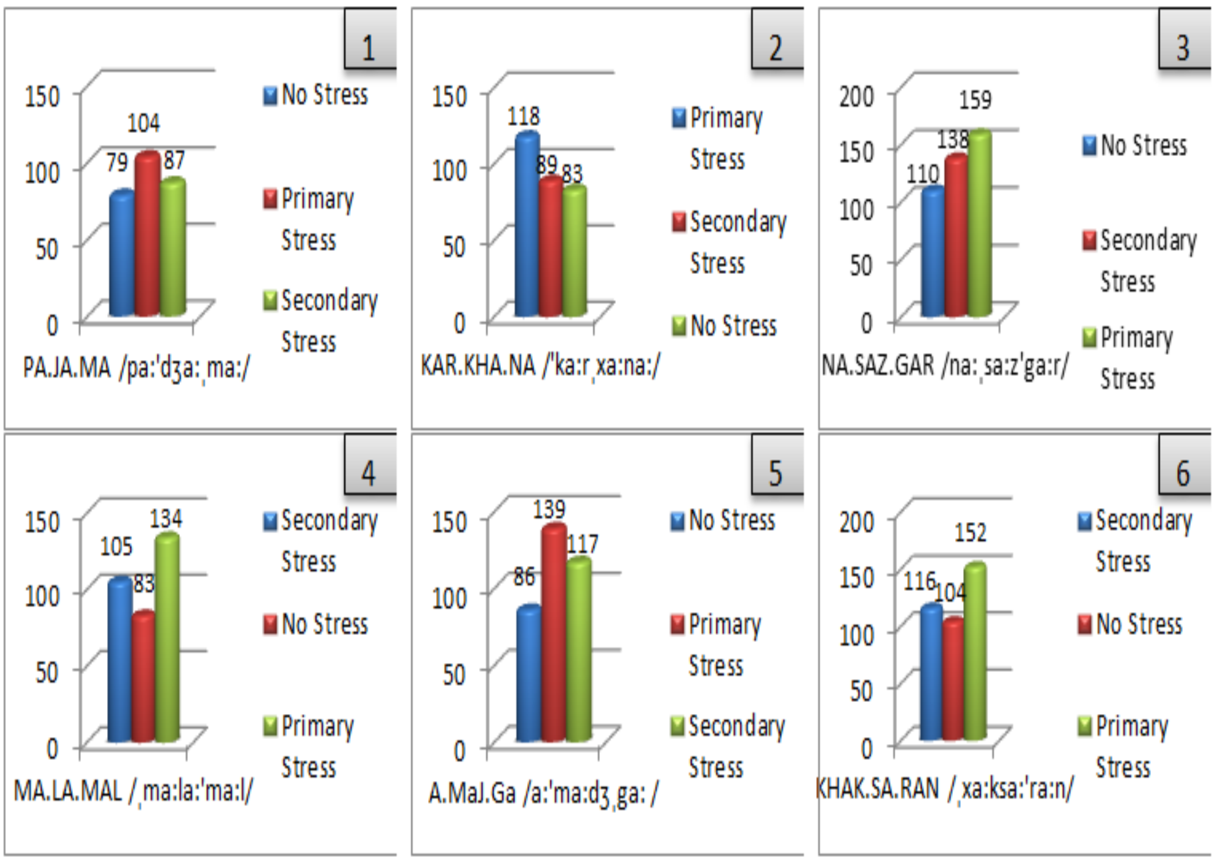

FIGURE 1. Mean values of the vowel duration (vowel /a:/ measurement in ms) in the target words

The first word ‘pajama’ has its primary stress on the penultimate syllable ‘ja’ that has the longest vowel duration, i.e., 104ms. Secondary stress falls on the final syllable ‘ma’ and the average vowel duration is 87ms while the first syllable ‘pa’ has zero stress with shortest vowel duration, i.e., 79ms. The second word ‘karkhana’ also has three stress levels and the stress patterns change here with the syllable templates. The first syllable (CVVC) has the main stress with longest vowel duration (118ms) while the penultimate syllable has secondary stress (89ms) and the final syllable was unstressed with the shortest vowel duration 83ms. The next target word is 'nasazgar' that has two [1]super-heavy and one heavy syllable (CVV.CVVC.CVVC). The competition between the two super-heavy syllables is won by the final syllable that has the longest vowel duration, i.e., 159ms while penultimate and first syllables have secondary and zero stress with 138ms and 110ms duration respectively. The fourth word 'malamal' has one super-heavy syllable while the other two are heavy. Main stress lies on the final syllable that has the longest duration (134ms) while the secondary stress falls on the first syllable (105ms) and the penultimate syllable has zero stress level with 83ms vowel duration. In the word 'amajga' the central vowel is super-heavy with the longest duration (139ms) while the final and first syllables carry secondary and zero stress respectively. The last word 'khaksaran' has two super-heavy syllables in the beginning and end while the penultimate syllable is heavy. Main stress falls on the last syllable /ra:n/ that has the longest duration (152ms) and the other super-heavy syllable 'khak' carries secondary stress (116ms).

[1] Syllables can be divided into three categories: light abbreviated as L (CV or V), heavy abbreviated H (CVV, CVC, VV, VC) and super-heavy abbreviated as S (CVVC, VVC). These are all possible syllabic weights in Urdu (Hussain 1997, 2005). Details of Urdu phonemic inventory and pronunciation guide can be found in Hussain (1997, pg. 147-158).

Analysis of variance test (ANOVA) was performed on the data to see the three stress levels in the multisyllabic words. ANOVA test is performed to see the relationship among more than two things to see if there any link exists among them. The following table presents the mean values, mean differences, f-values and significance against each target word. The statistical analysis shows that all the three levels have significant difference in the vowel duration; the longer the vowel duration, the higher the level of stress.

TABLE 2. Mean duration (in ms) of vowels in the three levels of stress in tri-syllabic Urdu words

Words	Primary		Secondary		Unstressed		F	Sig.
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation		
PA.JA.MA	104	10	87	9	79	11	44.52	1.2667E-13
KAR.KHA.NA	118	11	93	12	83	10	66.34	1.4777E-17
NA.SAZ.GAR	159	12	138	11	110	12	117.89	2.6535E-24
MA.LA.MAL	134	17	105	9	83	9	117.22	3.135E-24
A.MAJ.GA	139	12	117	11	86	22	76.39	4.2421E-19
KHAK.SA.RAN	152	13	116	12	104	8	132.61	8.0172E-26

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INTENSITY

Intensity values significantly vary across and within the speakers. As the cue of intensity is sensitive to the ways recording takes place, therefore, special care was taken while recording the data. The speakers were asked to record at a comfortable loudness, but the comfort level varies person to person as some people are naturally loud while others are naturally soft speakers. This phenomenon may cause variation in the intensity values. However, mean values of the data can give an idea about the amplitude of the stressed and unstressed segments. See the following table for the average values of intensity:

TABLE 3. Mean intensity (in dB), standard deviation, f-values and significance of vowels in the primarily, secondarily and unstressed syllables of tri-syllabic Urdu words

Words	Primary		Secondary		Unstressed		F	Sig.
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation		
PA.JA.MA	70.38	2.27	68.98	1.71	72.02	3.23	10.14207	0.000122
KAR.KHA.NA	68.44	3.50	66.30	2.76	67.22	3.08	3.204563	0.045973
NA.SAZ.GAR	68.15	2.77	67.93	2.64	68.04	2.34	0.049597	0.951643
MA.LA.MAL	66.22	2.75	67.41	3.05	67.22	2.98	1.278005	0.284361
A.MAJ.GA	68.87	1.57	70.60	2.00	70.21	2.28	5.70806	0.004858
KHAK.SA.RAN	66.89	2.47	67.74	2.84	67.89	2.65	1.114236	0.333332

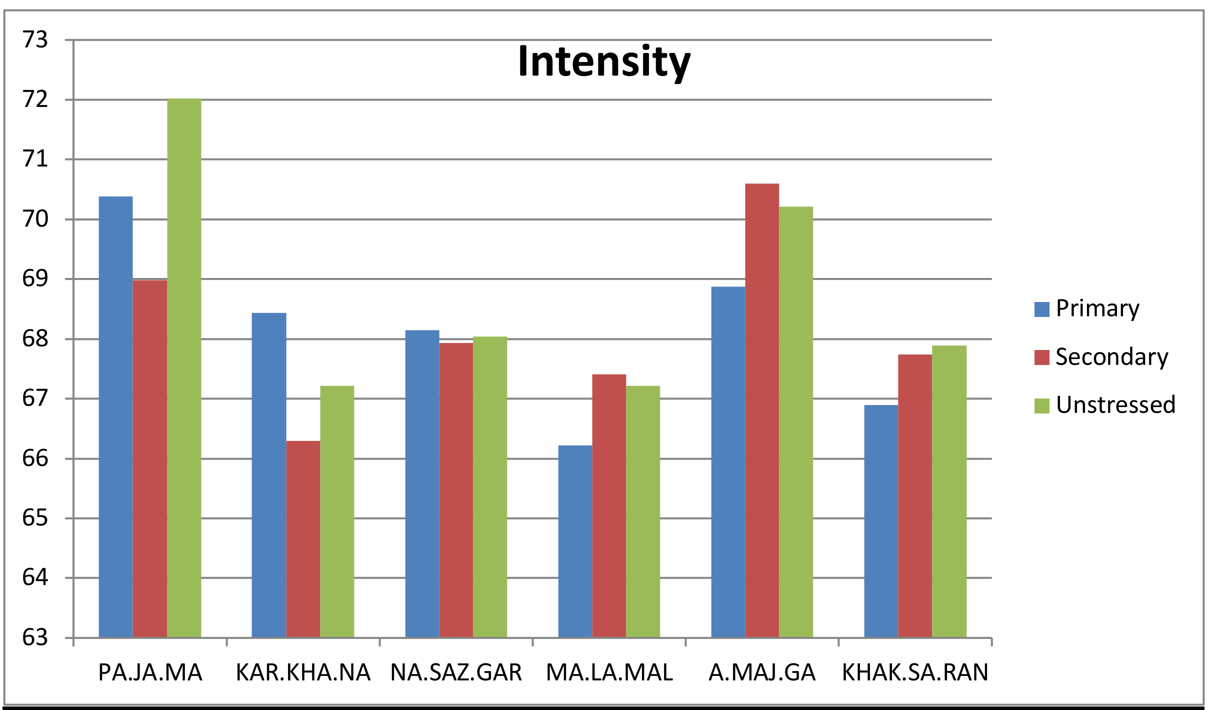

FIGURE 2. Mean intensity values (in dB) of the three levels of stress in the target words

The chart shows that the average intensity values differ across the three levels of stress but the patterns are not always consistent; i.e. it is not always high for the main stress. The patterns keep changing across the words. Previous researches on Urdu lexical stress show different results against the intensity cue. Whereas, Hussain (1997) finds high intensity values against the mainly stressed segments, Mumtaz (2014) finds wavering intensity values across different syllables and therefore, the latter suggests that different vowels might have caused variation in the intensity values. The present data, however, maintains uniformity on vowel by selecting the words that use same vowel in all contexts. This allows elimination of any variation in intensity values caused by vowels having different qualities. ANOVA results presented in the table 3 show mean values, standard deviation, *f-values* and significance of the intensity measurements across the three levels of stress. The data suggests that intensity can be a cue to Urdu lexical stress but it is not very reliable one as it does not make consistent patterns across the words.

FUNDAMENTAL FREQUENCY

Fundamental frequency was evaluated on three levels: overall behavior of pitch in the target word area, stylized pitch contour (the method applied by Mumtaz (2014) on Urdu data for stress analysis and it successfully worked for the data: abrupt fall/slide of pitch contours in the area of the stressed segments), and pitch measurements.

We don't see a uniform pitch behavior against the target words. Pitch behavior constantly changes across recordings of the target words. Similarly, stylized pitch-contour method could not word on the present data. We do not always see steep fall/rise of the pitch contours in the target word area. For example, see the following stylized pitch file of one of the recordings:

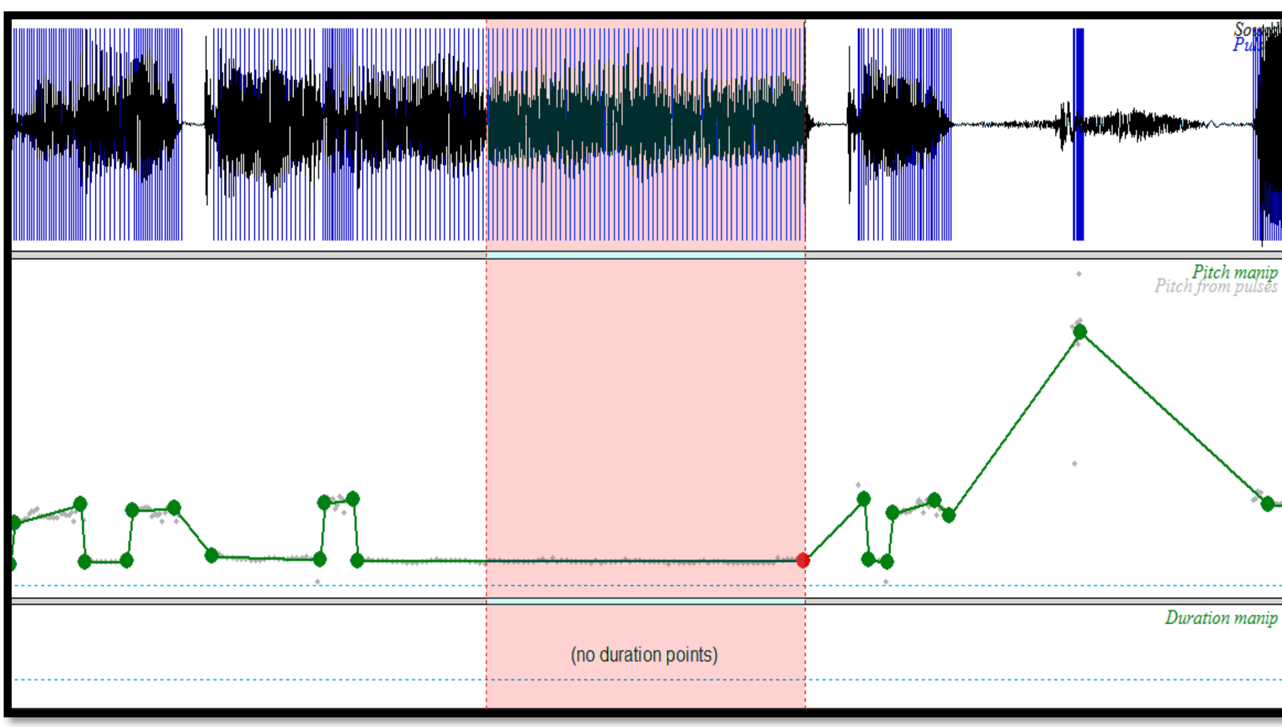

FIGURE 3. Stylized pitch of the word 'MA.LA.MAL'. The target word is highlighted pink.

Whereas, Mumtaz (2014) finds stylized pitch contour as one of the very helpful cues (contours are steep against the stressed segments and gradual/flat against the unstressed ones), the present data show multiple inconsistent pitch contours patterns across the target word areas. In figure 4, we see the pitch contours do not even exist in the target area. This is just one example; in other files, we see that pitch is either static or gradual fall/rise of contours is seen in the stressed segments areas. There are only a few instances where we find abrupt and steep pitch contours in the stressed segment areas. Therefore, we can say that stylized pitch contour method does not work in the present data.

Mean values of F0 have been presented in figure 5. When seen individually, the pitch data doesn't display constant patterns within and across the speakers. When seen collectively, F0 seems to correlate with the three levels of stress. In the first four words, it is lowest for the stressed segments while the other two levels show constantly wavering patterns of pitch. In the last two words, the pitch gets higher on the stressed segments.

TABLE 4. ANOVA results of F0 measurements (in Hz) in tri-syllabic words

Words	**Primary**		**Secondary**		**Unstressed**		**F**	**Sig.**
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**		
PA.JA.MA	167	46	198	34	198	32	6.229869	0.00309
KAR.KHA.NA	176	52	190	35	175	47	0.949829	0.391235
NA.SAZ.GAR	165	45	167	53	192	42	2.782415	0.068041
MA.LA.MAL	185	48	186	41	198	31	0.971648	0.382992
A.MAJ.GA	192	29	176	42	191	40	1.523194	0.224428
KHAK.SA.RAN	177	40	171	54	175	46	0.113844	0.892546
LA.TI.NI	191	34	184	41	203	39	1.706445	0.188216
AP.BI.TI	184	43	189	32	195	50	0.447411	0.640911
TA.RIKH.DAN	164	43	192	39	198	45	4.946998	0.00949
A.LI.SHAN	180	37	182	45	193	46	0.777301	0.463172
NA.RAS.TI	165	41	197	22	207	39	10.58631	8.56E-05
DIN.DA.RAN	157	53	194	44	164	47	4.620032	0.012699

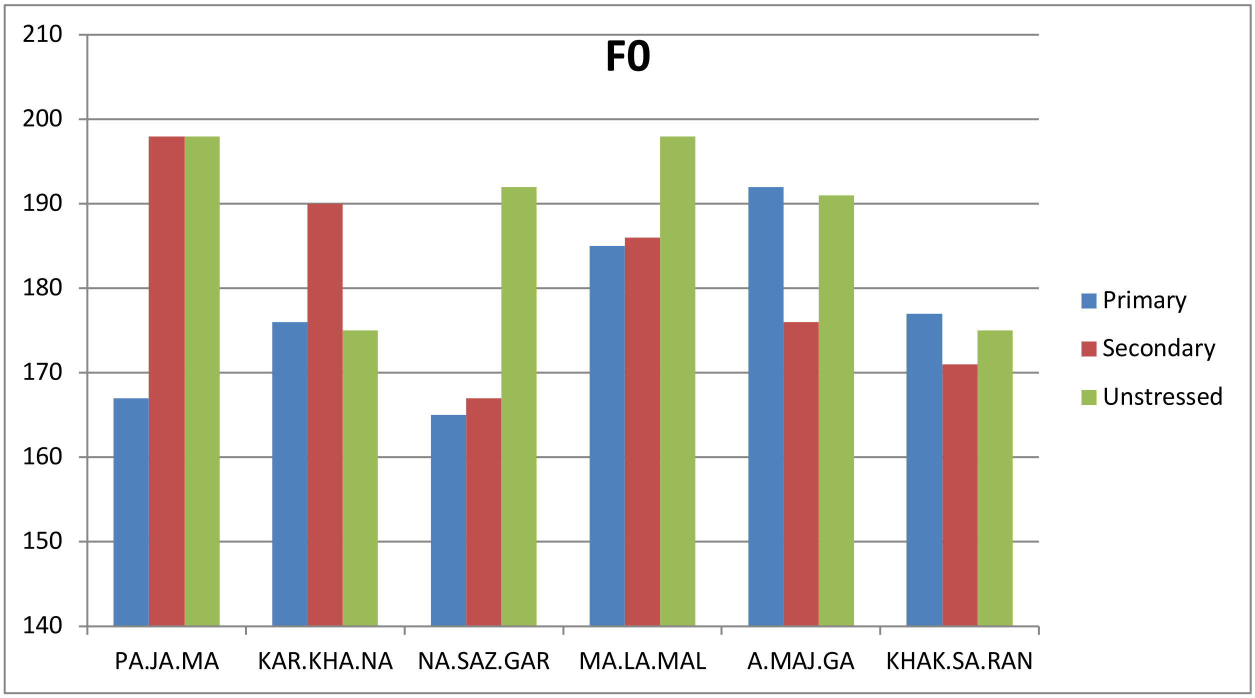

FIGURE 4. Mean F0 measurements (in Hz) of vowels in the target words

The overall values of the pitch data seem to correlate with the stress patterns of Urdu language. Hussain (1997) finds lower pitch values against the stressed segments. Similarly, the present data also present a trend of drooping pitch on the stressed syllables. In the first four words (pajama, karkhana, nasazgar and malamal), overall pitch values are lowest for the unstressed segments while the other two levels (unstressed and secondary) do not show uniform patterns; i.e., pitch is not always highest on the 'no stress' segments. Table 4 plots ANOVA test results. Mean values, standard deviation, f values and significance are presented in separate columns.

VOWEL QUALITY

First three formant values of each vowel in the target words were taken into account. A lot of variation can be seen in the values. No consistent patterns could be seen in the formant data.

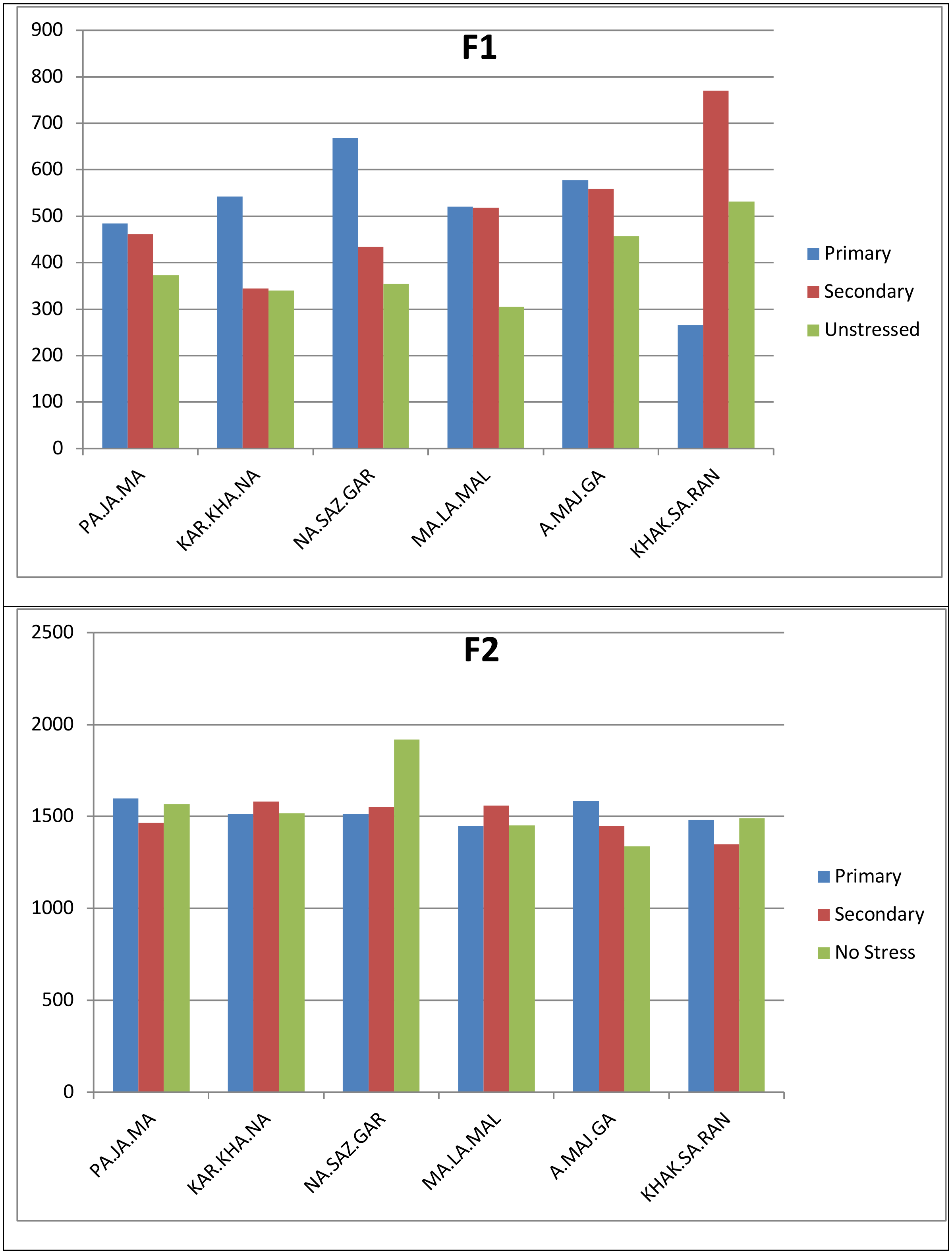

FIGURE 5. Means of the first three formants of the vowels of the three stress levels in the target words

We see consistent F1 patterns as far as the first five words are concerned, i.e., highest F1 values for primary stress, second highest for secondary stress and lowest for zero stress level. Interestingly, the word 'khaksaran' deviates from this pattern. One of the reasons can be it's very rarely used by the Urdu speakers. The word 'khaksaran' has Persian origin and is rarely used by the Urdu speakers. As far as F2 measurements are concerned, we see quite inconsistent patterns across the target words. The statistical test ANOVA was performed on the data. The results are given in the following table:

TABLE 5. ANOVA results of the first two formants of the vowels of the three stress levels in the target words

F1	Primary		Secondary		Unstressed			
Words	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**F**	**Sig.**
PA.JA.MA	484.46	237.49	461.53	243.19	372.80	186.84	1.87201	0.160659
KAR.KHA.NA	542.30	298.11	344.19	68.10	340.22	208.29	7.899011	0.000752
NA.SAZ.GAR	667.74	339.23	434.22	265.53	354.48	168.81	10.02801	0.000133
MA.LA.MAL	521.07	357.34	518.41	308.45	305.33	141.40	5.112022	0.0082
A.MAJ.GA	577.88	212.01	558.43	266.95	457.00	209.45	2.132051	0.125454
KHAK.SA.RAN	265.93	45.12	770.41	270.93	531.96	299.85	31.19918	1.11E-10
F2	**Primary**		**Secondary**		**Unstressed**			
Words	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**F**	**Sig.**
PA.JA.MA	1598.33	279.77	1465.30	118.23	1567.66	265.61	2.414519	0.096066
KAR.KHA.NA	1511.52	227.27	1581.56	189.94	1518.26	184.35	0.993509	0.374911
NA.SAZ.GAR	1511.11	229.97	1550.67	96.73	1917.22	628.82	8.874666	0.000337
MA.LA.MAL	1449.33	177.70	1558.11	382.30	1451.44	413.29	0.899176	0.41108
A.MAJ.GA	1583.16	484.78	1448.06	228.72	1337.74	325.06	3.114153	0.049983
KHAK.SA.RAN	1481.26	266.36	1347.56	194.75	1490.81	321.50	2.448395	0.093051

The table shows mean values of the first two formants, standard deviation, f-values and significance of mean differences across the three levels in the target words. If we see the previous studies in the context of vowel quality, we find that Hussain (1997) finds vowel quality a reliable stress cue for Urdu lexical stress; Mumtaz (2014) says otherwise. She finds inconsistencies in formant values across different levels of stress. The present data also displays widely varying results on the formant data across the three levels of stress.

The following figure presents the low-back-long vowel /a:/ on the typical vowel chart to show what position it approximately assumes across the three levels:

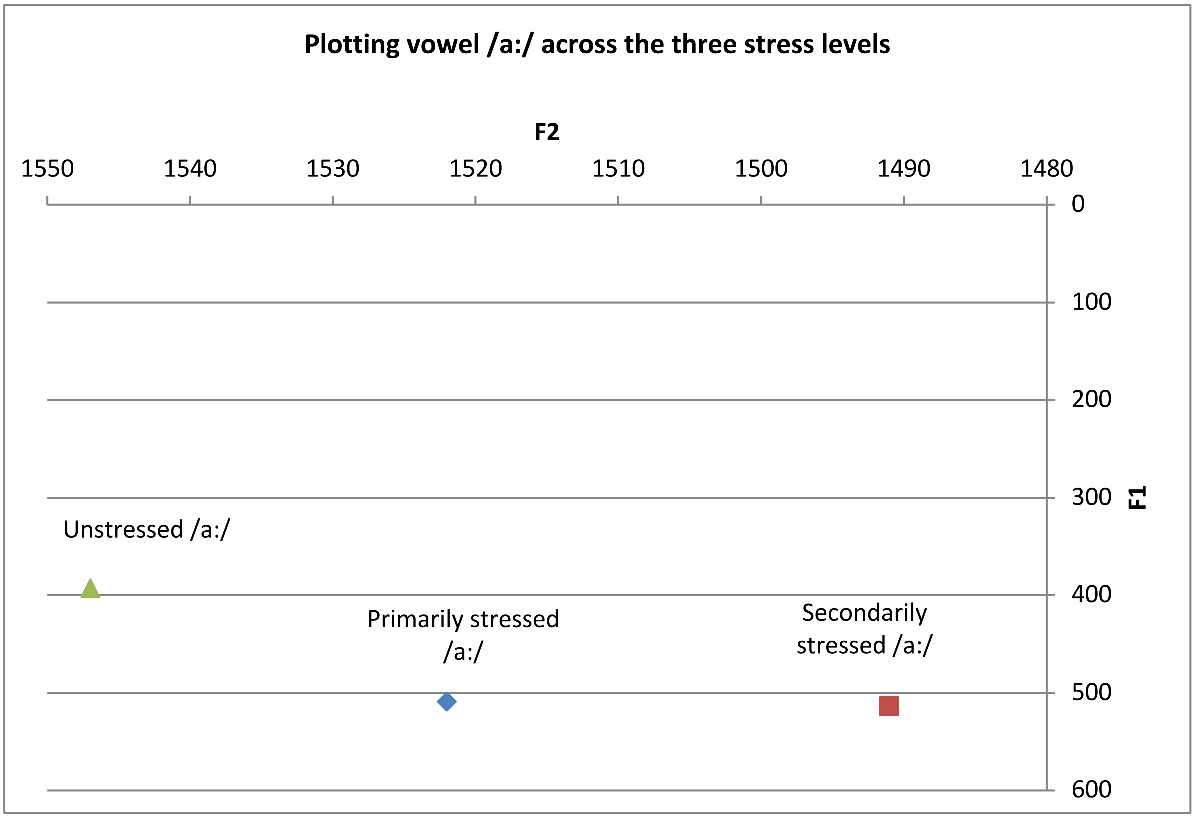

FIGURE 6. F1 and F2 plot for the vowel /a:/ across the three levels of stress

As far as the mean value of F1 is concerned, we see it is nestled at its natural place across the three levels, i.e. low. We see a lot of variation in the F2 values across the six target words and therefore, we see wide distances among the three levels on the horizontal axis.

To get a comprehensive picture of the whole data against the four cues, 'multiple comparisons' test was performed. The following table presents the comparison. The test facilitates comparison of one stress level with the other two. Zero '0' stands for 'No Stress Level', '1' stands for 'Primary Stress', and 'Secondary Stress' is coded as '2'.

TABLE 6. Multiple comparisons of the four stress cues in the tri-syllabic words

Stress Cues	**Stress Level**	**Compared with**	**Mean Difference**	**Std. Error**	**Sig.**	**95% Confidence Interval Lower Bound**	**Upper Bound**
Duration	0	1	-44.58*	1.375	.000	-47.28	-41.89
		2	-20.12*	1.375	.000	-22.82	-17.42
	1	0	44.58*	1.375	.000	41.89	47.28
		2	24.47*	1.375	.000	21.77	27.16
	2	0	20.12*	1.375	.000	17.42	22.82
		1	-24.47*	1.375	.000	-27.16	-21.77
F0	0	1	13.51*	2.966	.000	7.69	19.33
		2	5.13	2.966	.084	-.68	10.95
	1	0	-13.51*	2.966	.000	-19.33	-7.69
		2	-8.37*	2.966	.005	-14.19	-2.55
	2	0	-5.13	2.966	.084	-10.95	.68
		1	8.37*	2.966	.005	2.55	14.19
Intensity	0	1	-.0335	1.04011	.974	-2.0738	2.0069
		2	-.2125	1.04011	.838	-2.2528	1.8278
	1	0	.0335	1.04011	.974	-2.0069	2.0738
		2	-.1790	1.04011	.863	-2.2194	1.8613
	2	0	.2125	1.04011	.838	-1.8278	2.2528
		1	.1790	1.04011	.863	-1.8613	2.2194
		3	-5.2646*	1.64455	.001	-8.4906	-2.0385
F1	0	1	-107.1837*	18.69657	.000	-143.8600	-70.5074
		2	-91.1617*	18.69657	.000	-127.8380	-54.4854
	1	0	107.1837*	18.69657	.000	70.5074	143.8600
		2	16.0220	18.69657	.392	-20.6543	52.6983
	2	0	91.1617*	18.69657	.000	54.4854	127.8380
		1	-16.0220	18.69657	.392	-52.6983	20.6543
F2	0	1	310.6216*	35.41332	.000	241.1527	380.0905
		2	121.6724*	35.41332	.001	52.2035	191.1413
	1	0	-310.6216*	35.41332	.000	-380.0905	-241.1527
		2	-188.9492*	35.41332	.000	-258.4181	-119.4803
		3	72.4643	55.99337	.196	-37.3756	182.3043
	2	0	-121.6724*	35.41332	.001	-191.1413	-52.2035
		1	188.9492*	35.41332	.000	119.4803	258.4181
F3	0	1	178.9435*	33.47274	.000	113.2814	244.6056
		2	75.6522*	33.47274	.024	9.9900	141.3143
	1	0	-178.9435*	33.47274	.000	-244.6056	-113.2814
		2	-103.2913*	33.47274	.002	-168.9535	-37.6292
	2	0	-75.6522*	33.47274	.024	-141.3143	-9.9900
		1	103.2913*	33.47274	.002	37.6292	168.9535

FINDINGS

This study strived to see primary and secondary levels of stress in Urdu. Acoustic analysis was performed on six tri-syllabic words. As most of the acoustic information is obtained from the acoustic study of vowels, therefore, vowels were studied acoustically using the four popular cues of stress. The data was highly controlled as far as the vocal contexts are concerned; it used same vowel /a:/ in all the syllables of the target words. Similarly, all the variables were strictly matched in all respects (speakers, L1, active language, background, area, ages and recording conditions).
The findings suggest that vowel duration is the most reliable cue. Vowel duration is seen to have direct correlation with the lexical stress. We see that primarily stressed segments have the highest vowel duration values; secondarily stressed syllables have second highest duration values, and the unstressed segments have lowest values of vowel duration. However, it is important to note that no consensus could be developed for an average duration values for the three levels. It is so because duration values varied within the same stress level across the different words. For example, in the

first word 'PA.JA.MA', the main stress is on the central syllable 'JA' and the noted duration is 104ms while in the third word 'NA.SAZ.GAR', the unstressed segment 'NA' has even longer duration than the mainly stressed segment of the first word, i.e. 110ms. This shows that each word should individually be seen for vowel duration.

Intensity cue had widely varying values within and across the target words. Special care has to be taken while recording and each speaker was asked to maintain comfortable loudness and distance from the microphone while speaking but the comfort level varies from speaker to speaker and this may become one of the reason that intensity cue couldn't be of much help here. Previous studies on Urdu lexical stress (Hussain, 1997 and Mumtaz, 2014) also find big differences across the intensity values. Similarly, leaving some words aside, intensity values vary a lot and therefore we can say that it may not be one of the correlates of the Urdu lexical stress. However, if more cares are taken while recoding the data (uniform distance between mouth and microphone, anechoic room, balanced loudness, etc.), the results may achieve more uniformity.

Fundamental frequency was measured against the three levels of stress. F0 shows uniform patterns against the main stress level. Overall, lower pitch trend was seen at the mainly stressed segments. However, F0 values do not seem to show uniform patterns across all the levels of stress in the target words; for example, in the word /a:'ma:dʒˌga:/ the antepenultimate syllable /ma:dʒ/ carries primary stress but it carries highest F0 values. Leaving individual instances aside, overall pitch correlates with the stress patters. Hussain (1997) also sees lower pitch on stressed segments. Stylized pitch contour, a method used by Mumtaz (2014), was also applied on the present data; however, it didn't go along the different levels of stress. The pitch contours were either missing altogether in the target area or they didn't correlate with the different levels of stress. See figure 3 in this context.

Stress affects the quality of vowel: stressed vowels have more distinct articulation and formant frequencies than those of the unstressed (Beckman and Edwards, 1994; van Bergem, 1993). The cue of vowel quality correlated well with the primary level of stress in the first fives words. F1 has higher values in all the words leaving 'KHAK.SA.RAN' (the word has a Persian origin and is not very commonly used by the Urdu speakers). F2 values, however, waver widely across the different levels of stress. The findings under the vowel quality data are consistent with Mumtaz (2014) who finds highly varying results in the vowel quality section.

CONCLUSION

The study acoustically investigated the primary and secondary levels of lexical stress of the Urdu language. The previous studies (Hussain, 1997; Mumtaz, 2014) study a limited number of syllabic templates and investigate acoustic cues of primary stress Urdu stress only. Qurrat-Ul-Ain and Mahmood (2017) documented secondary stress of Urdu using 'duration' cue. This study used all the four popular acoustic cues of lexical stress to see their correlation with the primary and secondary levels of Urdu lexical stress. The study was conducted on a very controlled data. The target words had uniformity on vowel (low-back-long /a:/) in all the syllables. Similarly, the participants of the study strictly matched on different variables: mother tongue (Punjabi), active language (Urdu), gender (female), age (20-30 years), and education (M. A. English).

Acoustic analysis of the target words revealed that the stress levels correlate with the vowel duration; the longer the duration, the higher the level of stress. The results match with the previous studies (Hussain, 1997; Mumtaz, 2014; Qurrat-ul-Ain & Mahmood, 2017). As far as the other cues are concerned, we see wavering results. Generally, lower F0 is seen against the stressed segments

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while the unstressed syllables have higher pitch. Overall, we see intensity and formant values are higher on the stressed syllables.

Overall, we can say that the cue of duration is the most reliable to detect lexical stress of the Urdu language. The study can be further expanded using multiple vowels and syllabic templates. A comprehensive phonological analysis can be drawn using the present acoustic evidence for the primary and secondary lexical stress of Urdu. Different phonological theories like Metrical Stress Theory' by Hayes (1995) and Optimality Theory by Prince & Smolensky (2004) can be considered in this regard.

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