Kinnaird College for Women

Mechanism for Determining Urdu Stress Using Acoustic Cues

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Thesis

of

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Mechanism for Determining Urdu Stress Using Acoustic Cues

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DECLARATION

The work reported in this dissertation was carried out by me under the supervision of Ms. Priya Avais, Head of Department of Applied Linguistics, Kinnaird College for Women, Lahore. I hereby declare that the title of thesis "Mechanism for Determining Urdu Stress Using Acoustic Cues" and the contents of thesis are the product of my own research and no part has been copied from any published source (except the references, standard mathematical or genetic models /equations /formulas /protocols etc).

Signature of the Student: Benazir Mumtaz

Date:

ABSTRACT

This research aims to develop a mechanism for determining the stressed and unstressed syllables of Urdu language from the speech corpus. Phonological analysis of Urdu stress pattern has indicated that stress in Urdu is predicable depending on the weight of the syllable. However, stress analysis on the recorded Urdu speech shows that stress in speech is variable indicating rules defined for lexical stress marking cannot entirely be applied to mark the stress on speech. Therefore, this current research focuses to build on the previous research efforts and develop a mechanism for determining Urdu stressed syllables in speech using the five acoustic cues of stress such as duration, intensity, vowel quality, glottalization and fundamental frequency.

To develop a mechanism for stress marking, 330 sentences from three different speech corpora are recorded in 'mono' form at a sampling rate of 48 kHz. These sentences are recorded by three speakers in an anechoic chamber using PRAAT software. On these recorded sentences, stress is assigned after conducting the careful analysis of the vocalic properties of syllable in the spectrogram and time wave form.

Based on the results of these annotated sentences, a stepwise process has been formulated in order to maintain quality and consistency in marking the stress tier. In this stepwise process, cues for Urdu stress marking have been prioritized i.e. duration, fundamental frequency, glottalization and intensity of the vowel respectively.

The results of the acoustic analysis of the duration of stressed and unstressed syllables show that the vowel of a stressed syllable has more duration than unstressed syllables. It is observed that the duration of vowel of the stressed penultimate syllable is less than the duration of vowel of the stressed final syllable and stressed final syllable with pause. It is also noticed that stress always fall on the syllable with heavy coda (VCC). Similarly, stress can also influence the duration of consonants in Urdu. Results indicate that duration of few consonants such as /ʃ/, /s/, /j/, /n/ increases more than 100 ms with stress at onset and coda positions.

The analysis of stylized pitch contour indicates that both high pitch contour and low pitch contour can also be used to determine the stressed syllable in Urdu. The results illustrate that falling or rising slope between L* and H* is abrupt and steep for stressed syllables in Urdu whereas it is gradual and flat for unstressed syllables.

The analysis of the glottalization and vowel quality cue show variation in determining stressed syllable. Results show that glottalization at phrase initial position is an indicator of stress whereas at phrase final position, glottaliztaion indicates tapering off of the vowel. In addition, it is observed that intensity of an accented syllable in Urdu is on average 3-5dB more than an unaccented syllable. However, the change in intensity with stress is vowel dependent.

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To my family and friends who knew that I can do anything I want ..... as soon as I stop all the whining.

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LIST OF ABBREVIATIONS

Case Insensitive Speech Assessment Method Phonetic Alphabet (CISAMPA)

International Phonetic Alphabets (IPA)

Fundamental Frequency (F0)

Center for Language Engineering (CLE)

Formant 1 (F1)

Formant 2 (F2)

1 Introduction

1.1 Purpose of the Study

Several studies have been conducted to investigate the stress of various languages, but research in Urdu stress is still an unexplored area in Pakistan. Thus, the current research aims to build on the previous research efforts and develop a mechanism for determining Urdu stressed syllables using the five acoustic cues of perceived stress i.e. duration, intensity, glottalization, vowel quality and fundamental frequency. The mechanism developed in this study will facilitate the researchers to understand the acoustic characteristics of stressed and unstressed syllables of Urdu language. Furthermore, this research will assist those researchers who want to explore the emphatic stress, secondary stress and intonational patterns of Urdu language.

1.2 Statement of the Problem

Stress in speech is variable and a speaker can utter the same sentence using different combination of stressed and unstressed syllables. For example, the sentence of Urdu "me:ri: mə̃: a:i: / My mother came" (see Appendix A-1) which consists of four syllables shows different stress patterns assigned by the same speaker in the same sentence. In the first utterance of the sentence "My mother came", the pattern used is unstressed syllable, unstressed syllable, stressed syllable and stressed syllable. In the second utterance of the same sentence, the pattern used is stressed syllable, unstressed syllable, unstressed syllable and stressed syllable.

This example shows that same sentence uttered by the same speaker in two different contexts can have different stressed syllables. The combination of stressed and unstressed syllable a speaker is selecting might be depended on his/her intention or purpose of communication. In a fluent

speech, the intention of the speaker and topic of discussion can be changed very spontaneously and fluently and the moment "topic" and "intention in communication" changed, the stressed pattern and intonation of the speaker also gets changed. It means that intention of the speaker is somehow closely connected with the selection of stressed syllables and intonation patterns or vice versa.

There can be various types of intention in communication such as questioning, showing commitment, approving, and showing hesitation, etc. As discussed above very limited work has been conducted on the stress assignment of Urdu language. Therefore, in the initial stage of the research on Urdu stress, it might be very difficult to state what types of stressed and intonational patterns would be aligned with a particular intention in the communication. However, as a first step it can be investigated that how a listener distinguishes a stressed syllable from the unstressed syllable in Urdu language in a spontaneous speech. It means a mechanism/ guidelines need to be developed to differentiate a stressed syllable from an unstressed syllable, which lead us directly into the core of this research.

1.3 Objectives

The objectives of this research are to find out the:

- prioritized order of acoustic cues for stress marking in Urdu language
- duration of stressed and unstressed oral and nasal vowels of Urdu language at penultimate and final syllable positions
- intensity of stressed and unstressed oral and nasal vowels of Urdu language
- vowel quality of stressed and unstressed oral and nasal vowels of Urdu language

- nature of fundamental frequency/pitch contour of stressed and unstressed vowels of Urdu language

1.4 Research Questions

This study will report on the acoustic analysis of stressed and unstressed syllables of Urdu language. It will address the following questions:

1) What is the prioritized order of acoustic cues for stress marking in Urdu language?
2) What is the duration of stressed and unstressed oral and nasal vowels of Urdu language at penultimate and final syllable positions?
3) What is the intensity of stressed and unstressed oral and nasal vowels of Urdu language?
4) What is the vowel quality of stressed and unstressed oral and nasal vowels of Urdu language?
5) What is the nature of fundamental frequency/pitch contour of stressed and unstressed vowels of Urdu language?

1.5 Background of the Study

Stress is described as the display of prominence on a certain syllable. According to Cutler (2005), research on stress and stress perception has primarily focused on the acoustic characteristics of stressed versus unstressed syllables, and how listeners make use of acoustic cues to make judgments regarding the occurrence of stress.

Since from the beginning of 1950's, a number of studies investigated the acoustic correlates of lexical stress in the variety of languages such as English, Polish, French, and Swedish (Gay, 1978; Lehiste, 1970). These studies concentrated on four acoustic cues of perceived stress: duration, intensity, fundamental frequency, and vowel quality. In general, longer duration,

greater amplitude, higher fundamental frequency, and less vowel reduction in a syllable contribute to the perception of stress. (Bolinger, 1958; Fry, 1955; Lieberman, 1960; Lindblom, 1963). However, the individual contribution of each of these factors in determining lexical stress remains unclear. While some studies find that fundamental frequency appears to be most predominant cue to perceive stress, importance of vowel's duration, amplitude and formant structure cannot be ignored in stress marking process.

Moreover, the relative importance of each of these cues varies with the position of the lexical item in sentence and position of the syllable in the word (Morton & Jassem, 1965; Gay, 1978; Nakatani & Aston, 1978). In speech production, it becomes more difficult to determine what particular cue or series of acoustic cues such as fundamental frequency, duration, amplitude and vowel quality are contributing in the perception of contrastive stress as various combination of vowels and consonants are appearing in various position of the syllable in a spontaneous speech.

1.6 Rationale

The scope of this research will be multidimensional. This study can become the initiative to investigate the unexplored areas i.e., secondary stress, emphatic stress, break index and intonational pattern of Urdu language. This research can also help to develop an algorithm, which can assign the stressed and unstressed syllables automatically. Moreover, it can bring the consistency among annotators at stress marking level.

1.7 Delimitation of the Research

Although the sentences used for determining the mechanism of stressed syllables have been selected from the three corpora to ensure the coverage of all phoneme of Urdu language, it is still difficult to find the multiple occurrences of all the vowels in all the possible positions of the

syllables. Moreover, due to the limited time and resources, the data is recorded only from the female speakers.

1.8 Summary of the Subsequent Chapters

This research is organized in the following sections. The literature review on the acoustic analysis of stressed and unstressed syllables is presented in chapter 2. The methodology of Urdu speech corpus annotation at phoneme, word, syllable and stress level is detailed in chapter 3. In research methodology chapter, it is explained intensively by the researcher that how three hundred and thirty sentences have been recorded in 'mono' form at a sampling rate of 48 kHz in PRAAT software in an anechoic chamber. In this study, each syllable is distinctly assigned stressed or unstressed label after conducting the careful analysis of their vocalic properties in the spectrum and time wave form.

Result and data analysis of stressed and unstressed oral and nasal vowels are presented in chapter 4. Discussion on the mechanism of determining stressed and unstressed syllables of Urdu language is given in chapter 5 while findings and conclusion are discussed in chapter 6 and chapter 7 respectively.

2 Review of Literature

Before embarking on our journey towards determining the mechanism for Urdu stress using acoustic cues, it is crucial to know about the Urdu language.

2.1 Urdu Language

Urdu is the national language of Pakistan and spoken by 100 million people in all over the world. Urdu is phonetically similar to Hindi but it is different in alphabetical script and historical characteristics (Saleem, 2012). The pronunciation of Urdu varies with reference to geographical change in Pakistan (Saleem, 2012). Urdu is a Turkish word meaning "Camp or Army with its followers" and major languages participating in the camp of Urdu are Arabic, English, Persian and Portuguese (Saleem & Saksena, 2012).

2.1.1 Phonetic Inventory of Urdu

Urdu is a phonetically rich language with a large variety of vocalic sounds inventory (Raza, 2009). All sounds can be differentiated on the basis of duration, quality and nasalization (Raza, 2009). The number of consonants in Urdu varied in different researches. According to a research, Urdu has thirty six consonants (Hussain, 1997; Raza et al., 2009) whereas other studies indicate, there are forty-three (Qandeel et al., 2012; Saleem et al., 2002) or forty four consonants (Raza, 2009) in Urdu. The controversy in the number of consonants in Urdu is due to the aspirated consonants such as; aspirated nasals /mʰ/ and /nʰ/ aspirated lateral /lʱ/, aspirated flap /ɽʱ/ and aspirated trill /rʱ/ (Qandeel et al., 2012; Saleem et al., 2002) which are used rarely now a days. (See Table 1 for the chart of Urdu consonants).

Table 1: Consonants Chart of Urdu

	Bilabial	Labio-dental	Dental	Alveolar	Retro flex	Palatal	Velar	Uvular	Glottal
Stop	p b pʰ bʰ	t̪ d̪ t̪ʰ d̪ʰ			ʈ ɖ ʈʰ ɖʰ	ʧ ʤ ʧʰ ʤʰ	k g kʰ gʰ	Q	
Fricative		F		s z		ʃ ʒ		x ɣ	H
Nasal	M		N						
Lateral				l					
Flap				R	ɽ ɽʰ				
Glide		V				J			

2.1.2 Vowels

There are seven long oral and nasal vowels, three short oral and nasal vowels (Oxford Urdu English Dictionary, 2013; A. A. Raza, 2009) in Urdu language. Oxford Urdu English Dictionary has also reported three medial vowels in Urdu language.

2.1.2.1.1 Short Vowels

There are three short vowels in Urdu language i.e. /ɪ/, /ə/ and /ʊ/ (Oxford Urdu English Dictionary, 2013; Qandeel et al., 2012; Raza et al., 2009; Saleem et al., 2002; Hussain, 1997).

2.1.2.1.2 Medial Vowels

According to Oxford Urdu English Dictionary (2013), Urdu language also has three medial vowels i.e. /e/, /æ/ and /o/. The medial vowels are audible like long vowels but their duration is larger than short vowels and less than long vowels. Most of the time medial vowels are followed by /h/ or /ʔ/ sounds.

2.1.2.1.3 Long Vowels

In Urdu, there are seven long oral vowels i.e. /i:/,/e:/, /æ:/, /a:/,/ɔ:/, /o:/ and /u:/ (Oxford Urdu English Dictionary, 2013; Qandeel et al., 2012; Saleem et al., 2002).

2.1.2.1.4 Nasal vowels

Urdu language has also contrastive nasal vowels, equal in number to oral vowels i.e. /ĩ:/, /ẽ:/, /æ̃:/, /ã:/, /ɔ̃:/, /õ:/ and /ũ:/ (Oxford Urdu English Dictionary, 2013; Zahid S., 2010). Quadrilateral of Urdu oral and nasal vowels by A. A. Raza, 2009 is shown in Appendix A-2.

2.2 Stress

Stress, tone, and intonation are described as part of the prosody of a language. Prosodic features of speech are those that are not predictable from the intrinsic properties of the consonants and vowels. Trask (1996) defined stress as a certain "type of prominence" which in some languages is present upon certain syllables. He thinks that native speakers and phoneticians can easily determine which syllables bear stress, and even to distinguish varying degrees of stress, but the phonetic characterization of stress is exceedingly difficult. He associated stress with greater loudness, higher pitch and greater duration.

On contrary, Catford (1988) believed that it is unwise to talk of stress in terms of loudness, since it is a part of inherent sonority of sounds. He thought it is much more reliable to think of stress entirely in term of degrees of initiator power - the amount of energy expended in pumping air out of the lungs. For this, Catford defined stress as initiator power. If we compare the definitions of Task and Catford, it seems that Task (1996) is trying to portray the status of the syllable with stress while Catford's (1988) definition reflects on the process of stress production itself, he embodies what is involved while producing stress syllable.

In simple word, it can be said that lexical stress is related to syllable prominence within a word. The prominence of syllable can change the syntactic class of word. For example, in English the verb 'to permít' and the noun 'a pérmit' form a minimal pair, with the verb having stress on the second syllable and the noun having stress on the rest syllable. Similarly, in Urdu the verb الٹا (ʊl.ˊta) and the adjective a الٹا (ˊʊl.ta) form a minimal pair, with the verb having stress on the second syllable and the adjective having stress on the rest syllable.

Bolinger (1986) also analyzes the sentences in which words stand out and concludes the stressed syllable is the one that carries the potential for accent. In other words, a syllable may have lexical stress in the lexicon, but this abstract type of stress is only pronounced if the word has the accent, i.e. if the word is made to stand out in the sentence. This research would also focus on the accented stressed syllables in the spontaneous speech rather than the lexical stress found in dictionary.

2.3 Syllable or Syllabification

Syllabification is perquisite for stress marking. One cannot assign stress until he has clear idea about the syllable or syllabication. Though the word syllable came up a number of times, no definition was given yet. There are considerable theoretical difficulties in defining syllable. However, for discussing stress a notion of what a syllable is must be established. Apparently, syllable is a vowel surrounded by consonants. As this vowel is the centre of the syllable, we call it the nucleus but this vowel does not have to be surrounded by consonants all the times.

Roach (2002) thinks that syllable consists of three components: a beginning, a middle, and an end. The beginning is usually called onset, the middle is called nucleus and the end is called

"coda". However, it is not necessary for each syllable to have these three component at the same time. According to him, syllables are of four types:

1. A syllable consists of a nucleus. This type of syllables is also known as minimum syllable. Examples for this type of syllable in Urdu are as follows:
    a) "آ / a:"
    b) "آے /a:e:"
    c) "آو /a:o:"
    d) "آئی/ a:i:"
2. A syllable consists of onset and nucleus as in "جا / ʤa:, کھا/ kʰa:, and میں mæ̃:"
3. A syllable consists of nucleus and coda as in: " آم / a:m , اور ɔ:r, and آن a:n"
4. A syllable consists of onset, nucleus and coda as in "ہاتھ / ha:ʈʰ, رات ra:ʈ, and بات ba:ʈ"

2.3.1 Syllable Template in Urdu

A language can be syllabified using syllable template matching technique. As far as Urdu is concerned, it has eight syllables template scheme (Hussain, 2006) shown in Table 2.

Table 2: Template for Urdu Syllable

Sr. no.	Urdu Syllable Template
1	V
2	VC
3	VV
4	VVC
5	CV
6	CVC
7	CVV
8	CVVC

In many languages, the location of stress depends on the internal structure of the syllables in a word. These languages are said to have quantity-sensitive stress. Heavy syllables, which attract stress, are distinguished from light syllables, which do not. The specifics of which types of syllables are heavy and which are light vary from language to language, but generally, syllables with long vowels are heavy, and open syllables with short vowels are light. Closed syllables can be either heavy or light, depending on the language.

2.4 Review of Phonological Stress

Studying stress from a phonological perspective reveals that stress makes up the metrical organization of speech. According to Kager (1999), there are conflicting forces at work in lexical stress: rhythm, quantity-sensitivity, and edge-marking. Rhythm is the pressure toward a regularly alternating distribution of weak (unstressed) and strong (stressed) syllables. Quantity-sensitivity is the pressure to match syllable weight to prominence. Edge-marking is the pressure to mark the edges of morphemes. Languages that make linguistic use of stress can be divided into two categories: predictable lexical and unpredictable lexical stress.

2.4.1 Predictable and Unpredictable Stress in Languages

In some languages, stress merely distinguishes a word edge, in which case the position of the stressed syllable in a word is regular or predictable (Rietveld, 1980). In other languages, however, word stress may have a contrastive function, in which case primary stress is not fixed to a given position and different placement of stress within a word may result in a meaning difference (Jakobsen & Waugh 1979, Waugh & Burston 1990).

2.4.1.1 Predictable Stress Languages

Languages in which primary word stress serves a purely demarcative function will be labeled as 'predictable stress languages'. It means that in these languages primary word stress is regular and the position on which stress falls for a given word can be predicted based on phonological characteristics of the word alone (e.g., position of a syllable within the word, syllable weight). In the present study, French, Turkish and Arabic fall into this category.

2.4.1.2 Unpredictable Stress Languages

Languages in which stress is contrastive will be labeled as 'unpredictable stress languages' since primary stress is not fixed in one position. Depending on the word and the meaning associated with it, stress will surface on syllables in different positions of a given word. This is not to say that there is random stress placement in such languages, but rather that the phonological shape of the word is not the only factor determining the position of the stressed syllable, otherwise no word pairs contrasting only in stress would be possible.

2.4.1.3 Non-Stress Languages

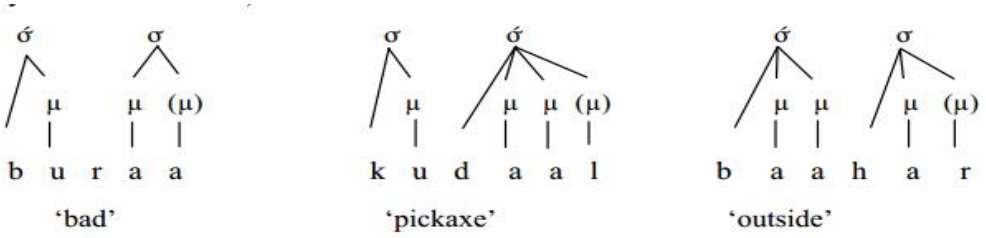
As opposed to languages with word-level stress as defined above, there is another class of languages where stress does not have either a demarcative or contrastive function on the word level. Instead, it is found that pitch which is one of the four acoustic correlates of stress mentioned in chapter 1 is used contrastively in these languages. There are two general subcategories among such languages: (a) tone languages (e.g., Chinese), where syllables within a word carry lexical tone (Gussenhoven, 2004), and (b) pitch-accent languages (e.g., Tokyo Japanese), where a pitch contour spans across the whole word and frequency features alone are responsible for signaling prominence (Beckman, 1986). This is not to say that such a language never expresses prominence on words in production, but rather that such prominence is not

assigned on the level of the lexical or phonological word. Instead, relative prominence may arise on certain prosodic constituents. Seoul Korean is the language that falls in to this category, since prominence in words is argued to be due to boundary tones from the accentual phrase or intonational phrase.

2.5 Hindi-Urdu Stress

Over the years, several accounts of Hindi-Urdu word stress have been published. Authors often agree on the location of stress in the words, although they may disagree about other issues, such as the way stress is manifested phonetically in Hindi-Urdu. Fairbanks (1981) studied the use of stress patterns in Hindi-Urdu verse. The literature strongly points that speakers have intuitions with respect to the location of stress in Hindi-Urdu words.

Generally, the location of word stress in Hindi-Urdu is predictable based on syllable weight. Probably the simplest account of stress placement in Hindi-Urdu comes from Hussain (1997). Based on the number of segments in the rhyme, Hindi-Urdu syllables can be classified as monomoraic or 'light' (V), bimoraic or 'heavy' (VV or VC), or trimoraic or 'superheavy' (VVC or VCC). Given these definitions, Hussain (1997) explains that the last heavy syllable is stressed, and if all syllables are light, the penultimate syllable is stressed. This account assumes a notion of extrametricality, which says the final mora of the word is invisible to the stress rule. Mohanan (1979) first used extrametricality for describing stress in Hindi, and this notion has since been used in several other descriptions. Some examples (μ=mora, σ = syllable, parentheses indicate extrametricality, stress indicated by acute accent mark) given by Mohanan are presented below:



Controversy surrounds the questions of whether word stress in Hindi-Urdu exists independently from intonation, and whether it is ever contrastive. The following is a summary of some of the ideas regarding these issues.

According to Trofimov (1923) and Jones (1927), 'the subject of stress is very closely connected with that of intonation. It is certain that much of the effect commonly ascribed to stress is really a matter of intonation.' Dixit (1963) discusses the relationship between stress and the 'rhythmic' properties of sentences. He says that Hindi is a highly rhythmic language. The arrangement of syllables in a word, of words in a phrase, and of phrases in a sentence gives a clue to the rhythmic pattern and to the placement of non-lexical stress on different levels. He also thinks that in a word only one syllable and in a phrase only one word gets prominent stress; all other syllables and words are evenly stressed. Stress on these levels is non-lexical and predictable. On the sentence level, 'sentence stress' or 'emphatic stress' plays a significant role.

Arun (1961) claims, 'stress is not as prominent in Hindi as in English. However, it is sometimes phonemic'. By 'sometimes' it is meant that in certain environments, a word may be stressed differently, leading to a few examples of words that contrast in stress only. Arun provides four examples, which he claims are 'distinguished only by means of stress.'

- /'ga: la / "throat"
- /ga: 'la:/ "melt something"

- /ˈgʰə taː/ "thick cloud"
- /gʰə ˈtaː/ "decrease something"

Mehrotra (1965) also thinks that stress plays a vital part in Hindi, although not as vital as in English, or Russian, or Greek. He states that there is not a single syllable that does not bear some degree of stress, but the weak stress has been considered to be 'no stress phoneme' and the heavy stress has been regarded as 'stress phoneme'. On the use of stress, he adds,

> Stress in Hindi is used mainly for 'emphasis' and for 'contrast.' It is found at the word level. A word may contain only one stress at some syllable of it at the most (and the rest of the syllables have no stresses), and it is not at all necessary that each word, or even any word in the whole sentence, should carry a stress. Sometimes only one word in a sentence is stressed.

Hussain (1997) uses the frame sentence / t̪ʊm neː ____ kəhaː / 'You said ____' in his study of Urdu stress correlates. He claims that (1997) 'within the target word, the syllable with lexical stress would attract the phrasal stress, making lexical stress more prominent.' Hussain (1997) lists the following as effects of stress:

- The results indicated a longer duration and lower F0 (due to the alignment of a low tone) for stressed vowels.
- In addition, high vowels got less intense and low vowels got more intense with stress. However, individual speaker data on intensity showed a lot of variation.
- In addition, the quality of the vowels changed with stress as unstressed vowels underwent more contextual assimilation than stressed vowels.

- Results from stops show that the closure, voicing during closure and aspiration of aspirated (and not voiceless and voiced) onset stops increased with stress.
- The closure of voiceless, voiced and breathy coda stops and voicing during closure of voiced coda stops also increased with stress.
- The duration of closure of aspirated coda stops decreased with stress.

2.6 Acoustic Cues of Stress

If stress is considered as prominence from a phonological point of view, how can it be seen acoustically? This is not an idle question: if one has to detect stressed and unstressed segments, first he/she needs to know about the acoustic cues of stress.

Cutler (2005) thinks that to find out a stressed or unstressed syllable, most of the researches have mainly focused on the acoustic characteristics of stressed versus unstressed syllables, and how listeners make use of acoustic cues to make judgments as regards the occurrence of stress. Most phoneticians agree that the three acoustic dimensions involved in the realization of stress are duration, fundamental frequency and intensity. These acoustic properties correspond to the perceptual phenomena of length, pitch, and loudness, respectively. Some phoneticians also include vowel quality as an additional dimension (Laver, 1994; Hayward, 2000). In general, stress is described as the display of prominence by the exaggeration of one or more of the phonetic parameters on certain syllables when contrasted with other (Laver, 1994). Hence, a syllable displaying such prominence can be said to have possibly longer duration, higher pitch, greater acoustic intensity, and more carefully articulated phones in contrast to unstressed syllables (Hayward, 2000).

However, some linguists make more specific claim as to which parameters play a larger role in the realization of stress. Ladefoged (2003) states it is likely to be some combination of pitch, length, and loudness, with the first two playing the greatest role.

De Jong et al. (1993) claim that stressed syllables have "more distinctive articulations," whereas unstressed syllables are "undershoot" due to greater coarticulatory overlap with their neighboring segments' gestures. This means that the influence of adjacent sounds on the unstressed syllable is larger than the influence on stressed syllables. It is as though stressed syllables are so strong they can "fight off" the influence of neighboring segments. Ewen and van der Hulst (2001) speak of duration, amplitude and pitch as phonetic exponents of stress, at least in Dutch and English. They think that stressed segments have a longer duration, higher amplitude and most likely, higher pitch.

2.6.1 Background of Studies Conducted to Find Out Stressed Syllables Using Acoustic Cues

Experiments have shown that the physical parameters of stress (i.e. F0, duration, and amplitude) contributed to the perception of stress. Some studies have suggested that F0 provides the most important cue (Fry, 1955, 1958; Lehiste, 1970; Gay, 1978a, 1978b; Ladd, 1996).

While other studies suggest that intensity and duration are significant cues. In Fry's 1955 study listeners were presented with noun and verb forms of words such as "subject, digest, permit" and asked whether they heard the stress on the first or second syllable. Results show that when a syllable was long and of high intensity it was perceived as strongly stressed and when it was short and of low intensity, it was perceived as weakly stressed. The results of Fry's 1958 study show that F0 differed from duration and intensity in that it tended to produce an 'all-or-none

effect'. He also stated that when intensity and duration were studied separately, duration was the overriding cue.

Lehiste mentioned that because vowels have different intrinsic intensities (Lehiste, 1970; Fry, 1979), intensity can only be regarded as a reliable cue to stress where two syllables are intrinsically identical and vowel quality remains constant as in PERvert vs. perVERT. There is a similar connection between vowel quality and fundamental frequency (F0) associated with it. If other factors are kept constant, then it can be observed that high /i/ and /u/ have higher intrinsic F0, and open vowels such as /a/ are associated with lower intrinsic F0. Lehiste (1996) research showed that F0 at the peak of the F0 contour averaged across five speakers was 183 Hz for /i/, 182 Hz for /u/, and 163 Hz for /a/. However, the effects of intrinsic F0 are probably compensated for perceptually by listeners (Silverman, 1984), and are unlikely to affect the importance of pitch as a cue to stress.

But Kochanski, Grabe and Rosner (2005) who carried out quantitative measurements of accented syllables in a large corpus of natural speech in the IViE project are contrary to widely held views in the intonational literature (mainly based on laboratory speech) that F0 is a major cue to prominence. The authors concluded that accent and prominence is marked by loudness and duration cues and that F0 plays a minor role. They state that none of their subjects used large excursions of F0 previously associated with prominence in the general literature, and loudness was a better predictor of prominence. Similarly, research on Ma'ay language confirms that duration is a most reliable accent cue: 88.9 percent of the syllables can be classified correctly on the basis of their raw duration only.

Ladd also concludes that duration, intensity and spectral properties, if properly measured, could be reliable indicators of stress in English. Gay (1978) after reviewing Fry's experiments in the light of his own investigations concludes that production differences in amplitude, fundamental frequency, and first and second formant frequencies between stressed and unstressed syllable pairs were preserved across fast and slow speaking rates. Vowel duration differences, however, were not so great for the faster speaking condition, and for two speakers vowel duration in the faster speaking rate was the same in stressed and unstressed pairs.

2.7 Influence of Stress on Consonants

So far, consonants did not enter the picture. Consonants are generally disregarded in the literature about stress. This may be because vowels are the most noticeable part of syllables, and they most strikingly carry acoustic information about stress. However, according to Dalen (2005) the stress property of all segments in a syllable should match. It means the consonant of the stressed syllable should also be stressed and consonants of unstressed syllable also should be unstressed.

2.8 Influences of Stress on Sounds/Phonemes

Mehrotra (1965) based on his observation, lists the following influences of stress on the sounds and sound-attributes of the language.

- Stress makes a vowel tense
- Stress causes some sounds to be longer than when they are in some unstressed syllables
- Stress may double a consonant, e.g. /kaṯ/ may be pronounced /kaṯṯ/
- Stress may introduce aspiration in an initial stop
- Contrarily, an unstressed syllable may show the loss of aspiration somewhere in it

- High and low vowels head towards the mid central vowel, if they are unstressed
- Some rise in pitch of the sounds may also be an effect of the stress
- Stress may also fall with increase in pitch

2.9 Prioritization of Order of Acoustic Cues in Different Languages for Identifying the Stress

Although lexical stress is characterized by differences in amplitude, duration, and F0, different languages may rely on sub-sets of these acoustic cues to mark stress. Thus, some languages base the distinction between their stressed and unstressed syllable more on F0 differences, other languages more on duration differences, others more on amplitude differences. Moreover, in some cases, the selection of one or more cues to detect stress may also vary according to other features of the languages phonological systems. In a tone language as Thai, for example, listeners perceive stress using duration alone (Potisuk, Gandour, & Harper, 1996), because F0 is used to realize tones.

In most cases, the language specific cues are not rule based. To illustrate, in Dutch, stress perception is driven by duration (Reinisch & McQueen, 2010; Sluijter & van Heuven, 1996) and amplitude (Sluijter & Heuven, 1996). In Spanish, listeners perceive stress exploiting F0 and duration or F0 and amplitude (Llisterri et al, 2003).

As for lexical stress in Italian, recent research has shown that Italian listeners use duration to detect stress (Alfano, 2006; Alfano et.al, 2009). Stressed vowels are longer than unstressed vowels and this difference indexes the stress position. As far as English is concern, Beckman (1986) found that total amplitude "seems to be an exceedingly robust criterion for stress in English". She contrasted Japanese and English and found that for Japanese pitch change was the

only cue to accent, while for English she found that other features hold a significant role, such as duration and amplitude.

2.10 Influence of Acoustic cues on the Position of Syllables

Acoustic cues to lexical stress are further complicated in relation to the location of the stressed syllable in a word. Specifically, previous studies have suggested that the relative contributions of intensity, f0, and duration vary depending on whether lexical stress is on the first syllable or second syllable of a word. Evidence for this finding is seen in studies that have compared lexical stress production between a non-native speaker and a native speaker (Lai & Sereno, 2008; Zuraiq & Sereno, 2009) and between disordered speech and normal speech (Walker et al, 2009). For example, in normal speech produced by healthy native American English speakers, a greater number of cues such as intensity, f0, and duration were utilized for marking the stressed first syllable of a noun, while only duration was used for the stressed second syllable of a verb [Lai & Sereno, 2008; Walker et. al, 2009]. On the other hand, Zuraiq et al (2009) reported that duration and amplitude, but not f0, were used to a greater degree when stress was on the first syllable rather than the second syllable.

2.11 Summary

This literature survey summarizes that to find out the stressed and unstressed syllables, one acoustic cue alone is not sufficient. However, combination of acoustic cues such as duration, intensity F0, and vowel quality need to be analyzed for the perception of lexical stress. In different languages order of prioritized acoustic cues for determining stressed syllables are also different. Moreover, on different position of syllables, acoustic cues of stress will behave

differently. It is also noticed that as compare to consonants, vowels are more influenced by the stress.

3 Methodology

This chapter gives a detailed description about the sampling size, selection of corpus and environment of recording sessions. It also elaborates how the speech corpus has been annotated at segment, word and syllable levels to determine the stressed and unstressed syllable and to develop a mechanism.

3.1 Speakers

Recording of speech corpora was obtained from three native female speakers (NT, SM, and WH) of Urdu. All the speakers had spent most of their lives in Lahore – the district where Punjabi is the mother tongue of most of the people. The age of the speakers range between 24 to 40 years, and all used Urdu language in their daily life. Two speakers (NT, SM) who were asked for recordings are the professional speakers and they were also paid for the recording.

3.2 Corpus

Data for recording has been taken from three different corpora for this study. Description of these three corpora is given below.

3.2.1 First Corpus

The text for the first corpus is selected from three different corpora, i.e. is 35 million words corpus, 1 million words corpus, and Urdu news corpus (Habib, 2014). Thirty five million words corpus is written in 882 different text files. These files do not only cover Urdu characters but also has coverage of English and Arabic characters, digits, URLs and special symbols.

One million words corpus has been collected from Urdu digest. The corpus from Urdu digest has been divided into two different basic categories: imaginative and informational. Imaginative

category consists of books reviews, short stories, and novels whereas Informational category deals with various domains such as culture, entertainment, health, press, religion, science and sports.

Urdu news corpus has been collected from Urdu Jang online. The online news is from the year 2005 and covers different sections from the news. These sections are business, editorials, news and sports. Greedy algorithm has been used to select sentences from these three corpora. Greedy algorithm uses following criterion to pick the sentences from the corpora;

Select a sentence which has:

- Maximum distinct units
- Maximum tokens of units such as unigram, bigram and trigram
- A small length

Using these criterions, two hundred sentences have been selected for this study from the first corpus (See Appendix C).

3.2.2 Second Corpus

The text for the second corpus has been selected from the Punjab textbook of class forth Urdu. Eighty sentences have been randomly extracted from this text for the recording (See Appendix D).

3.2.3 Third Corpus

The text for the third corpus has been selected from the phonetically rich short stories available at CLE websites. These short stories cover all the consonants and vowels of Urdu language. For this study, fifty sentences have been taken from these stories (See Appendix E).

The recording of first corpus is obtained from NT, second from WH, and third from SM respectively.

3.3 Recording

Sentences selected from three different corpora are recorded in the software 'Praat'. This speech is recorded in 'mono' form at a sampling rate of 48k Hz in an anechoic chamber. During recording, the microphone is positioned at the left side of the speakers at 45° to avoid direct air puffs. Speakers have never faced the microphone directly. Clip board is also used for placing the material to be recorded to avoid noise produced by paper swapping during the recording session. Recording of only twenty sentences is conducted in one session. This one session is subdivided into two batches, one batch has only ten sentences, and there is five minutes break between batches.

The silence period is ensured in the Praat recording window at the start and end of each sentence. Every batch is started with the following sentences to avoid the boundary effects i.e., low or high intensity, deletion of phonemes and non-speech sounds.

-ہے تاریخ----------ہے اور آج---------- میرا نام/ My name is _____. Today's date is _____.

The text is read in a natural reading style. Same range of f0 and level of intensity is maintained within a batch and across the batches. The speed of the reading is normal and consistent within a sentence and across the sentences. It is neither too fast nor too slow. Same distance from the mike is also maintained within a batch and across the batches. There are appropriate pauses after the punctuation marks i.e. comma, exclamation mark, question mark and full stop etc.

Each word is pronounced correctly according to its pronunciation in the dictionary. If a word is mispronounced in a sentence during recording, the recording is conducted again with the correct pronunciation.

3.4 Segmentation of Speech Corpus

Stress is always assigned at syllable level. Therefore, it is very necessary to annotate the speech corpus at syllable tier before assigning the stress. However, to annotate the speech corpus at syllable tier, it is crucial to know about the starting and ending boundaries of a word because syllables are always marked at word level. An annotator can recognize the precise boundaries of words only when he/she has the idea from where the phoneme in the spectrogram and wave signal starts and where it ends.

Therefore, speech corpus needs to be annotated at phoneme/segment, word and syllable levels before initiating the process of assigning the stress. Guidelines have been developed to annotate the speech corpus at multiple levels to ensure the quality of the data.

3.4.1 Guidelines for Marking the Segments

For the purpose of segment labeling, the Case Insensitive Speech Assessment Method Phonetic Alphabet (CISAMPA) is being used (see Appendix B). Since the IPA symbols are difficult to use in PRAAT, symbols in the Speech Assessment Method Phonetic Alphabet (SAMPA) are matched to the IPA symbols and used for labeling.

Silence is marked in the start and end of the sentence. Each consonant and vowel is distinctly marked in the TextGrid file. A sample text Grid file is given Appendix A-3.

The guidelines presented by Mumtaz (2014) have been used for marking the boundaries of the segments. These guidelines are as follows:

1. Mark each label carefully after analyzing the wave form and the spectrum of the sound. If a sound is not visible it should not be marked.
2. Each point should be marked at the zero crossing line going from negative to positive value.
3. While splitting a vowel + consonant sound, the boundary of the consonant should be marked where the personality of the vowel disappears. (This is done by zoomed in view of the time wave form.)
4. If a few periods of the wave form are creating ambiguity in determining the personality of the vowel then the periods having mixed properties (both of the consonant and the vowel) should be included in the vowel.
5. While splitting the vowel and vowel junction, the periods with mixed properties of both vowels should be divided into equal halves.
6. In case of gemination across the words or within the word, sounds should be divided in the middle and mark as two distinct sounds.
7. In case of geminated stops and affricates, closure period of stops and affricates should be divided into equal halves.
8. In case of consonant clusters within or across the words, the periods with mixed properties of both consonants should be divided into equal halves and mark as two distinct sounds.

9. If a sentence or phrase is starting with the voiceless stop or affricate (there should be silence before the word), the closure duration of the onset voiceless stop should be 100 ms for the stressed and 87 ms for the unstressed (Hussain, 1997).
10. If a sentence or phrase is ending with a voiceless stop, (there should be silence after the word) and the burst of the stop is not visible, the closure duration of the coda voiceless stop should be taken 77 ms for the stressed syllable and 73 ms for the unstressed syllable (Hussain, 1997).
11. If a sentence starts with a glottalization, it should be added to the following vowel.
12. If the behavior of a phoneme is different in two different contexts or due to the effect of natural speech fluency, it should be labeled according to the standard label for that sound.
13. The voicing at the end of the vowel should be completely included in the sound, only when the vowel is followed by silence, pause or breath. This is done by zoomed in view of the time wave form. If the voicing of the vowel has started to merge with the amplitude of the silence, it should not be included.
14. A vowel should be labeled as a nasal vowel only if it is contrastively nasalized, if a vowel is contextually nasalized, it is labeled as an oral vowel.

3.4.2 Word Boundary Segmentation

Annotation at word level is done in two stages. Firstly, the researcher listened and observed the spectrogram of the wave file very carefully to find out that all the words in the file are pronounced properly. In case of mispronunciation/misreading, insertion of extra phoneme in a word or deletion of required phoneme from the word, the wave file is rejected and recorded again. In the second stage, the word boundaries of correctly pronounced words are marked manually. These boundaries are completely aligned with the boundaries of the segments.

Since the boundaries of words in Urdu language cannot always be identified on the basis of space, it becomes very difficult to determine where the word boundary mark should be placed, especially in the case of compound words. For example it is challenging to decide that the word خوش شکل (Xʊʃ ʃəkəl\good looking) should be marked as one word or two. Therefore, the principles developed to annotate the Urdu speech corpus at word level have been used (Mumtaz, 2014) to mark the boundaries between compound words.

3.4.3 Syllable Segmentation

Syllable tier is also marked manually using the algorithm for syllabification presented by Hussain (2007). The algorithm for the syllabification is as follows:

I. Convert the input phoneme string to consonant and vowel string
II. Start from the end of the word (i.e., right to left)
III. Traverse backwards to find the next vowel
IV. If there is a consonant before a vowel than mark a syllable boundary before the consonant
V. Else mark the syllable boundary before this vowel
VI. Repeat from step (iii) until the phonemic string is consumed completely.

3.5 Mechanism for segmenting the Corpus at Stress Level

To initiate the process of stress marking, researcher has developed tentative guidelines for stress marking after surveying the literature. These tentative guidelines are as follows:

3.5.1 Tentative Mechanism/Guidelines for Urdu Stress Marking

Stress in a syllable can be determined using following four acoustic cues:

1. Duration of a vowel
2. Fundamental frequency/pitch
3. Intensity of a vowel
4. Vowel quality (Fry, 2004)

Preference should be given to the syllable that meets all the cues or the maximum number of cues, if any such syllable is not found it should meet at least one cue.

3.5.1.1 Duration of a Vowel

Duration is the most reliable cue to find out the stressed syllable (Shen, 2013). The vowel of a stressed syllable has more duration than the duration of the same vowel in an unstressed syllable. While comparing the duration of vowels, position of syllable must always be kept in mind because final syllables are significantly longer than penultimate syllables in the words (Ramijsen, 2002).

To find out whether a penultimate syllable is stressed or not, compare the vowel duration with that of the other same shortest vowels in the file under process. If same vowel is not present in the file, the vowel duration can also be compared with the similar vowel in the same file. If there is no similar vowel compare it with any other vowels in the file but do not compare a penultimate syllable with a final syllable or vice versa.

3.5.1.2 Fundamental Frequency/F0

F0 always align with the accented syllable (Hussain, 1997). An accented syllable will have a lower or higher F0 than the unaccented syllable.

Higher F0 contour is very helpful in finding out the accented syllable. According to a research, if the H tone is accented, the falling slope between this H* and the following L would be sharp,

steep and consistent whereas if the H tone is unaccented, the falling slope between this H and the following L would be gradual (Jun, 2002).

3.5.1.3 Intensity of a Vowel

Intensity of a vowel may also be considered as an indicator of stress. Intensity of an accented penultimate syllable will be on average 3dB more than unaccented penultimate syllable whereas intensity of an accented final syllable will be on average 10dB more than unaccented final syllable (Ramijsen, 2002).

To find out whether a penultimate syllable is accented or not, compare the vowel intensity with that of the other same shortest vowels in the file under process. If same vowel is not present in the file, the vowel intensity can also be compared with the similar vowel in the same file. If there is no similar vowel compare it with any other vowels in the file. Do not compare the intensity of a penultimate syllable with the intensity of a final syllable or vice versa.

3.5.1.4 Vowel Quality

Vowels quality also changes with the stress. The distance (in HZ) between F1 and F2 is more for stressed syllable than an unstressed syllable. On average, the distances between stressed and unstressed vowel is 85Hz (Hussain, 1997).

3.5.1.5 How to Mark Stress in a Textgrid File?

Once the accented syllable has been identified, assign number 1 to stressed syllable and number 0 to unstressed syllable.

After finalizing the tentative guidelines, the researcher has assigned stress to 180 sentences. Researcher knew that stress increases the duration and intensity of a vowel but to what extent an

Urdu oral or nasal vowel can increase its duration and intensity at various position of syllable was still an unexplored dimension for her.

Therefore, while assigning stress to 180 sentences, researcher was depended mostly on her perception. To check the reliability of 180 sentences, researcher has requested another expert linguist (who was working in a research center as a senior researcher since 2010) to mark the same 180 sentences independently using her perception. The detail of mismatch result between the stressed and unstressed syllable between two annotators is shown in chapter 4 (See section 4.1.1, Table 3).

The result shows 30% inconsistency among the annotators. Therefore, both the researcher and the linguistics sit together to revise and analyze the thirty percent mismatched syllables. Based on the results of analysis, mechanism for stress marking has been revised again by the researcher. The results obtained after the analysis of the duration, intensity and vowel quality of stressed and unstressed syllables are given in session 4.3, 4.4 and 4.5 respectively.

3.5.2 Mechanism/Guidelines for Stress Marking

For marking stress, assign number '1' to a stressed syllable, number '0' to an unstressed syllable and '?' to an ambiguous syllable as shown in Figure 1.

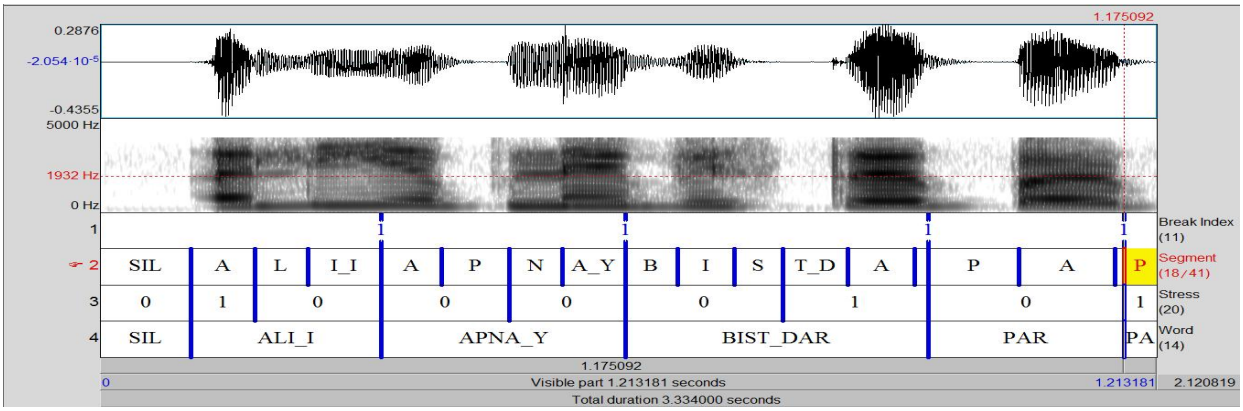


Figure 1: Numbering used for stress marking

Following points must be considered before initiating the process of annotating the stress tier:

- *Start from left to right to mark stress tier.*
- *While listening to the file for the stress marking, take sub phrases ending in pauses or glottalization.*
- *Stress is always assigned at syllable level.*
- *It might be possible that no syllable in a word carries stress.*
- *In a multisyllabic word, more than one syllable can carry stress.*

Several cues can be used to mark stressed and unstressed syllables such as duration, intensity, glottalization and pitch track of a vowel. In order to maintain quality and consistency of stress tier, a stepwise process has been formulated. In this step wise process, the order of cues used for stress marking has been prioritized after using the theoretical knowledge acquired from the literature survey and practically implementing that knowledge on the Urdu data. The stepwise process used for annotating stress tier is discussed below:

1. Duration of a vowel
2. Stylized pitch track of a vowel

3. Glottalization
4. Intensity of a vowel

3.5.2.1 Duration of a Vowel

The first cue that should be used to annotate stress tier is the duration of a vowel. The vowel of a stressed/accented syllable has more duration than the duration of the same vowel in an unstressed syllable. While comparing the duration of vowels, vowels should be categorized in the following four categories:

I. Short vowels
II. High long vowels
III. Low long vowels
IV. Medial vowels

After categorizing the vowel, position of a vowel in a syllable should be analyzed. A vowel can occur at three positions which are as follows:

I. Penultimate position of a syllable
II. Final position of a syllable
III. Final position of a syllable with pause

After categorizing the vowel and analyzing its position, the process of stress marking using durational cues should initiate. While conducting durational analysis, two methods can be used in parallel which are as followed:

I. Compare the duration of the target vowel with the duration of the same shortest vowel

II. Compare the duration of the target vowel with the duration of the similar shortest vowel

The first method would be used as a first step to initiate the process of stress marking. Following steps would be used in this stage.

I. Compare the duration of the target vowel with the duration of the same shortest vowel in the file under process. For example, compare A_Y duration with smallest A_Y in the file.

II. Two points must be consider while selecting a shortest vowel:

- Do not select a vowel which comes at the "final syllable with PAU" position
- The duration of the shortest same vowel for the short and long vowels should be less than 57ms and 100ms respectively.

III. If the duration of targeted vowel is more than its stressed duration (see Appendix F for the values of stressed and unstressed vowel duration), assign number '1' to the targeted syllable but if the duration of targeted vowel is less than its stressed duration, assign number '0' to the targeted syllable.

If the same vowel is not present in the file, use the second method of comparing similar vowels. Following steps would be used in this stage.

I. While comparing similar vowels, first compare front vowels with back vowels and back vowels with front vowels (i.e. A_A with A_E) in the same file. If such vowels are not present in the file, then compare front vowels with front vowels or vice versa.

II. The duration of the shortest similar vowel for the short and long vowels should be less than 57ms and 100ms respectively.

III. If the duration of targeted vowel is more than its stressed increased duration (see Appendix F for the values of stressed and unstressed increased vowel duration), assign number '1' to the targeted syllable but if the duration of targeted vowel is less than its stressed increased duration, assign number '0' to the targeted syllable.

IV. If the pause is less than 20ms, it will not be considered as a "final position of a syllable with PAU"; rather it would be considered as final position syllable.

Do not use duration as a cue, if there is no similar vowel in a file for durational analysis.

3.5.2.2 Stylized Pitch Track of the Vowel

In case the duration of the vowel does not give any cue about the stress, then check the stylized pitch track of the vowel. Use the following steps to find out the stressed syllable.

I. Stylize the wave file of a sentence using PRAAT software.

II. After stylizing the sentence, select the targeted vowel from the textgrid file.

III. Consider only the pitch point of stylize pitch which comes within the middle of a vowel.

IV. If there is no pitch point in the middle of a vowel, then select the point which comes in the beginning of a vowel.

V. Zoom out a sentence completely to analysis the pitch contour of a vowel.

VI. After zooming out the pitch contour completely, two types of pitch contour can be found: High pitch contour and low pitch contour. Higher F0 contour is

very helpful in finding out the stressed syllable. If the H tone is stressed, falling slope between this H* and the following L would be sharp, steep and consistent whereas if the H tone is unstressed, the falling slope between this H and the following L would be gradual and flat. Lower F0 contour is also useful in finding out the accented syllable. Similar to H* contour, if the L tone is stressed, the rising slope between this L* and the following H would be sharp and steep whereas if the L tone is unstressed, the rising slope between this L and the following H would be gradual.

VII. Assign number '1', if the pitch track (both in the high to low and low to high contexts) is steep and abrupt. Assign number '0', if the pitch track (both in the high to low and low to high contexts) is gradual and flat.

VIII. Do not use lower F0 contour cue at final syllable position with PAU.

IX. Do not use pitch track as a cue, if the pitch track of a vowel has no pitch point or more than two pitch points.

3.5.2.3 Glottalization

When pitch analysis does not help in determining where to mark stress, then use glottalization as a cue to find out stressed syllable. An accented syllable is glottalised at phrase initial position. Assign '1' to the context where the word initial syllable has strong glottalization (See Appendix A-4). If the syllable has weak glottalization as shown in Appendix A-5 or no glottalization, then moves towards the next cue, which is intensity.

3.5.2.4 Intensity of a Vowel

Compare the vowel intensity with that of the other same shortest vowels in the file under process. While selecting the shortest vowel, following points must be considered:

I. The duration of the shortest vowel for the short vowels should be less than 57ms.

II. The duration of the shortest vowel for the long vowel should be less than100ms.

Using this mechanism, 150 new sentences were assigned stress by the researcher. To assess the reliability of this mechanism, another experienced linguist has been asked to annotate the same 150 new sentences independently using the process described in the guidelines. The result of mismatches between the stressed and unstressed syllables' identification after developing the mechanism is given in section 4.1.2.

4 Results

Mismatches in the identification of stressed and unstressed syllables before and after developing the mechanism have been investigated. Based on the analysis of the mismatches, a mechanism for marking stressed and unstressed syllables has been developed. According to the mechanism, the most helpful cue for determining the stressed and unstressed syllables is duration, followed by the stylized pitch, glottalization, and intensity respectively. Effects of stress on the duration, intensity, vowel quality and pitch have also explored on all the oral and nasal vowels of Urdu language.

The data from the annotated corpus was entered into a MS Excel spreadsheet and was collated. The duration, intensity and vowel quality cues were analyzed using quantitative methods while glottalization and stylize pitch contour were analyzed qualitatively.

4.1 Inter-Annotator Mismatches between Stressed and Unstressed Syllables' Identification

Before developing a mechanism, it is necessary to know the percentage of inconsistency between the annotators in identifying the stressed and unstressed syllables.

4.1.1 Mismatches before Determining the Mechanism for Stress identification

Table 3: Mismatches before mechanism

	Number of Marked Syllables	Inter-annotator mismatch between stressed and unstressed syllables	Percentage of Inter-annotator Mismatch between stressed and unstressed syllables
First Corpus	852	258	30.2%
Second Corpus	773	237	30.6%
Third Corpus	746	229	30.6%
Mean			30.4%

Table 3 indicates that the total number of syllables in first, second and third corpora were 852, 773, and 746 respectively. On average there is 30% inconsistency between annotators in identifying the status of syllables (0, 1) which indicates that thirty percent syllables were assigned different markers (0, 1) by two annotators in first, second and third corpus.

4.1.2 Mismatches after Determining the Mechanism for Stress identification

Table 4: Mismatches after mechanism

	Number of Marked Syllables	Inter-annotator mismatch between stressed and unstressed syllables	Percentage of Inter-annotator mismatch between stressed and unstressed syllables
Corpus 1	200	10	5%
Corpus 2	100	11	11%
Corpus 3	25	6	24%
Mean			13%

Table 4 indicates that the total number of syllables in first, second and third corpora were 200, 100, and 25 respectively. On average there is only13% inconsistency between annotators after developing the mechanism which clearly indicates that on average 87% syllables were assigned the same markers by the two annotators independently in first, second and third corpus after developing the mechanism.

4.2 Significance of Acoustic Cues in Determining the Stressed and Unstressed Syllable of Urdu Language

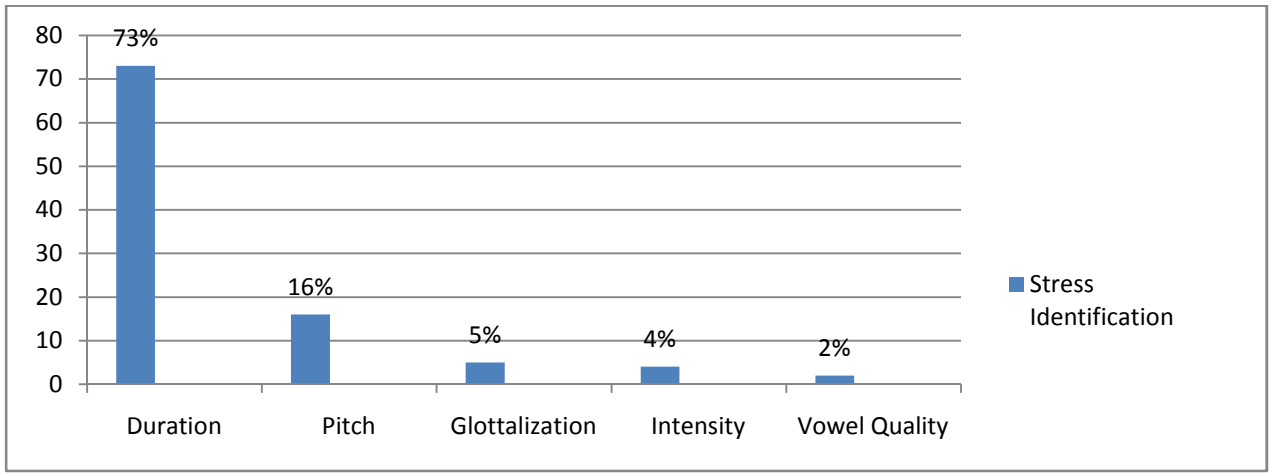


Figure 2: Acoustic Cues prioritization

Figure 2 indicates that the duration of a vowel is the most helpful cue in determining the stressed syllables whereas intensity and vowel quality are the least helpful cues in determining the stressed syllables. Seventy three percent data is assigned stress using durational values (see Appendix F) of stressed and unstressed vowels. Sixteen percent data is assigned stress using stylized pitch as a cue, 5% data is assigned stress using glottalization cue, 4% data is assigned stress using intensity cue and only 2% data is assigned stress using vowel quality as a cue.

4.3 Duration of Vowel

Vowels in stressed syllables are longer in duration than the same vowels in unstressed syllable. For durational analysis, short vowels /ɪ/, /ĩ/,/ʊ/, /ʊ̃/, /ə/, /ə̃/, medial vowels /e/, /æ/, /o/, long vowels /i:/, /ĩ:/, /u:/, /ũ:/, /e:/, /ẽ:/, /ɔ:/, /ɔ:/, /o:/, /õ:/, /æ:/, /æ̃:/, /ɑ:/ /ɑ̃:/ are represented by CISAMPA symbols /A/, /A_N/, /U/, /U_N/, /I/, /I_N/, /A_Y_H/, A_E_H/, /O_O_H/, /I_I/, /I_I_N/, /U_U/, /U_U_N/, /A_Y/, /A_Y_N/, /A_A/, /A_A_N/respectively.

4.3.1 Duration of Oral and Nasal Short Vowels

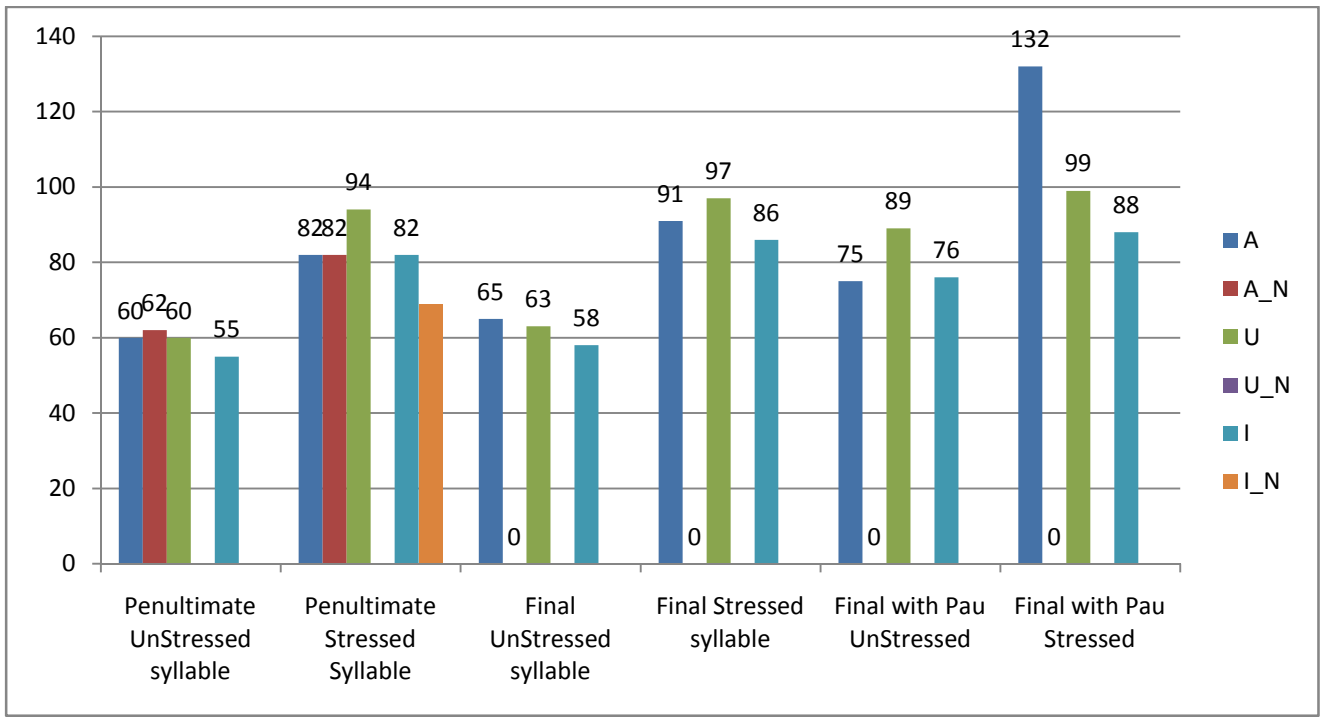


Figure 3: Mean duration of stressed and unstressed oral and nasal short vowels in ms over all speakers

The average duration of stressed and unstressed short oral and nasal vowels is presented in figure 3. These stressed and unstressed short vowels are analyzed at three positions of syllable: penultimate syllable, word final syllable and word final with pause syllable. Average duration for unstressed /A/, /I/ and /U/ at penultimate syllable position was 60ms, 55ms and 60ms respectively whereas the average duration for stressed /A/ at penultimate syllable position was 82ms and for stressed /U/and /I/ it was 94ms and 82 respectively. Average duration for unstressed /A/, /I/ and /U/ at final syllable position was 65ms, 58ms and 63ms respectively whereas the average duration for stressed /A/, /I/ and /U/ at final syllable position was 91ms, 86ms and 97ms respectively. Average duration for unstressed /A/, /I/ and /U/ at final syllable with pause position was 75ms, 76ms and 89ms respectively whereas the average duration for

stressed /A/, /I/ and /U/ at final syllable with pause position was 132ms, 88ms and 99ms respectively. As far as nasal short vowels are concerned, only the instance of /A_N/ vowel at penultimate position is found. The average duration for unstressed /A_N/ at penultimate position of syllable was 62ms and for stressed /A_N / it was 82ms.

The mean difference between the stressed and unstressed short vowels at penultimate syllable position and at final syllable with pause position was 26ms whereas at final syllable position it was 30ms.

4.3.2 Duration of Long Low Vowels

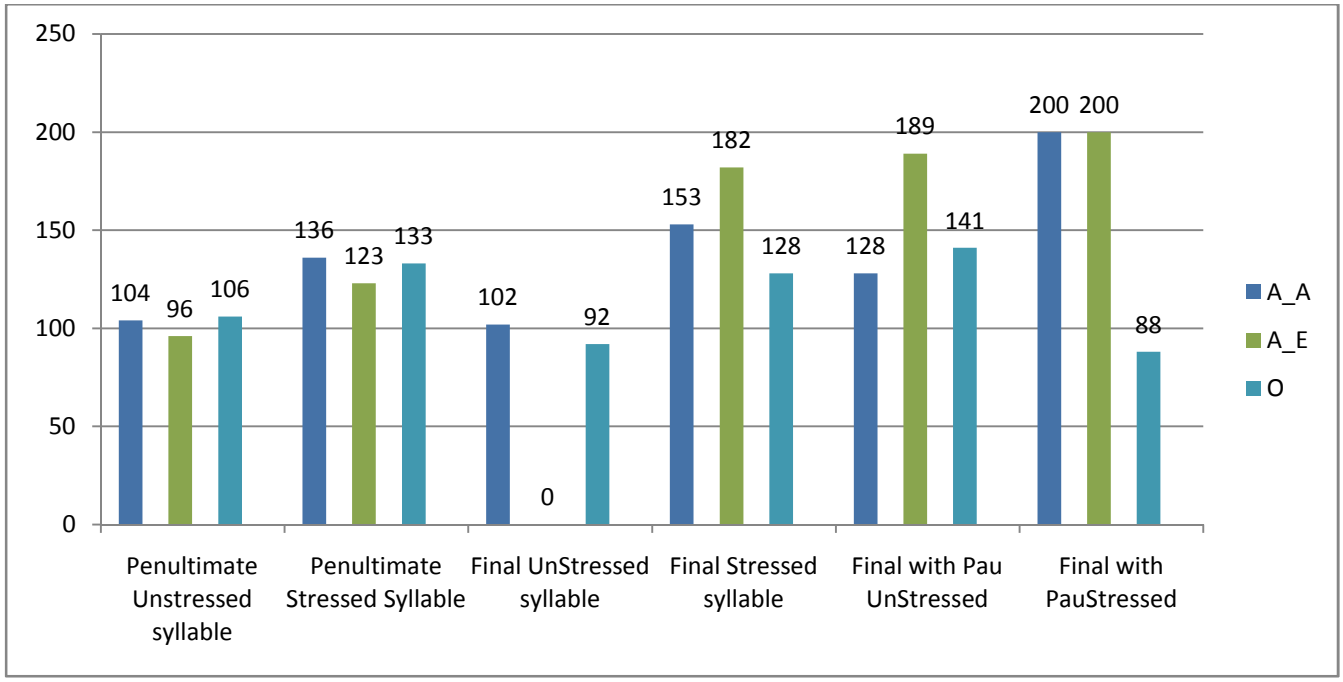


Figure 4: Mean duration of stressed and unstressed long low vowels in ms over all speakers

Figure 4 presents the average duration of stressed and unstressed long low vowels. These stressed and unstressed long low vowels are also analyzed at three positions of syllable. Average duration for unstressed /A_A/, /A_E/, /O/ at penultimate syllable position was 104ms, 96ms and

106ms respectively whereas the average duration for stressed /A_A/, /A_E/, /O/ at penultimate syllable position was 136ms, 123ms and 133ms respectively. Mean duration for unstressed /A_A/, /O/ at final syllable position was 102ms and 92ms respectively whereas the mean duration for stressed /A_A/, /A_E/, /O/ at final syllable position was 153ms, 182ms and 128ms respectively. Average duration for unstressed /A_A/, /A_E/, /O/ at final syllable with pause position was 128ms, 200ms and 141ms respectively whereas the average duration for stressed /A_A/ and /A_E/ at final syllable with pause position was 200ms and for /O/ it was 88ms.

The mean difference between the stressed and unstressed long low vowels at penultimate syllable position was 29ms, at final syllable position it was 43ms and at final syllable with pause position it was 10ms.

4.3.3 Duration of Nasal Long Low Vowels

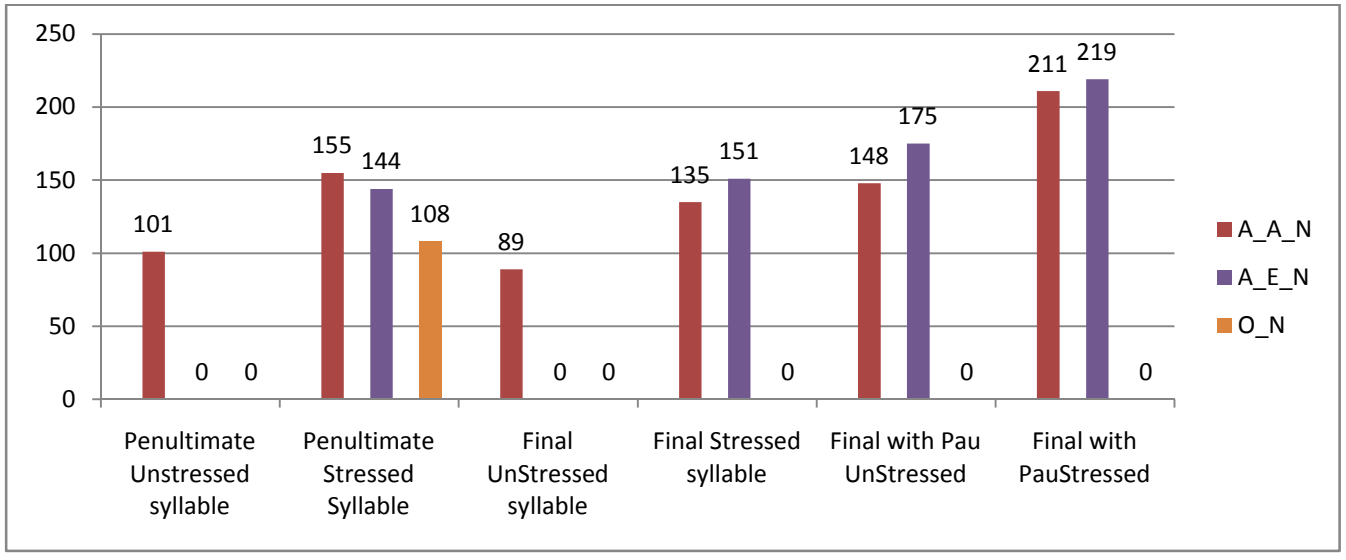


Figure 5: Mean duration of stressed and unstressed nasalize long low vowels in ms over all speakers

Figure 5 describes the average duration of stressed and unstressed nasal long low vowels. These stressed and unstressed nasal long low vowels are also investigated at three positions of syllable. Average duration for unstressed /A_A_N/ at penultimate syllable position was 101ms whereas the average duration for stressed /A_A_N/, /A_E_N/, /O_N/ at penultimate syllable position was 155ms, 144ms and 108ms respectively. No instance of unstressed /A_E_N/and /O_N/ vowels at penultimate syllable position was found in the annotated corpus. Average duration for unstressed /A_A_N/ at final syllable position was 89ms whereas the average duration for stressed /A_A_N/, /A_E_N/ at final syllable position was 135ms and 151ms respectively. Average duration for unstressed /A_A_N/, /A_E_N / at final syllable with pause position was 148ms and 175ms respectively whereas the average duration for stressed /A_A_N/, /A_E_N / at final syllable with pause position was 221ms and 219ms respectively.

The mean difference between the stressed and unstressed nasal low long vowels at penultimate syllable position and at final syllable with pause position was 54ms whereas at final syllable position it was 46ms.

4.3.4 Duration of Long High Vowels

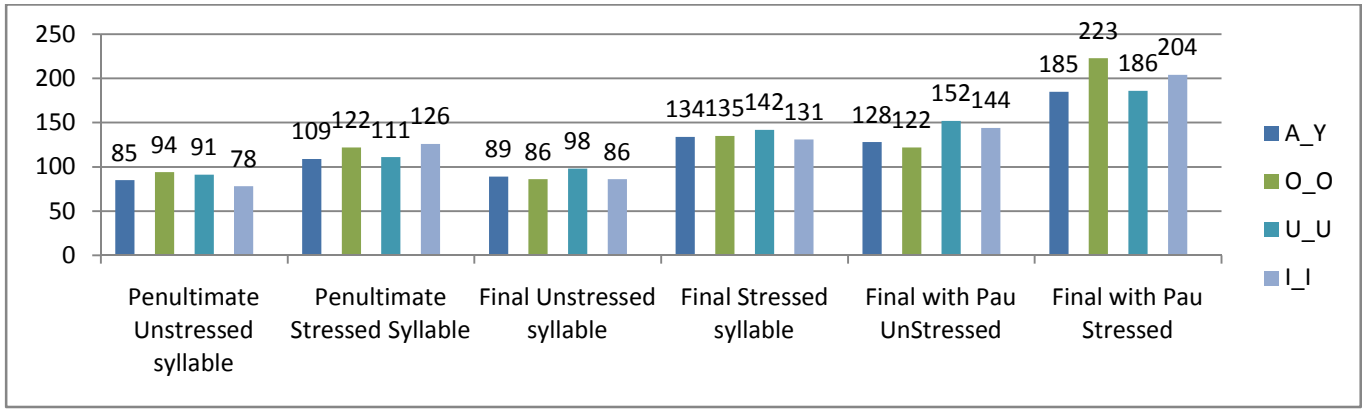


Figure 6: Mean duration of stressed and unstressed long high vowels in ms over all speakers

The average durations of stressed and unstressed long high vowels are shown in Figure 6. These stressed and unstressed long high vowels are observed at three positions of syllable. Average duration for unstressed /A_Y/ and /I_I/ at penultimate syllable position was 85ms whereas for /O_O/ and /U_U/ it was 94ms and 91ms respectively. The average duration for stressed /A_Y/, /O_O/, /U_U/ and /I_I/ at penultimate syllable position was 109ms, 122ms, 111ms and 126ms respectively. Average duration for unstressed /A_Y/, /O_O/, /U_U/ and /I_I/ at final syllable position was 89ms, 86ms, 98ms, 90ms respectively whereas the average duration for stressed /A_Y/, /O_O/, /U_U/ and /I_I/ at final syllable position was 134ms, 135ms, 142ms and 124ms respectively. Average duration for unstressed /A_Y/, /O_O/, /U_U/ and /I_I/ at final syllable with pause position was 128ms, 122ms, 152ms and 167ms respectively whereas the average duration for stressed /A_Y/, /O_O/, /U_U/ and /I_I/ at final syllable with pause position was 185ms, 223ms, 186ms and 202ms respectively.

The mean difference between the stressed and unstressed high long vowels at penultimate syllable position was 28ms, at final syllable position it was 43ms and at final syllable with pause position it was 57ms.

4.3.5 Duration of Nasal Long High Vowels

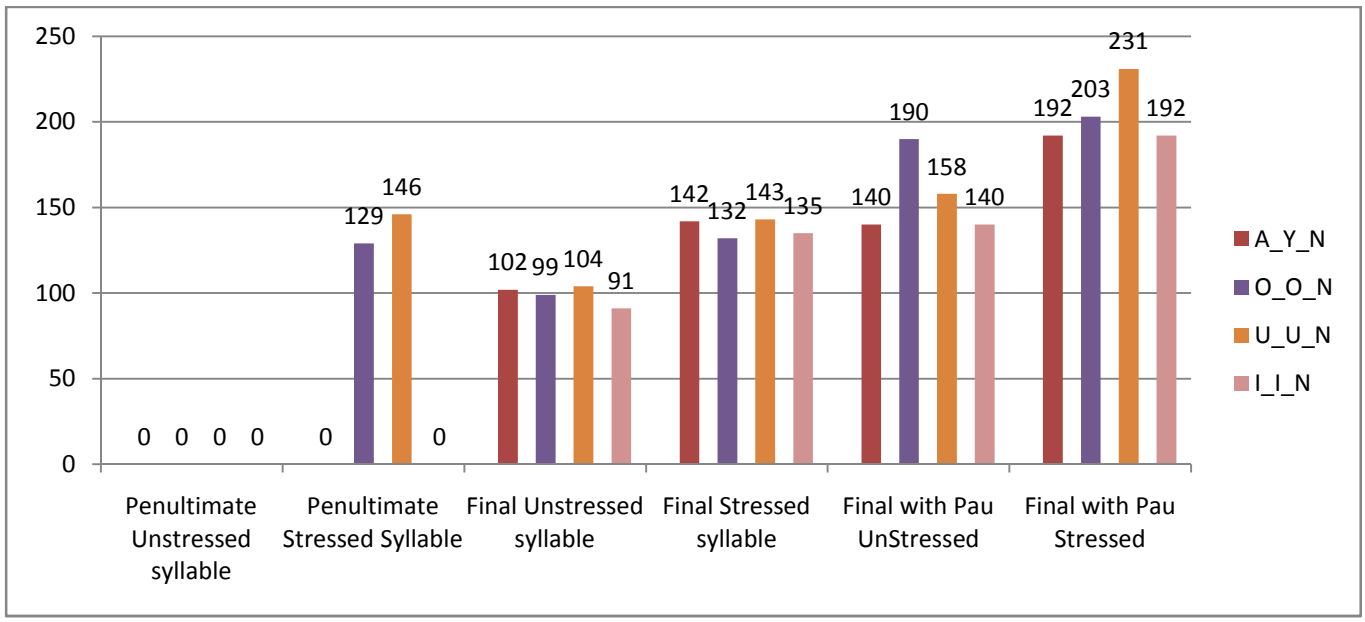


Figure 7: Mean duration of stressed and unstressed nasalize long high vowels in ms over all speakers

The average durations of stressed and unstressed nasal long high vowels are shown in Figure 7. These stressed and unstressed long low vowels are observed at three positions of syllable. The average duration for stressed /O_O_N/ and /U_U_N/ at penultimate syllable position was 129ms and 146ms respectively whereas the average duration for unstressed /A_Y_N/, /O_O_N/, /U_U_N/ and /I_I_N/ at penultimate syllable position was unavailable in the annotated corpus. Average duration for unstressed /A_Y_N/, /O_O_N/, /U_U_N/ and /I_I_N/ at final syllable position was 93ms, 99ms, 104ms, 95ms respectively whereas the average duration for stressed /A_Y_N/, /O_O_N/, /U_U_N/ and /I_I_N/ at final syllable position was 135ms, 132ms, 143ms and 135ms respectively. Average duration for unstressed /A_Y_N/, /O_O_N/, /U_U_N/ and /I_I_N/ at final syllable with pause position was 140ms, 190ms, 158ms and 140ms respectively

whereas the average duration for stressed /A_Y_N/, /O_O_N/, /U_U_N/ and /I_I_N/ at final syllable with pause position was 192ms, 203ms, 231ms and 196ms respectively.

The mean difference between the stressed and unstressed nasal high long vowels at final syllable position was 39ms and at final syllable with pause position, it was 49ms.

4.3.6 Duration of Medial Vowels

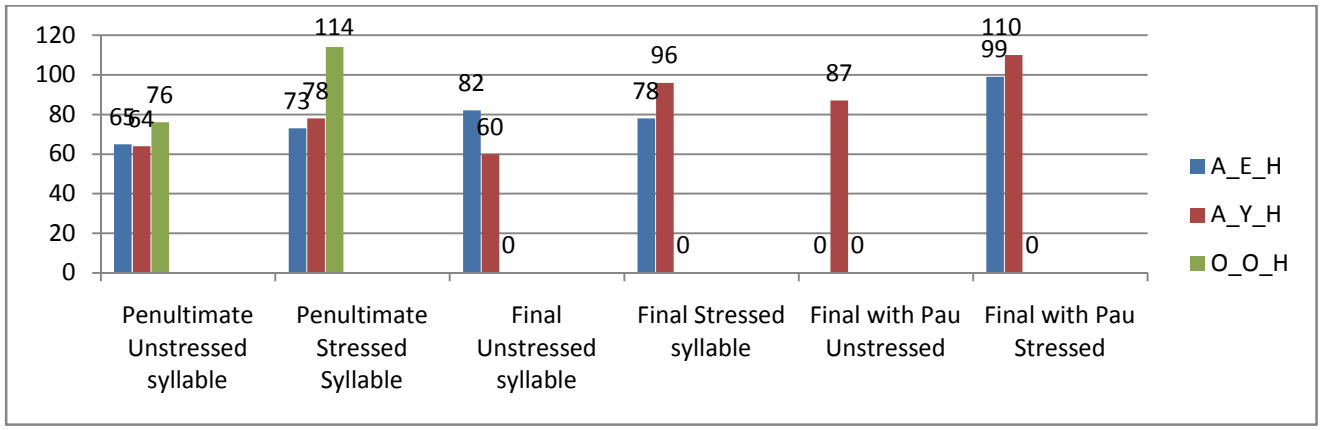


Figure 8: Mean duration of stressed and unstressed medial vowels in ms over all speakers

Figure 8 explicates the average duration of stressed and unstressed medial vowels. These stressed and unstressed medial vowels are also explored at three positions of syllable. Average duration for unstressed /A_E_H/, /A_Y_H/ and /O_O_H/ at penultimate syllable position was 65ms, 64ms and 76ms respectively whereas the average duration for stressed /A_E_H/, /A_Y_H/ and /O_O_H/ at penultimate syllable position was 73ms, 78ms and 114ms respectively. Average duration for unstressed /A_E_H/ and /A_Y_H/ at final syllable position was 82ms and 60ms whereas the average duration for stressed /A_E_H/ and /A_Y_H/ at final syllable position was 78ms and 96ms respectively. Average duration for unstressed /A_Y_H/ at final syllable with

pause position was 87ms whereas the average duration for stressed /A_E_H/ and /A_Y_H/ at final syllable with pause position was 99ms and 110ms respectively.

The mean difference between the stressed and unstressed medial vowels at penultimate syllable position was 20ms, at final syllable position it was 16ms and at final syllable with pause position it was 23ms.

4.4 Intensity Results

As explained in chapter 3, though speakers are instructed to maintain same level of intensity within a recording session and across the recording sessions, no firm measure was taken to control the intensity variation. Literature survey indicates that stress increases the intensity of vowels but data analysis of stressed and unstressed vowels of Urdu indicates that change in intensity is vowel dependent. Intensity of few vowels increases with stress, whereas few vowels' intensity decreases with stress. It is also noticed few vowels do not show any change in intensity with stress.

4.4.1 Intensity of Short Vowels

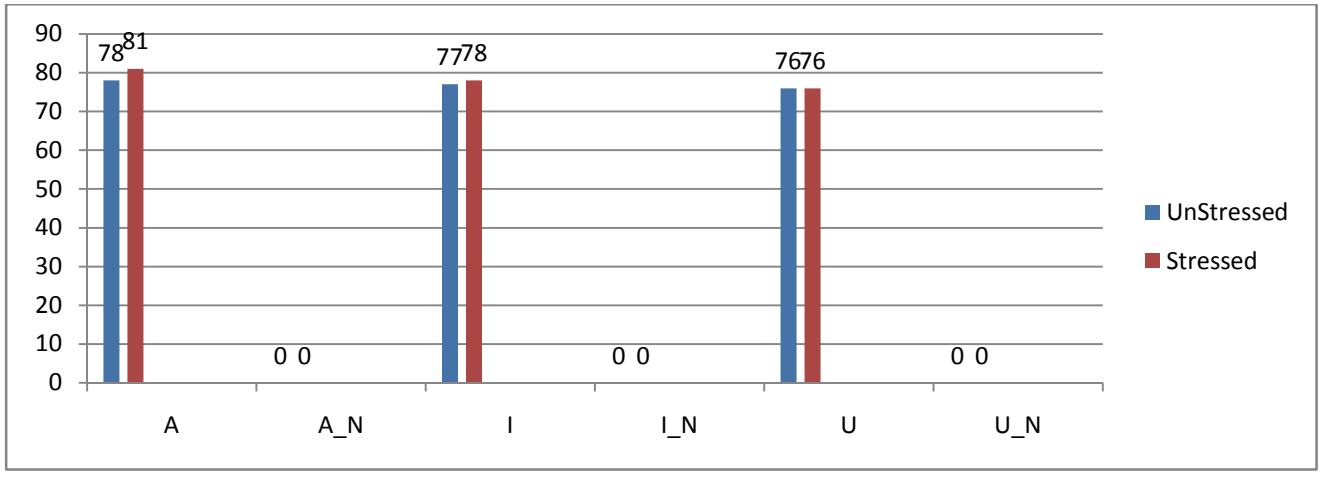


Figure 9: Mean intensity of stressed and unstressed short vowels in db over all speakers

Figure 9 explicates the mean intensity of stressed and unstressed short vowels. Mean intensity for unstressed /A/, /I/ and /U / was 78db, 77db and 76db respectively whereas the mean for stressed /A/, /I/ and /U / was 81db, 78db and 76db respectively.

The mean difference between the stressed and unstressed short vowel /A/ was 3db, for /I/ it was 1db and for /U/ it was 0db. Instances of nasalize short vowels for intensity analysis ware not found in the annotated corpus.

4.4.2 Intensity of High Long Vowels

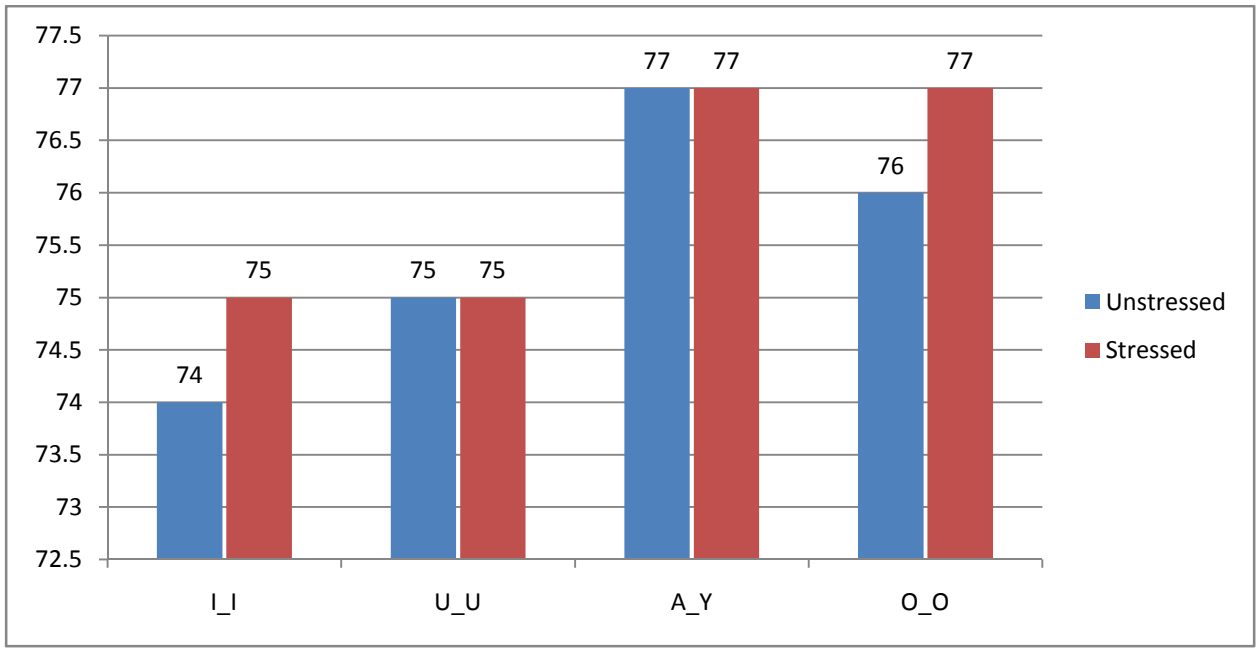


Figure 10: Mean intensity of stressed and unstressed high long vowels in db over all speakers

Figure 10 presents the mean intensity of stressed and unstressed high long vowels. Mean intensity for unstressed /I_I /, /U_U/, /A_Y/ and /O_O / was 74db, 75db, 77db and 76db respectively whereas the mean intensity for stressed /I_I / and /O_O / was 74db and 77db respectively. It is also analyzed that there was no change in the mean intensity of stressed /U_U/,

/A_Y/ from their unstressed instances. The mean differences between the stressed and unstressed / I_I / and /O_O/ was 1db and for /U_U / and /A_Y/ it was 0db.

4.4.3 Intensity of Nasal High Long Vowels

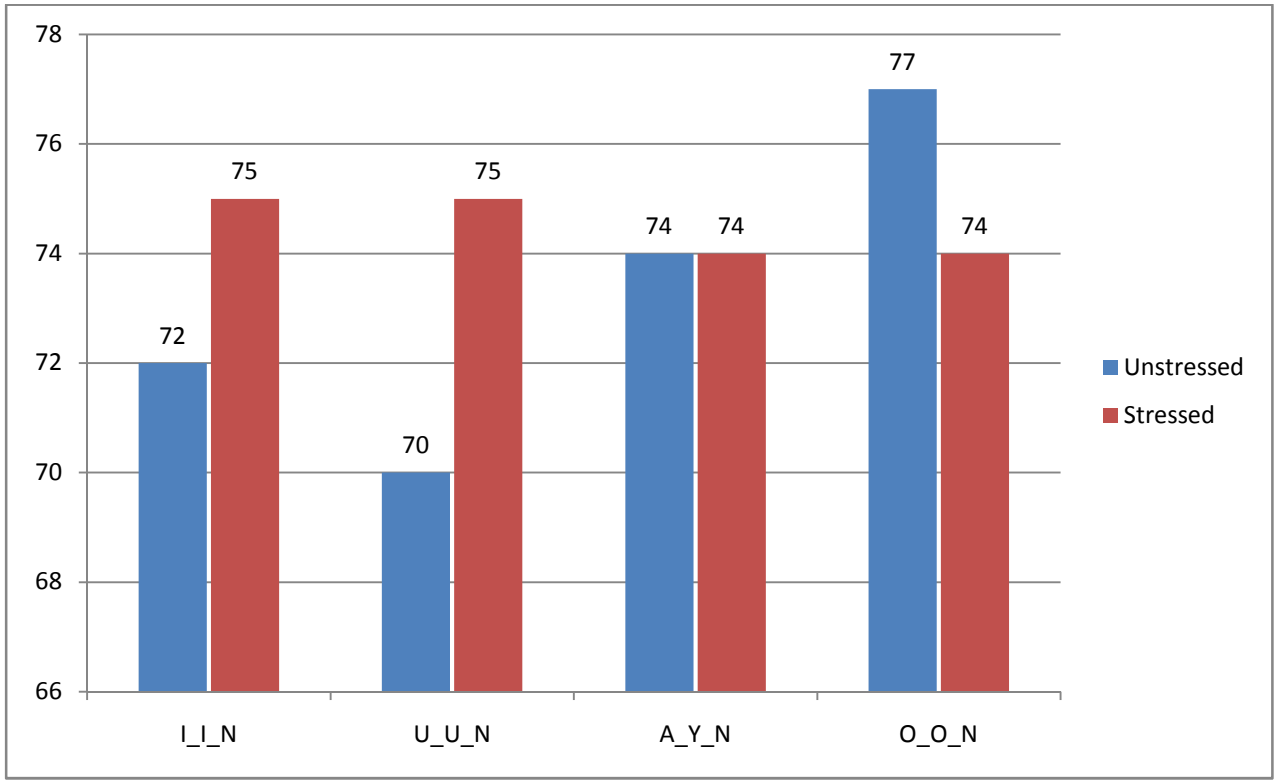


Figure 11: Mean intensity of stressed and unstressed nasalize high long vowels in db over all speakers

Figure 11 presents the mean intensity of stressed and unstressed nasalize high long vowels. Mean intensity for unstressed /I_I_N /, /U_U_N/, /A_Y_N/ and /O_O_N / was 72db, 70db, 74db and 77db respectively whereas the mean intensity for stressed /I_I _N/ and /A_Y_N / was 75db. It is also observed that there was no change in the mean intensity of stressed /A_Y_N/ from its unstressed intensity value and the intensity of /O_O_N/ vowel decreases with stress. The mean difference between the stressed and unstressed / I_I_N / was 3db, for /U_U_N/ it was 5db, and for /A_Y_N / and /O_O_N/ it was 0 and -3db respectively.

4.4.4 Intensity of Oral and Nasal Low Long Vowels

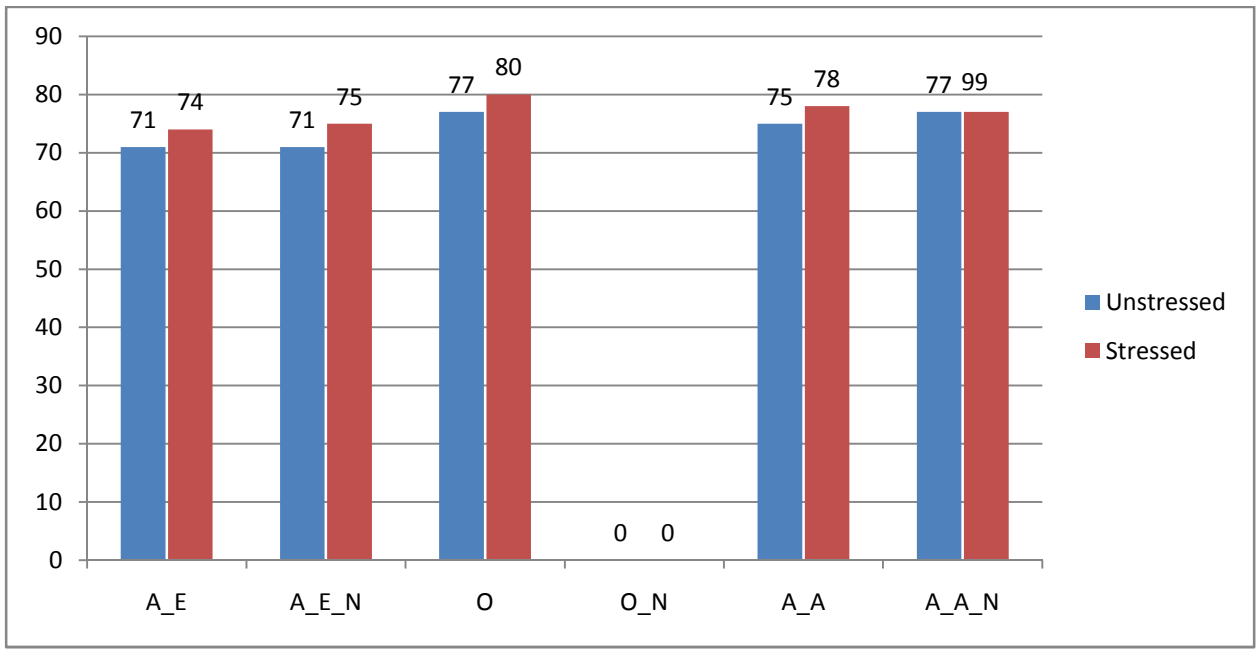


Figure 12: Mean intensity of stressed and unstressed oral and nasal low long vowels in db over all speakers

Figure 12 describes the mean intensity of stressed and unstressed oral and nasal low long vowels. Mean intensity for unstressed /A_E / was /A_E_N/ was 71db whereas for unstressed /O/, /A_A/ and /A_A_N / it was 77db, 75db and 77db respectively. Mean intensity for stressed /A_E /, /A_E_N/, /O/, /A_A/ and /A_A_N / was 74db, 75db, 80db, 78db and 99 db respectively. The mean difference between the stressed and unstressed / A_E / was 3db, for /A_E_N/ it was 4db, for /O / and /A_A/ it was 3 db, and for /A_A_N/ it was 22db.

4.4.5 Intensity of Medial Vowels

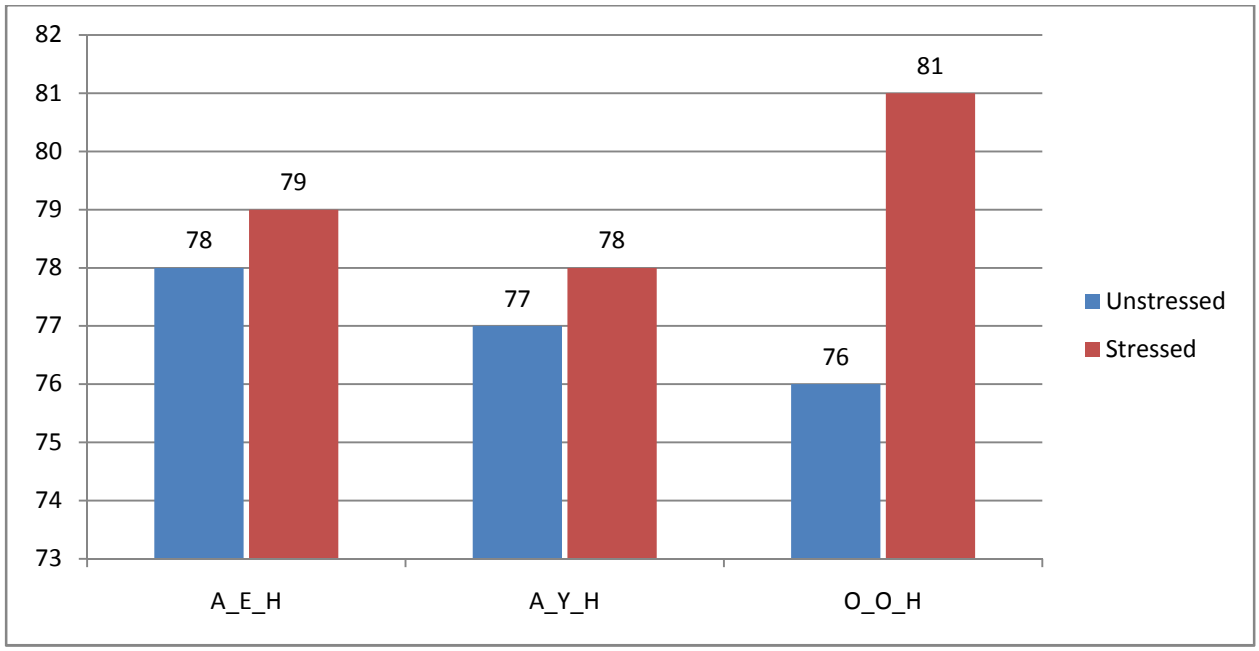


Figure 13: Mean intensity of stressed and unstressed medial vowels in db over all speakers

Figure 13 describes the mean intensity of stressed and unstressed medial vowels. Mean intensity for unstressed /A_E_H /, /A_Y_H/ and /O_O_H / was 78db, 77db and 76db respectively whereas the mean intensity for stressed /A_E_H /, /A_Y_H/ and /O_O_H / was 79db, 78db and 81 db respectively. The mean difference between the stressed and unstressed /A_E_H/ and /A_Y_H/ was 1db and for /A_A_N/ it was 5db.

4.5 Vowel Quality

Many researchers think that stress can influence the quality of vowel. Vowel quality is represented through F1 and F2 values of vowels. To see the influence of stress on F1 and F2 values, stressed and unstressed values of F1 and F2 are drawn in the scatter chart. In the following figures, unstressed and stressed vowels' averages are presented using '0' and '1' number

scheme along with their CISAMPA symbols. Horizontal line presents F1 values whereas vertical line presents F2 values.

4.5.1 Vowel Quality of Unstressed and Stressed Short Vowels

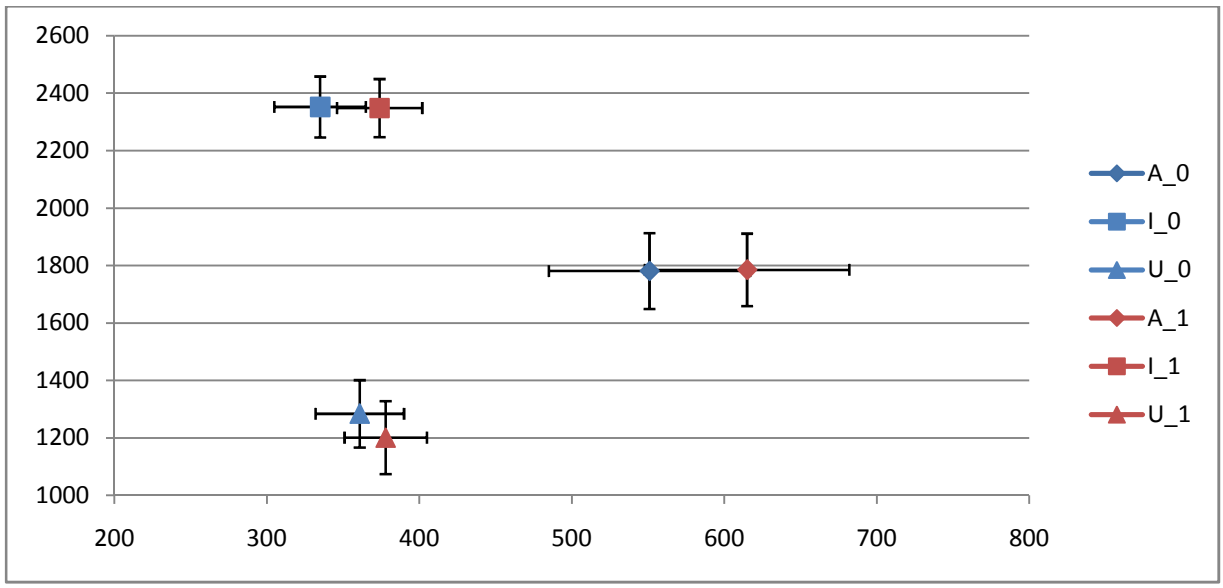


Figure 14: F1 and F2 values of unstressed and stressed short vowels

Figure 14 shows the mean F1 and F2 of unstressed and stressed short vowels along with their standard deviation. Mean F1 and F2 for unstressed /A / was 551Hz and 1781Hz respectively, for unstressed /I/ it was 335Hz and 2352 Hz and for unstressed /U / it was 361Hz and 1284 Hz whereas the mean F1 and F2 for stressed /A / was 615Hz and 1785Hz respectively, for stressed /I/ it was 374Hz and 2348 Hz and for stressed /U / it was 378Hz and 1201 Hz.

4.5.2 Vowel Quality of Unstressed and Stressed High Long Vowels

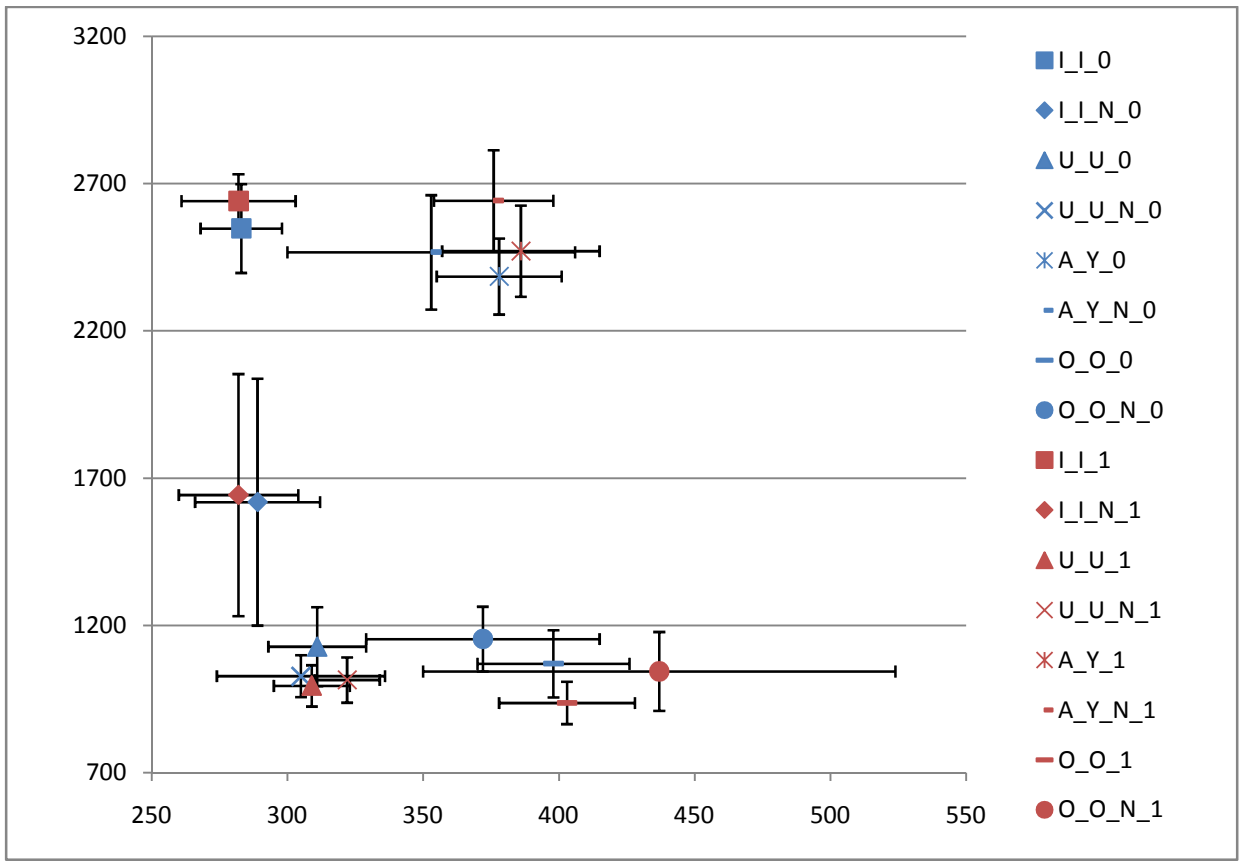


Figure 15: F1 and F2 values of unstressed and stressed high long vowels

Figure 15 describes the mean F1 and F2 of unstressed and stressed high long vowels along with their standard deviation. Mean F1, F2 for unstressed /I_I / and /I_I_N/ was 283Hz, 2548Hz and 289Hz, 1619Hz respectively. Mean F1, F2 for unstressed /U_U / and /U_U_N/ was 311Hz, 1128Hz and 305Hz, 1028Hz respectively. Mean F1, F2 for unstressed /O_O / and /O_O_N/ was 398Hz, 1070Hz and 372Hz, 1154Hz respectively.

Mean F1, F2 for stressed /I_I / and /I_I_N/ was 282Hz, 2441Hz and 282Hz, 1643Hz respectively. Mean F1, F2 for stressed /U_U / and /U_U_N/ was 309Hz, 995Hz and 322Hz, 1015Hz respectively. Mean F1, F2 for stressed /A_Y / and /A_Y_N/ was 386Hz, 2471Hz and

376Hz, 2642Hz respectively whereas mean F1, F2 for stressed /O_O / and /O_O_N/ was 403Hz, 937Hz and 437Hz, 1044Hz respectively.

4.5.3 Vowel Quality of Unstressed and Stressed Low Long Vowels

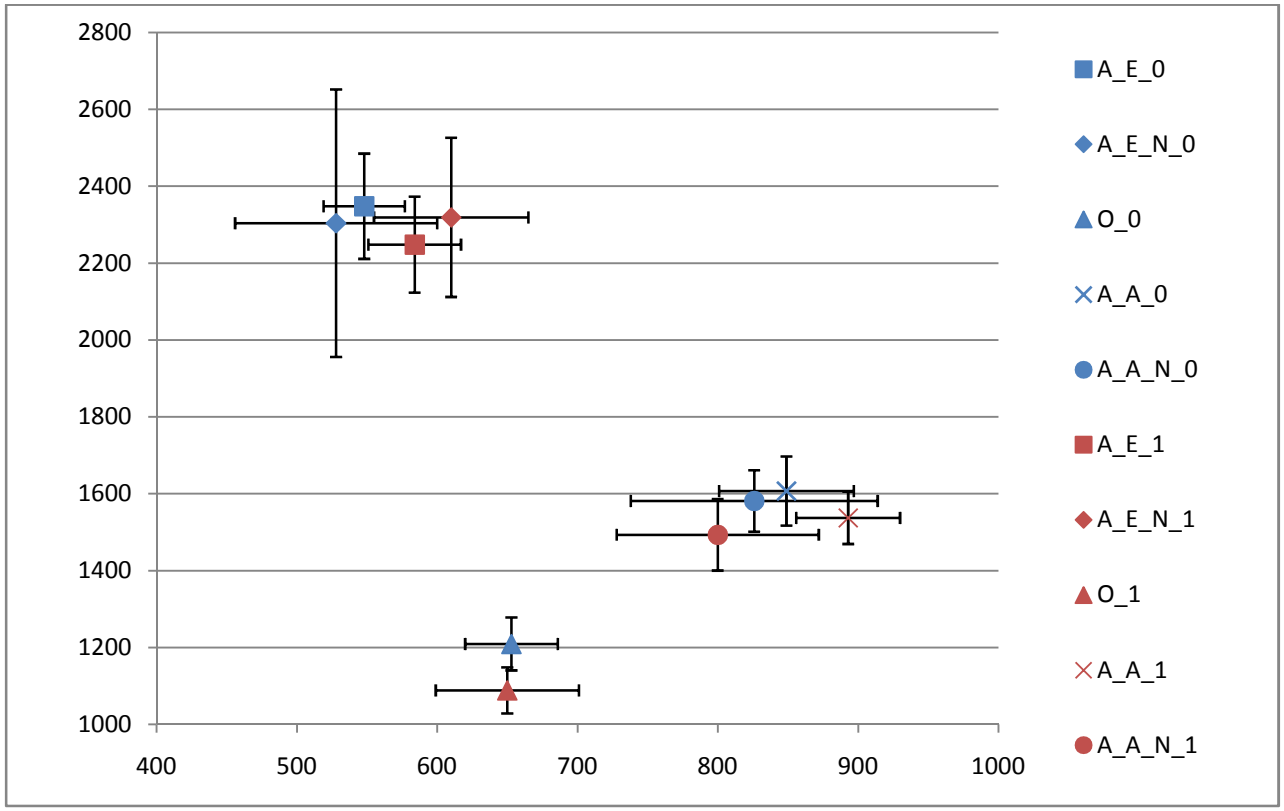


Figure 16: F1 and F2 values of unstressed and stressed low long vowels

Figure 16 describes the mean F1 and F2 of unstressed and stressed low long vowels along with their standard deviation. Mean F1, F2 for unstressed /A_E / and /A_E_N/ was 548Hz, 2348Hz and 528Hz, 2304Hz respectively. Mean F1, F2 for unstressed /O /, /A_A/ and /A_A_N/ was 653Hz, 1209Hz; 849Hz, 1607Hz and 826Hz, 1581Hz respectively.

Mean F1, F2 for stressed /A_E / and /A_E_N/ was 548Hz, 2248Hz and 610Hz, 2319Hz respectively whereas the mean F1, F2 for stressed /O /, /A_A/ and /A_A_N/ was 650Hz, 1088Hz; 893Hz, 1537Hz and 800Hz, 1493Hz respectively.

4.5.4 Vowel Quality of Unstressed and Stressed Medial Vowels

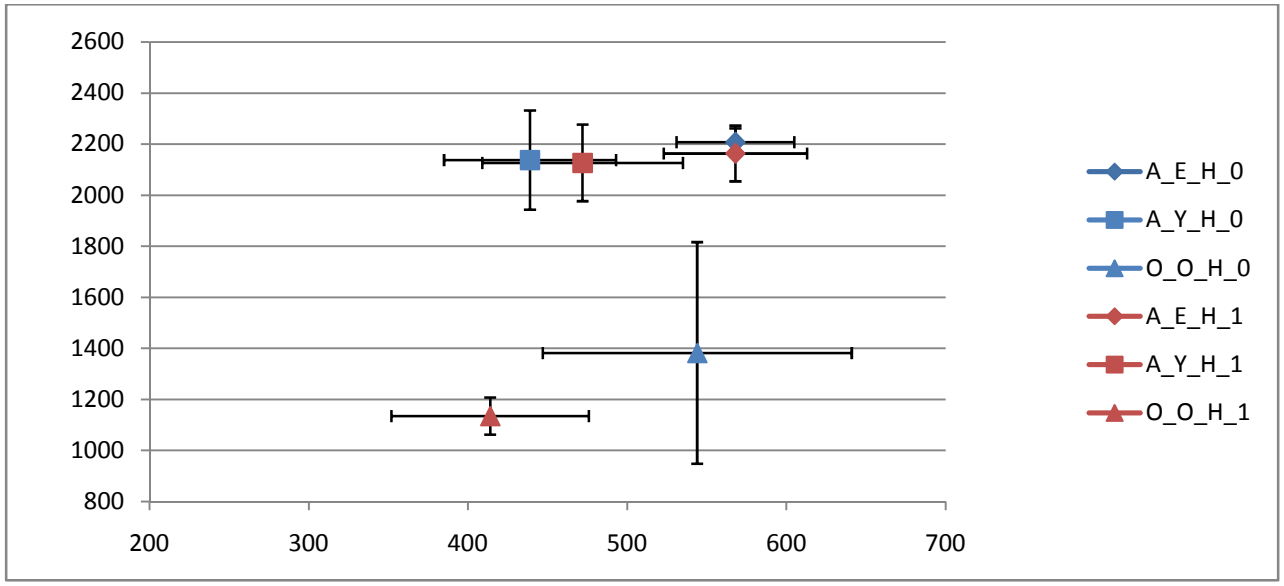


Figure 17: F1 and F2 values of unstressed and stressed medial vowels

Figure 17 shows the mean F1 and F2 of unstressed and stressed medial vowels along with their standard deviation. Mean F1 and F2 for unstressed /A_E_H/ was 568Hz and 2207Hz respectively, for unstressed /A_Y_H/ it was 439Hz and 2137 Hz and for unstressed /O_O_H/ it was 544Hz and 1382 Hz whereas the mean F1 and F2 for stressed /A_E_H / was 568Hz and 2163Hz respectively, for stressed /A_Y_H/ it was 472Hz and 2126Hz and for stressed /O_O_H / it was 414Hz and 1135Hz.

4.6 Stylized Pitch Contour

Data analysis of syllables indicates that the stylized pitch contour is second most important cue in the identification of stressed and unstressed syllables. Researcher has found two types of pitch contour while annotating the stress tier: High pitch contour and low pitch contour.

It is observed that the stressed syllables in Urdu can have both types of pitch contours. In high pitch contour case, the falling slope between this H* and the following L is sharp, steep and consistent whereas if the H tone is unstressed, the falling slope between this H and the following L is gradual as shown in the figure 18.

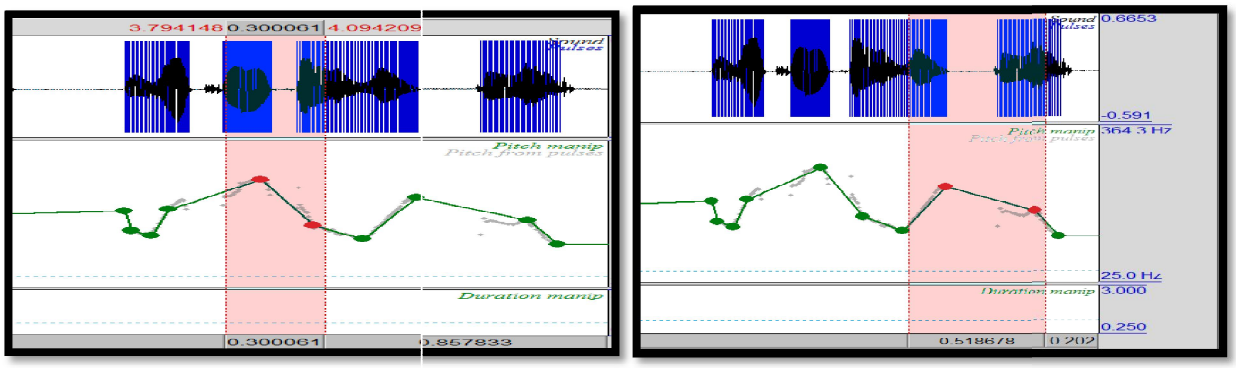


Figure 18: Stressed and unstressed high pitch contour

First part of the highlighted figure 18 represents the high to low contour of a stressed syllable whereas second highlighted part of the figure 18 shows the unstressed high to low contour. In the first part of the figure, highlighted contour is sharp whereas in the second part of the figure, the highlighted portion is gradual.

Lower F0 contour is also helpful in finding out the accented syllable. Similar to H* contour, if the L tone is stressed, the rising slope between this L* and the following H would be sharp, steep

and consistent whereas if the L tone is unstressed, the rising slope between this L and the following H would be gradual as shown in the figure 19.

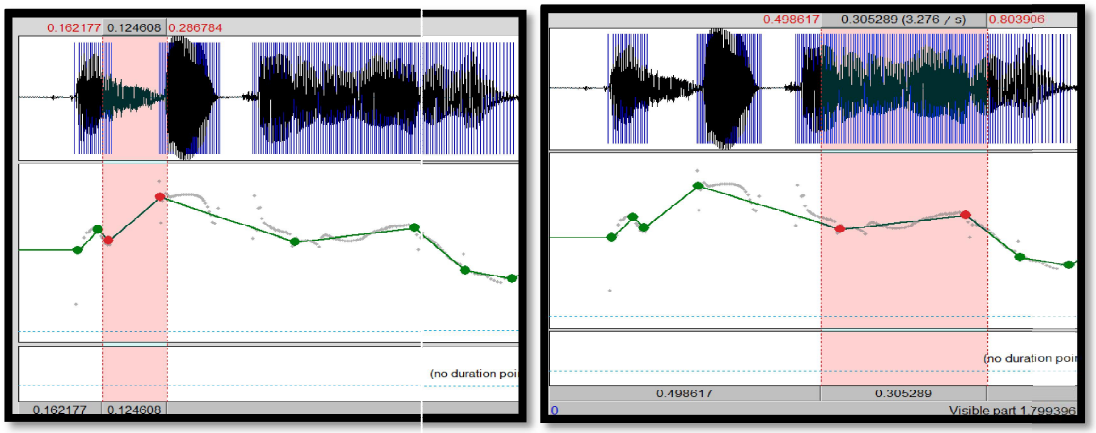


Figure 19: Stressed and unstressed low pitch contour

First part of the highlighted figure 19 represents the low to high contour of a stressed syllable whereas second highlighted part of the figure 19 shows the unstressed low to high contour. In the first part of the figure, the highlighted contour is sharp whereas in the second part of the figure, the highlighted portion is gradual. It is also noticed that lower pitch contour cue does not help out in identifying the stressed syllable at final syllable with pause position.

4.7 Glottalization

While assigning stressed and unstressed syllables, it is noticed that glottalization can make the syllable stress in Urdu language. Glottalization is an irregular vibration of vocal folds. Two types of glottalization are observed in data while assigning stress: strong glottalization and weak glottalization. It is noticed that syllable became stressed, if there is a strong glottalization at phrase initial position of a syllable as shown in the figure 20.

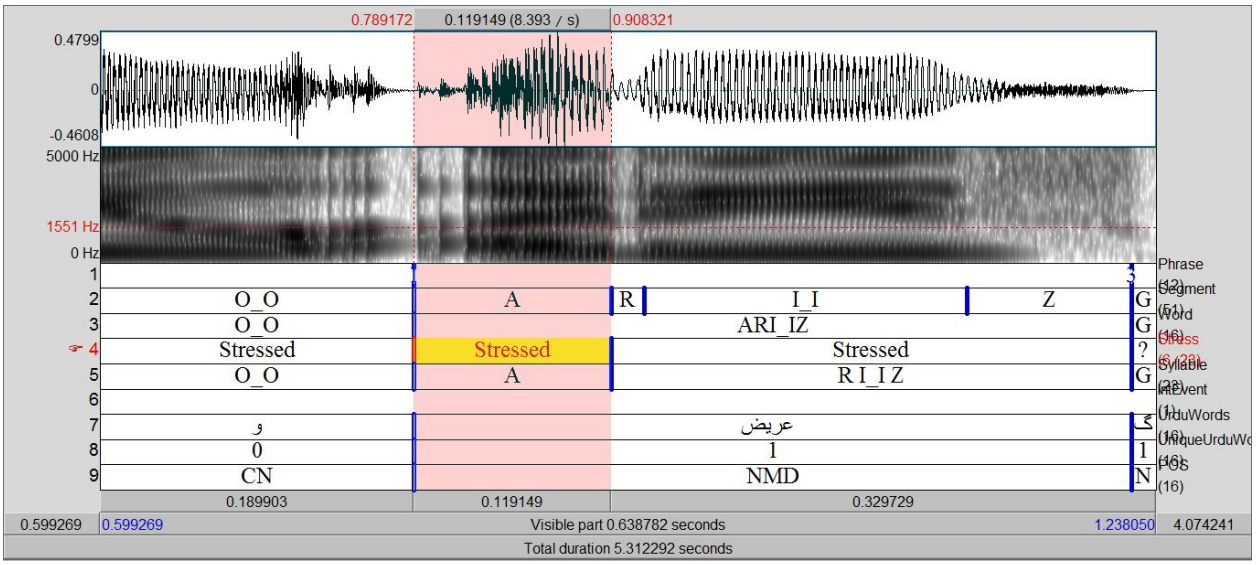


Figure 20: Strong glottalization at phrase initial position of a syllable

It is also observed that phrase initial glottalization increases the duration of a vowel. As it can be seen in figure 20, the duration of /A/ is 119ms which 38ms more than its stressed penultimate syllable mean value. Besides strong glottalization, weak glottalization can also appear at phrase initial position as shown in figure 21.

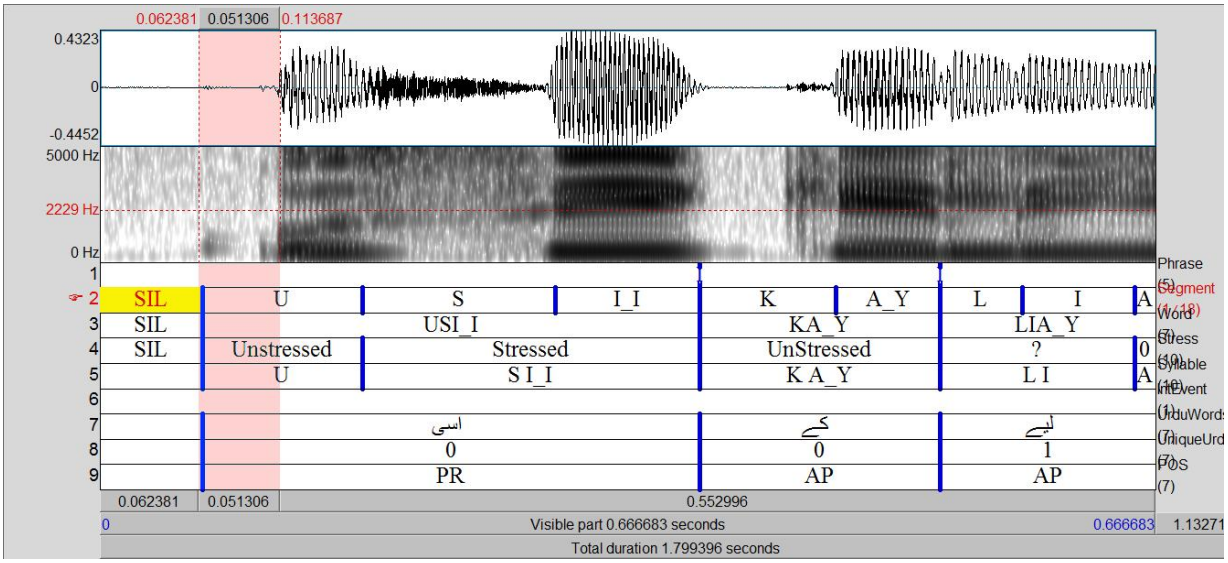


Figure 21: Weak glottalization at phrase initial position of a syllable

Although appearance of weak glottalization at phrase initial increases the duration of the vowel, it does not make syllable stress. Stress in Urdu is perceptually correlates with strong glottalization. The highlighted area in figure 21 represents weak glottalization.

5 Discussion

This study is conducted to develop a mechanism for determining the stressed and unstressed syllables in Urdu language. This study has also investigated how different acoustic properties such as duration, fundamental frequency, formant values and intensity of Urdu oral and nasal vowels change with stress.

Firstly, to develop a mechanism for assigning stress in Urdu a tentative process has been developed by the researcher. In this process, all acoustic cues of stress marking are used simultaneously. The process of using all these acoustic cues simultaneously has helped to prioritize the order of acoustic cues for Urdu stress marking i.e. duration, fundamental frequency, glottalization and intensity of the vowel respectively. Analysis of data highlighted that similar to Dutch (Reinisch & McQueen, 2010), stress perception in Urdu is mostly driven by duration of vowel in Urdu.

Results show that 73% data is assigned stress using durational values of stressed and unstressed vowels. Sixteen percent data is assigned stress using stylized pitch as a cue, 5% data is assigned stress using glottalization cue, 4% data is assigned stress using intensity cue and only 2% data is assigned stress using vowel quality as a cue.

While comparing the duration of vowels, vowels are categorized into four categories: short vowels, high long vowels, low long vowels and medial vowels. The reason of categorizing the vowels into four categories is that low long vowels are intrinsically longer than high long vowels as they require more movement of jaw as compare to others for articulation. Similarly, long high vowels are inherently longer from medial vowels and medial vowels are inherently longer than the short vowels. Analysis of data has shown that average duration of unstressed short vowels,

high long vowels, low long vowels and medial vowels is 58ms, 89ms, 102ms and 68ms respectively.

Therefore, while assigning stress, the duration of the targeted vowel is always compared with the duration of the same shortest vowel in the file under process. However, if the same vowel is not present in the file wave, the duration of the target vowel is compared with the duration of similar vowel. However, the duration of short vowels with high vowels and high vowels with medial vowels are never compared.

Results of durational analysis have indicated that both short and long vowel increase their duration with stress. The increase in the duration of stressed short vowels, high long vowels, low long vowels, high nasal vowels, low nasal vowels and medial vowels on average is 26ms, 28ms, 29ms, 39ms, 54ms and 20ms respectively. However, increase in the duration of vowel depends on the position of a syllable. Previous studies have also suggested that the relative contributions of duration, pitch and intensity differ depending on whether lexical stress is on the first syllable or second syllable of a word.

The general focus of literature survey is only on two positions of syllable: penultimate and final syllable. While annotating the stress tier, it is noticed that these two types of distinction in syllable positions cannot be used in Urdu context. It is observed that duration of a same vowel in Urdu behaves differently at three positions of syllables: penultimate syllable, word final syllable and word final with pause (See Appendix F for detail). For example, the average duration of stressed /e:/ vowel at penultimate syllable position is 109ms, at final syllable it is 134ms and at final syllable with pause position it is 185ms. Interestingly, it was found that the duration of penultimate syllable vowel is less than final syllable vowel and the duration of final syllable

vowel except /o:/ and /æ/ vowels is always less than the duration of final syllable with pause vowel.

Besides vowel, stress can also alter the duration of consonants in Urdu. It is analyzed that consonant lengthening can occur at both onset and coda positions in Urdu. Usually the duration of a stressed consonant is 100ms but affricate sounds can increase their duration more than 200ms with stress.

Second cue which has assisted in the process of developing stress marking mechanism for Urdu language is pitch. Contrary to this research, Kochanski, Grabe and Rosner (2005) who carried out quantitative measurements of stressed syllables in a large corpus of natural speech concluded that pitch plays a minor role in identifying the stress syllables. However, Trofimov (1923) and Jones (1927) argue that stress is very closely connected with pitch and intonation.

Hussain (1997) also states that pitch can determine the stress. According to his study, pitch/ f0 is lower for stress syllables in Urdu. Though this study and the research conducted by Hussain (1997) support the view that pitch can help to determine stress, results obtained from the data are different from Hussain's (1997) research. The analysis of stylized pitch contour indicates that both high pitch contour and low pitch contour can be used to determine the stressed syllable in Urdu. It is not the height or the lowness of pitch contour that determine stress; stress is determined by the abruptness or flatness of pitch contour. The results illustrate that falling or rising slope between L* and H* is abrupt and steep for stressed syllables in Urdu whereas it is gradual and flat for unstressed syllables. It is also observed that lower f0 contour cue does not help to find out the stress at final syllable position with pause.

Third cue which has helped out in determining stress for Urdu language is glottalization. Studies conducted in past mostly concentrated on four acoustic cues of perceived stress: duration, intensity, fundamental frequency, and vowel quality (Bolinger, 1958; Fry, 1955; Lieberman, 1960; Lindblom, 1963). Glottalization is not usually focused as an acoustic cue. Data analysis of 330 sentences has highlighted that strong glottalization at phrase initial position has been used as a cue for marking stress. This shows that glottalization somehow perceptually correlates with stress in Urdu. Glottalization can also occur at phrase final position. However, phrase final glottalization is an indicator of tapering off the vowel and is weaker in intensity than the stressed phrase initial glottialization.

Moreover, intensity and vowel quality cues are analyzed to find a stressed syllable in Urdu language. Lehiste (1970) mentioned that intensity can only be regarded as a reliable cue to mark stress when two syllables are intrinsically identical and vowel quality remains constant. Therefore, while developing a mechanism for stress marking, intensity of the targeted vowel is always compared with the intensity of the same shortest vowel in the file under process. The duration of the shortest vowel for the short vowels is set less than 57ms and for the long vowels it was set less than 100ms to ensure that shortest vowel selected for intensity analysis is unstressed.

The data analysis of intensity cue shows lot of variation. Stress increases the intensity of few vowels such as /ɪ/ /ə/ /ɑ:/ /æ:/ /ĩ:/ /ũ:/ whereas few vowels such as /ʊ/ /u:/ /ɑ̃:/ /e:/ /ẽ:/ do not show any change in intensity with stress. Moreover, the intensity of /õ:/ vowel decreases with stress. Results show a vowel needs to increase its intensity on average at least 3db to become stress. Due to the unpredictable behavior of intensity cue, it is considered as a least reliable cue and placed at the last number in the prioritized cues list for stress marking in Urdu.

Similar to intensity, analysis of vowel quality cue shows inconsistency in determining the stressed syllable. Standard deviation for F1 F2 of stressed short vowels, long vowels and medial vowels is 40 118, 29 147, and 56 110 respectively. Due to the extreme standard deviation in F1 F2 values, vowel quality cue has not been used to develop the mechanism for Urdu stress marking. Based on the analysis of result, a model for Urdu stress marking has also been proposed (see Appendix G).

Though it has been (Mesica, 1991) thought that Urdu and Hindi are same languages, results obtain from this study are different from the research conducted on Hindi stress. Dixit (1963) states that in a word only one syllable and in a phrase only one word gets prominent stress in Hindi; all other syllables and words are evenly stressed. However analysis of this research indicates that it is possible that no syllable in a word carries stress and it is also possible in multisyllabic word, more than one syllable can carry stress. It is also noticed that a syllable with heavy coda (CVCC/ VCC template) is always stressed as in the words /fərz/ (duty) and /ʃəxs/ (person).

For the annotation of stress tier, a numbering scheme has been used. Number '1' is assigned to a stressed syllable and number '0' is assigned to an unstressed syllable in a textgrid file. However, while marking the stress tier, it is noticed that data cannot be simply categorized into two categories: stressed syllable and unstressed syllable. On average 11% data is found which neither fall in stressed category nor in unstressed category. To highlight this ambiguous data, symbol of '?' is used.

This ambiguous data has been evaluated and was found that there is specific context for assigning '?' to a syllable. Symbol of '?' is assigned where there is no increase in the duration of

vowel but the syllable seems stressed because of consonant lengthening or because of high intensity of a vowel. It is also analyzed that increase in the duration of the consonant is more than 100ms and the increase in intensity of vowel is more than 3 to 5db than its shortest instance. This ambiguous data needs more investigation and can be used for future researches to find out the secondary stress in Urdu language.

6 Findings

This study has developed a mechanism for identifying stressed and unstressed syllables for Urdu language using acoustic cues. The nature of stressed and unstressed syllables has been investigated after conducting the careful analysis of wave form and spectrogram of the wave file. The findings of this study are as follows;

- In a multisyllabic word, more than one syllable can carry stress.
- It might be possible that no syllable in a word carries stress in a spontaneous speech.
- A syllable with heavy coda (CVCC/ VCC template) is always stressed in Urdu as in vəkt̪ and d̪ə.rəxt̪.
- In Urdu, stress perception is driven by duration and pitch contour.
- The mean duration for unstressed short and long vowels is 58ms and 94ms respectively.
- In Urdu, duration of vowel depends on the position of syllable. The results of the acoustic analysis of the duration of stressed and unstressed syllables show that the duration of vowel of the stressed penultimate syllable is less than the duration of vowel of the stressed final syllable and stressed final syllable with pause.
- The results have also shown that the duration of vowel of the stressed final syllable with pause is more than the duration of vowel of the stressed penultimate syllable and stressed final syllable.
- If the pause is less than 20ms, the increase in corresponding vowel would be less.
- The mean difference between the stressed and unstressed short vowels at penultimate syllable position and at final syllable with pause position was 26ms whereas at final syllable position it was 30ms.

- The mean difference between the stressed and unstressed long low vowels at penultimate syllable position was 29ms, at final syllable position it was 43ms and at final syllable with pause position it was 10ms.
- The mean difference between the stressed and unstressed nasalized low long vowels at penultimate syllable position and at final syllable with pause position was 54ms whereas at final syllable position it was 46ms.
- The mean difference between the stressed and unstressed high long vowels at penultimate syllable position was 28ms, at final syllable position it was 43ms and at final syllable with pause position it was 57ms.
- The mean difference between the stressed and unstressed nasalized high long vowels at final syllable position was 39ms and at final syllable with pause position, it was 49ms.
- The mean difference between the stressed and unstressed medial vowels at penultimate syllable position was 20ms, at final syllable position it was 16ms and at final syllable with pause position it was 23ms.
- Results indicate that duration of few consonants such as /ʃ/, /s/, /j/, /n/ increases more than 100 ms with stress at onset and coda positions.
- The analysis of stylized pitch contour indicated that both high pitch contour and low pitch contour can also be used to determine the stressed syllable in Urdu. The results indicated that falling or rising slope between L* and H* is abrupt and steep for stressed syllables in Urdu whereas it is gradual and flat for unstressed syllables.
- Lower F0 contour cue does not work at final syllable with pause position.

- The analysis of the glottalization cue shows variation in determining stressed syllable. Results show that glottalization at phrase initial position is an indicator of stress whereas at phrase final position, glottaliztaion indicates tapering off of the vowel.
- In addition, it is observed that intensity of an accented syllable in Urdu is on average 3-5dB more than an unaccented syllable. However, the change in intensity with stress is vowel dependent.

7 Conclusion

This research has developed a mechanism for annotating the stress tier using acoustic cues. Analysis of the results indicated that 87% consistency between annotators can be achieved after using the mechanism developed for stress annotation. This mechanism has prioritized the order of acoustic cues for Urdu stress marking i.e. duration, fundamental frequency, glottalization and intensity of the vowel respectively.

The acoustic analysis of the duration of stressed and unstressed syllables indicate that duration of vowel depends on the position of syllable in Urdu. Results show that duration of vowel of the stressed final syllable with pause is more than the duration of vowel of the stressed final syllable and penultimate syllable. Few Consonants such as /s/, /j/, /ʃ/, /n/ also increase their duration more than 100ms with stress.

In addition, the analysis of stylized pitch contour shows that falling or rising slope between L* and H* is abrupt and steep for stressed syllables in Urdu whereas it is gradual and flat for unstressed syllables. Moreover, strong glottalization at phrase initial position makes syllable stressed. Results have also highlighted that vowel quality and intensity are least reliable cues as they show lot of variations in determining the stressed and unstressed syllables of Urdu language. Hence, this study concludes that Urdu stressed vowels have longer duration, abrupt pitch track, strong glottalization and most likely higher intensity.

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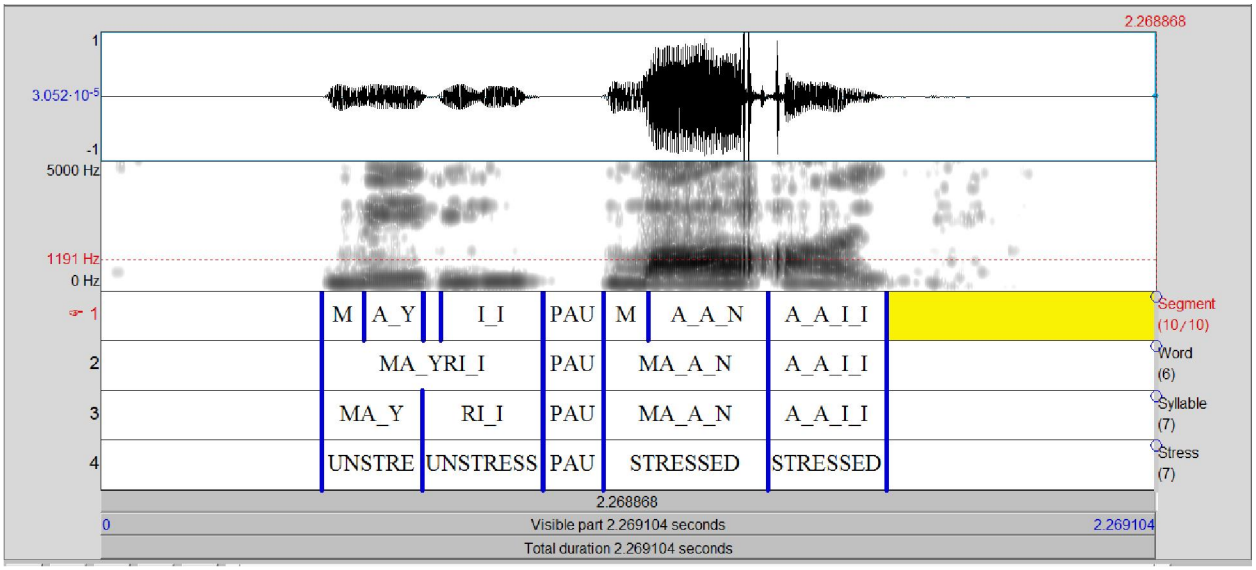
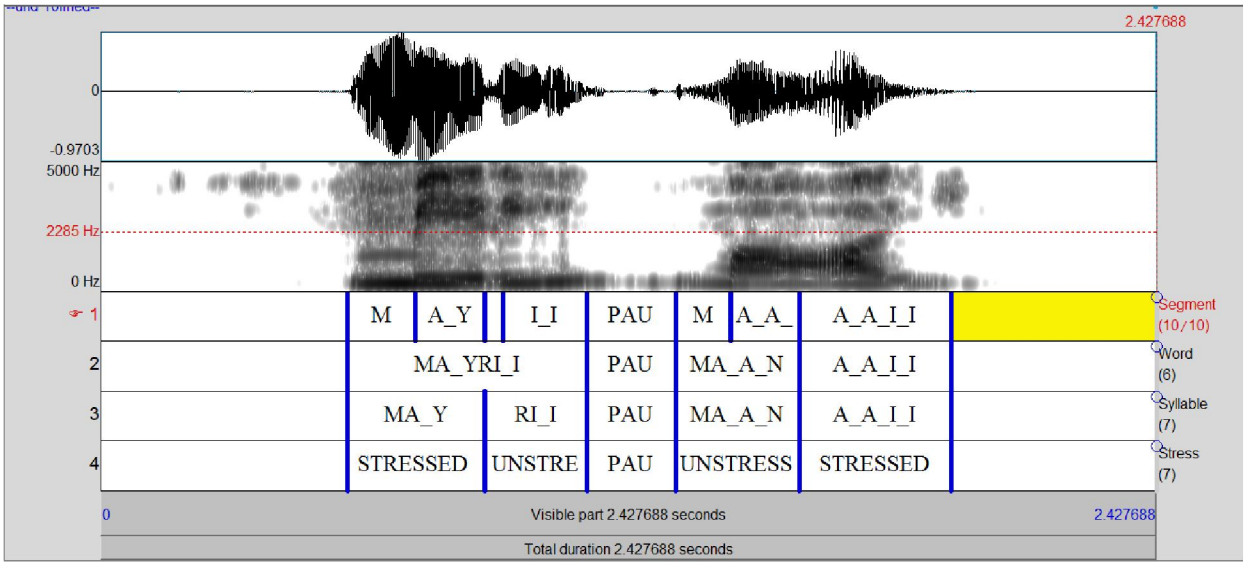
Appendix A-1



Unstressed, unstressed, stressed and stressed syllables pattern



Stressed, unstressed, unstressed and stressed syllables pattern

Appendix A-2

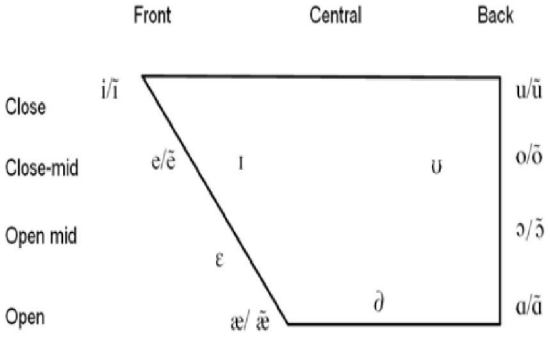


Figure: Quadrilateral Chart of Urdu Vowels

Appendix A-3

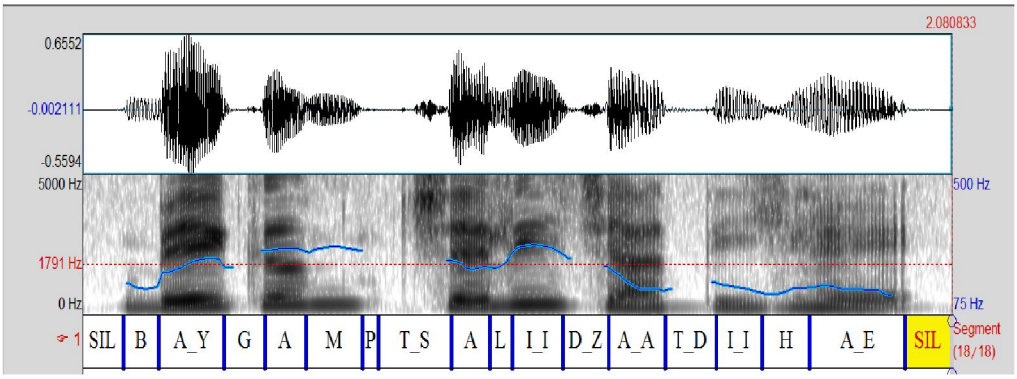


Figure: A Sample of TextGrid File

Appendix A-4

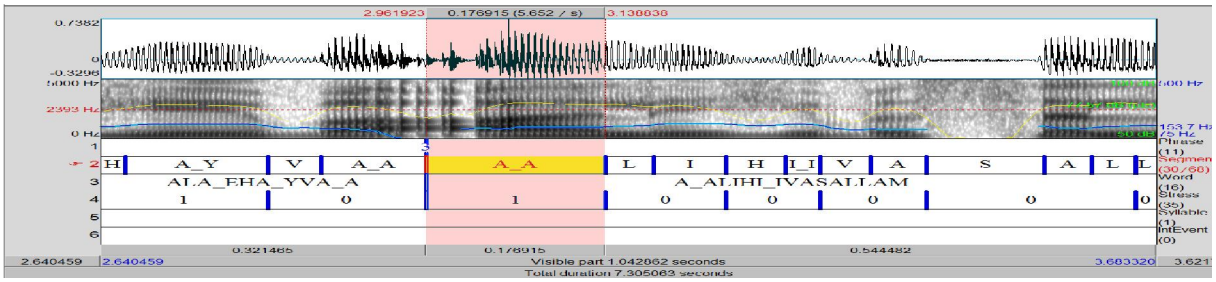


Figure: Glotalized accented syllable

Appendix A-5

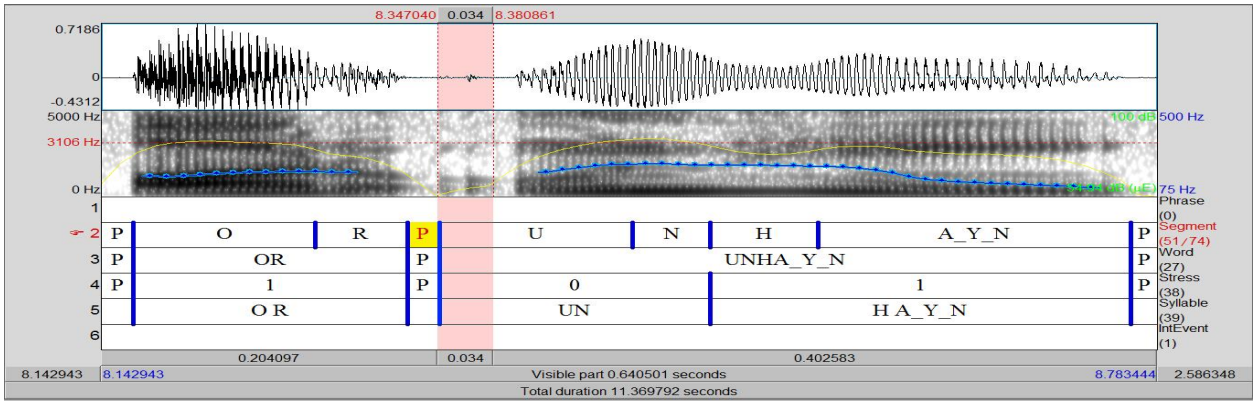


Figure: Weak Glottalization

Appendix B

Sr.#	Urdu Letter	IPA	CISAMPA	Sr.#	Urdu Letter	IPA	CISAMPA
1	پ	P	P	35	ر	R	R
2	پھ	pʰ	P_H	36	رھ	rʰ	R_H
3	ب	B	B	37	ڑ	ɽ	R_R
4	بھ	bʰ	B_H	38	ڑھ	ɽʰ	R_R_H
5	م	M	M	39	ی	J	J
6	مھ	mʰ	M_H	40	یھ	jʰ	J_H
7	ت،ط	t̪	T_D	41	چ	ʧ	T_S
8	تھ	t̪ʰ	T_D_H	42	چھ	ʧʰ	T_S_H
9	د	d̪	D_D	43	ج	ʤ	D_Z
10	دھ	d̪ʰ	D_D_H	44	جھ	ʤh	D_Z_H
11	ٹ	T	T	45	ُو	u:	U_U
12	ٹھ	tʰ	T_H	46	ُوں	ũ:	U_U_N
13	ڈ	D	D	47	و	o:	O_O
14	ڈھ	dʰ	D_H	48	وں	õ:	O_O_N

15	ن	N	N	49	وَ	ɔ:	O
16	نھ	n^h	N_H	50	وَں	ɔ̃:	O_N
17	ک	K	K	51	ا،آ	ɑ:	A_A
18	کھ	k^h	K_H	52	ان،آں	ɑ̃:	A_A_N
19	گ	g	G	53	ی	i:	I_I
20	گھ	g^h	G_H	54	یں	ĩ:	I_I_N
21	ن in نگ, نک, نکھ, نگھ	Ŋ	N_G	55	ے	e:	A_Y
22	ق	Q	Q	56	یں	ẽ:	A_Y_N
23	ع	ʔ	Y	57	ہ ِ	E	A_Y_H
24	ف	F	F	58		e	A_E_H
25	و	V	V	59	ہ ُ	O	O_O_H
26	س،ص،ث	S	S	60	ے	æ:	A_E
27	ض،ظ،ز،ذ	Z	Z	61	یَں	æ̃:	A_E_N
28	ش	ʃ	S_H	62	ِ	ɪ	I
29	ژ	ʒ	Z_Z	63	ُ	ʊ	U

30	خ	X	X	64	ءٰ◌َ	ə	A
31	غ	ɣ	G_G	65	ں◌ِ	ĩ	I_N
32	حٰ◌ه	H	H	66	ں◌ُ	ʊ̃	U_N
33	ل	L	L	67	ں◌َ	ə̃	A_N
34	لھ	lʰ	L_H				

Appendix C: Corpus 1

1۔ اور اللہ نے ان پر کوئی ظلم نہیں کیا۔

2۔ میں بیان کئے گئے ہیں۔

3۔ میرے ہوش و حواس جواب دے رہے ہیں۔

4۔ جاؤ، اللہ کی امان میں دیا۔

5۔ یہ چولہا عجیب ساخت کا تھا۔

6۔ اس باب میں حضرت حفصہ رضی اللہ تعالی عنہا سے بھی روایت ہے۔

7۔ اس موضوع پر ہم نے دیگر مقامات پر بھی بحث کی ہے۔

8۔ جو سینئر اساتذہ یونیورسٹی میں کام کر رہے تھے۔

9۔ کہیں ان کا انداز مثبت ہوتا ہے اور کہیں منفی۔

10۔ شام کو گیا تو آپ بالکل تندرست تھے۔

11۔ مثلاً عبداللہ بن سلام وغیرہ۔

12۔ اور اس وقت سے جب میں نے اسے نہیں دیکھا تھا۔

13۔ اور یقیناً اس میں آپ نہ تو پیاسے رہیں گے اور نہ دھوپ کھائیں گے۔

14۔ جس کے پاس ہی جنت الماوی ہے۔

15۔ بیسویں صدی کے ساتھ ساتھ ان کی تعداد میں اضافہ ہوتا چلا گیا اور ان کا اثر بڑھتا گیا۔

16۔ جس میں آپ کی امت پر ہر دن رات میں پچاس نمازیں فرض ہوئیں۔

17۔ اتنا پیار تھا اس سے لوگوں کو۔

18۔ سوال وہاں سے پھر اللہ نے کس طرح نکالا۔

19۔ ان کا بھی خیال تھا کہ اپنی زبان میں لکھا جائے۔

20۔ پانچ سال سے کہہ رہا ہوں کہ کسی دوسرے کو چن لو۔

21۔ اور اسی کا ہے جو کچھ ہے آسمانوں میں اور زمین میں، اور اسی کا انصاف ہے۔

22۔ اس کتاب کو انھوں نے کلکتہ سے خریدا تھا۔

23۔ پھر اس کی صحت ثابت ہو جانے کے بعد اسے تسلیم کرنا ضروری ہوتا ہے۔

24۔ اس نے سر جھکا کر جواب دیا۔

25۔ نزع کے اصلی معنی فساد کے ہیں وہ خواہ غصے سے ہو یا کسی اور وجہ سے۔

26۔ خواجہ نصر الدین نے جواب دیا۔

27۔ پھر کرسی پر بیٹھ گئے۔

28۔ اس دنیا کے لوگ ان سے اس طرح بے تعلق نہیں ہیں جیسے کہ یہ ہیں۔

29۔ کسی حلال کو حرام قرار دے دیں۔

30۔ اس کے پس منظر میں دو چیزیں بالکل نمایاں نظر آتی ہیں۔

31۔ پھر یہ ہے کہ مسلمانوں کو تکریم نبوی کا حکم دیا ہے۔

32۔ اس نے کسی کی بات نہیں مانی۔

33۔ ایسی کوئی بیماری بھی نہیں تھی جس سے کسی کو تشویش لاحق ہوتی۔

34۔ جس کے نتیجے میں ان میں حق و ہدایت کی کسی صدا و پکار کا کوئی اثر ہی نہیں ہوتا۔

35۔ عمرو بن دینار یہی فرماتے ہیں۔

36۔ ہمارے سامنے عاجزی کرنے والے تھے۔

37۔ بعد ازاں اسے کالے پانی کی سزا ہوئی۔

38۔ خان صاحب کی نماز جنازہ تیار تھی۔

39۔ اب اس کے جانے کا غم نہ کرو اور خود کو سنبھالو۔

40۔ آگے چل کر ان کے نام سامنے آتے ہیں۔

41۔ ناف کو واضح کرنے کی وجہ یوگ کی تربیت ہے۔

42۔ اسے استعمال نہ کرنا۔

43۔ حضرت ابی بن کعب، معاذ بن جبل، زید بن ثابت اور ابو زید رضی اللہ عنہم۔

44۔ شیخ مبارک بھی بلائے گئے۔

45۔ ہر سال بڑا جلوس نکالتے تھے۔

46۔ ہم اسی کے جلال و جمال سے متاثر ہوتے ہیں۔

47۔ اب جو کوئی اپنی بہتری چاہے اس وقت کی تیاری کر رکھے۔

48۔ ہم تماشائی نہیں ہیں بلکہ ہم کھیل میں شامل ہیں، ہم جشن منا رہے ہیں۔

49۔ اور جب آمنہ نے خوشامد کی۔

50۔ شیخ برادری سے ان کا تعلق ہے۔

51۔ ایسا الزام اسلام دشمنی کی وجہ سے ہے۔

52۔ تم اپنے رب کے حکم پر صبر کرو۔

53۔ ہمارے ملک میں کسی چیز کی کمی نہیں۔

54۔ تو حیران کرنے والی قدرت رکھتا ہے تو عظیم معجزے کرتا ہے۔

55۔ ننھے بھائی کی نگاہیں التجا کر رہی تھیں کہ مجھے بچاؤ۔

56۔ پیٹ کے دوزخ کا پر ہونا ضروری تھا۔

57۔ جس کا نام محمود تھا۔

58۔ ابتدائی تعلیم مادری زبان یا علاقائی زبان میں ہو، اگر ہمیں ترقی یافتہ قوم بننے میں دلچسپی ہے۔

59۔ البتہ وہ شخص استعمال کر سکتا ہے جس کے پاس جوتے نہ ہوں۔

60۔ یہاں تھوڑی سی سہولت میسر آئی۔

61۔ جب انھوں نے یہ بات سنی تو سر تسلیم خم کر دیا۔

62۔ وہ نیکیاں بھی کرتے ہیں جن کا تعلق انہی کی ذات سے ہے۔

63۔ اور اس شہر کے لوگوں کو مار ڈالا۔

64۔ اللہ کا شکر ادا کیا۔

65۔ چنانچہ باری تعالی کا ارشاد ہے۔

66۔ اس کے ساتھ بھی ایسا ہی ہوا۔

67۔ کیا سمجھ رکھا ہے تم نے مجھے۔

68۔ حضرت نے فرمایا۔

69۔ اور وہ شخص بے حس و حرکت پڑا تھا۔

70۔ سوچ سمجھ کر فرمایا کہ میں سقم ہوں یعنی ضعیف ہوں۔

71۔ اور آفاق وانفس میں غور و فکر اور عقل و فطرت کے دلائل کی بنیاد پر ہو۔

72۔ آپ نے اس عورت سے فرمایا مجھے پانی پلاؤ۔

73۔ بڑے بڑے بہادر سورما شہید ہو گئے۔

74۔ آپ کے بعد۔

75۔ روس جانے کا ارادہ ہے۔

76۔ جو اس بات کا غماز تھا کہ صبح ہو رہی ہے۔

77۔ راست باز بنو اور اچھے کام کرو۔

78۔ وہ نبی کے پاس آئیں۔

79۔ پس تم دونوں اپنے رب کی کس کس نعمت کو جھٹلاؤ گے۔

80۔ اعضاء میں مناسبت رکھی۔

81۔ پیارے مارکس تمھاری چال ڈھال۔

82۔ اس سے ثابت ہوا کہ وہ ایمان لائے۔

83۔ اگرچہ حکم دیا تھا کہ اس رسم میں ہماری رفاقت ضرور نہیں۔

84۔ اس کے ساتھ اپنے رویے پر مجھے افسوس تھا۔

85۔ فلکیات سے تاریخ تک، فلسفے سے ادب تک، فزکس سے دست شناسی تک۔

86۔ کہ اس پر سوار ہو۔

87۔ حسین بن منصور روئی دھنتے تھے۔

88۔ جس نے شدت اختیار کر کے، آخر کار انکار کا روپ دھار لیا۔

89۔ ہم آپ ﷺ کے پاس گئے۔

90۔ بخاری و مسلم حدیث کے الفاظ مسلم کے ہیں۔

91۔ یہ اور قسم کے لوگ ہیں۔

92۔ ہم خود قدر ہیں، اگر چاہیں تو اسی جیسا کلام کہہ دیں۔

93۔ اس کی گردن میں تم نے موتیوں کی یہ ست لڑی دیکھی۔

94۔ اس شہر میں میری عام نمائش ہوئی۔

95۔ ہر چھوٹی چھوٹی بات کی طرف دھیان دیتے ہیں۔

96۔ ۶۰ میل کے فاصلے پر ہے۔

97۔ ساری دنیا میں اس کا نام ہے۔

98۔ جب کہ حضرت امام ابو یوسف اور حضرت امام محمد نے ان سب کو مکروہ کہا ہے۔

99۔ شمال کا رنگ حد درجہ سنہرا ہے۔

100۔ اس کی زبان ایسی ہے کہ ایک عام آدمی سمجھ سکتا ہے۔

101۔ وہ اس رشتے سے انکار کر دے گی۔

102۔ چلو دیکھتے ہیں اور کیا کیا ہے۔

103۔ اور چونکہ رستے میں کہا ہے اور موقع وقت سامنے ہے۔

104۔ رسول اللہ صلی اللہ علیہ وسلم سے پوچھا گیا۔

105۔ اے تمام جہانوں کے پالنے والے ہمیں بھی بخش دے اور ان کو بھی۔

106۔ اس طرح میں اسلام کی طرف متوجہ ہوا۔

107۔ اللہ ان کے کام ضائع نہ کرے گا۔

108۔ پھر اس کا علاج کیا ہے کہ خدا کے ساتھ لڑائی غیر ممکن ہے۔

109۔ اس لئے اس نے خود ہی فائر کرنے کی ٹھانی۔

110۔ تب آپ کو یقین آئے گا۔

111۔ خدا تم سے کچھ نہیں پائے گا۔

112۔ دو بھائی پی ایچ ڈی ہیں۔

113۔ مسند احمد میں ہے حضرت ابو ہریرہ رضی اللہ تعالی عنہ فرماتے ہیں شراب تین مرتبہ حرام ہوئی۔

114۔ اتنے میں کسی نے آکر انہیں خبر دی کہ دیکھو۔

115۔ وہیں رہے یہاں تک کہ آپ نے وصال فرمایا۔

116۔ اور خدا نے ان پر لعنت کر دی ہے۔

117۔ کھانا چیک کر لیا جائے گا۔

118۔ گالی کیوں دیتے ہو۔

119۔ عورتوں نے کی خرید و فروخت۔

120۔ مگر ابو صالح بہت جوشیلا ہے۔

121۔ ہم نے اس قرآن کو عربی قرآن بنایا ہے تاکہ تم سمجھ لو۔

122۔ دیکھتے ہیں کہ مومنوں قطار بنائے فرش مکان پر چل رہے ہیں۔

123۔ کرنے کے لئے اور بہت سی باتیں ہیں۔

124۔ لیکن یہاں اس کی تعبیر بتانے والا کوئی نہیں ہے۔

125۔ سرداری چاہتے ہو تو ہم تمہیں سردار مانے لیتے ہیں۔

126۔ یہ پارک پہاڑوں کے دامن میں واقع ہے۔

127۔ ان خواہشات کو پورا کرنے کے لیے وہ کچھ بھی کرنے کے لیے تیار ہے۔

128۔ گائے ہم پر مشتبہ ہو گئی ہے اور اگر خدا نے چاہا تو ہم اسے ضرور ڈھونڈ لیں گے۔

129۔ اب کوئی نہ ہو گا کہ جواب دے۔

130۔ مجھے تو ہر وقت اس کی فکر کھائے جا رہی ہے۔

131۔ بشارت منت سماجت کرتے رہے۔

132۔ نیم دلی سے انہوں نے تلاش کرنے کی کوشش کی۔

133۔ ماں باپ سے دوری ہونے لگی تھی۔

134۔ ناؤنوش کی ایک ایسی ہی ملاقات میں مجھ پر سرور طاری ہو چلا تھا۔

135۔ اللہ تعالی کسی شخص کو اس کی طاقت سے زیادہ تکلیف نہیں دیتا۔

136۔ یہ اجماع زمانۂ صدیق میں منعقد ہوا۔

137۔ آخر میں یہ نتیجہ اخذ کرے کہ اس سفر میں اسے کیسا لگا۔

138۔ تمہیں اور بھی دینا ہو گا۔

139۔ تو ہم سب ہی موت کو ناپسند کرتے ہیں۔

140۔ کسے ضرورت ہے کہ غریب بہنوں کا بھائی بنے۔

141۔ اصل میں تو وہ ایسے لوگ ہیں جو تم سے خوفزدہ ہیں۔

142۔ عزیز اس سے نہیں ہے کوئی۔

143۔ جدیدیت کے ذہنی تعفن کو دور کرنے کا کریڈٹ۔

144۔ شاید اسی لیے تم نے اپنی طرف سے ایک آواز اٹھائی۔

145۔ جو ٹھٹھ سے تعلق رکھتے ہیں۔

146۔ قریش ہی نہیں، سارے دشمن قبائل متحدہ ہوکر اسلام کے خلاف اپنا آخری داؤ چل چکے تھے۔

147۔ یقیناً یہ اللہ کے لیے آسان ہے۔

148۔ یہاں مومنین کا بھی اضافہ ہے جن کو اللہ کے رسول کے بتلانے سے علم ہو جاتا ہے۔

149۔ یہی لوگ ہیں جو اپنے پروردگار سے منکر ہوئے ہیں۔

150۔ طب میں اس قدر مہارت نہ تھی۔

151۔ مرزا بیدل اور میر تقی میر کی تقلید۔

152۔ کہو، سب کچھ اللہ ہی کی طرف سے ہے۔

153۔ یہ ہے دنیا میں انسان کی، اور انسان کے لیے دنیا کی اصل حیثیت۔

154۔ موقف حساب سے دوزخ کی طرف۔

155۔ بیٹی کیا یہ ضروری ہے۔

156۔ جس کا مطلب ہے کہ ہمارے پاس اب بھی وقت ہے۔

157۔ کہیں یوں تو نہیں کہ۔

158۔ کوئی شخص اپنے بھائی کو اس کی جگہ سے اٹھا کر خود اس کی جگہ پر نہ بیٹھے۔

159۔ مخدوم جہانیاں جہاں گشت رحمۃ اللہ علیہ حیات و تعلیمات۔

160۔ بفر ٹکرا ٹکرا کر دھکے دے رہے تھے۔

161۔ اس نے بعد میں مجھ سے کہا۔

162۔ تم کو اس کا ثواب مل جائے گا۔

163۔ بر صغیر کی آزادی کے بعد لاہور آ گئے۔

164۔ میرا خیال تھا کہ وہ پوچھے گا کہ آپ نے کیا فیصلہ کیا۔

165۔ تورات جو حضرت موسی پر نازل ہوئی۔

166۔ لوگ یہ بھی کہتے ہیں۔

167۔ یہاں جو مشاعرے ہوتے تھے، میں ان میں برابر شریک ہوتا۔

168۔ پیٹ بھر کر کھلاتا۔

169۔ جن حضرات کو یحیی بن سعید نے چھوڑا ہے ان سے عبداللہ بن مبارک وبن خزاع ہیں ۔

170۔ لا حول ولا قوۃ۔

171۔ اور زمین کی اور اس کی جس نے اسے بچھایا۔

172۔ اس مضمون کی اور بھی بہت سی آیتیں قرآن پاک میں موجود ہیں ۔

173۔ اس لئے یعقوب کھانا لا کر دیا تو اس نے کھانا کھا لیا۔

174۔ آتے تھے اور اپنے اپنے دوستوں کو بلا لاتے تھے ۔

175۔ مان لو وہ کہیں چھپ گیا ہو تو۔

176۔ یہ وہی خوشخبری کا کلام ہے جو تمہیں سنایا گیا تھا۔

177۔ وہ مشرقی سمت میں پائے جانے والے ملک کو چلے گئے ۔

178۔ آزاد کرنے والے کو بھی مولی کہتے ہیں اور غلام کو بھی ۔

179۔ خالق وہ ہوتا ہے جو اپنے بندوں کے رزق کا ضامن ہو۔

180۔ اسی دن کے لئے پیدا کیا تھا تجھے تیری ماں نے۔

181۔ سرمد خجل سا ہو گیا۔

182۔ لسی پیو گے یا دودھ۔

183۔ اور اسی کی طرف لوٹ کر جانا ہے ان سب نے۔

184۔ اسی دوران میں نے محسوس کیا کہ میں پہلے سے زیادہ اس سے محبت کرنے لگا ہوں۔

185۔ بعض علماء نے بیان کیا۔

186۔ ثانیا لوگوں کو یہ بتایا گیا ہے کہ اللہ ہی ساری کائنات کا مالک و مختار ہے۔

187۔ وہ چیخ چیخ کر کہہ رہی تھی۔

188۔ کیا شہید وہ لوگ ہیں جو اللہ کی راہ میں قتل ہوئے۔

189۔ تم ان کی طبیعت سے اچھی طرح واقف ہو۔

190۔ رام تھکا ہوا ہو گا۔

191۔ اور جان رکھو کہ خدا غالب اور صاحب حکمت ہے۔

192۔ آپ نے فرمایا بے شک اس کی محبت تمہیں جنت میں لے جائے گی۔

193۔ ماں ہم نے جو کچھ کیا ہے، ٹھیک کیا ہے۔

194۔ ہم ہی نے تمہیں پیدا کیا ہے، پھر تم تصدیق کیوں نہیں کرتے۔

195۔ تمہاری رائے ہم کو اس بات میں پسند ہے۔

196۔ اے اللہ میں تیری پناہ مانگتا ہوں۔

197۔ دیکھنا یہاں کیا خوب بیان فرماتے ہیں۔

198۔ بعض لوگ حالت احرام میں تھے اور بعض لوگ بغیر احرام کے تھے۔

199۔ ضرورت سے زیادہ تحفظ نے ایک عذاب میں مبتلا کر دیا ہے۔

200۔ قریب تھا کہ قلعہ ٹوٹ جائے۔

Appendix D: Corpus 2

1۔ وہاں اُنھیں کچھ فرائض بھی ادا کرنے ہوتے ہیں۔۔

2۔ کسی شہری کے فرائض سے مراد وہ ذمہ داریاں ہیں جن کا پورا کرنا ہر شہری پر لازم ہے۔

3۔ اچھا شہری ہمیشہ اپنے ملک، قوم اور وطن کا وفادار ہوتا ہے۔

4۔ اُس کے ملک کے مفاد میں ہوں۔

5۔ ہر طالب علم بھی ایک شہری ہے۔

6۔ شہری کی حیثیت سے اُس پر بھی کچھ فرائض عائد ہوتے ہیں۔

7۔ ایک طالب علم کا فرض ہے کہ دِل لگا کر تعلیم حاصل کرے

8۔ کیونکہ تعلیم کے بغیر نہ تو کوئی فرد اچھا شہری بن سکتا ہے

9۔ اور نہ ہی مہذب زندگی بسر کر سکتا ہے۔

10۔ کسی ملک میں صحیح تعلیم و تربیت جس قدر عام ہوگی

11۔ فرائض کی ادائیگی اتنی ہی آسان ہوگی

12۔ اگر ہر طالب علم اپنی تعلیم کے ساتھ ساتھ ایک ناخواندہ کو بھی پڑھاتا رہے

13۔ تو ملک سے بہت جلد جہالت کا خاتمہ ہوسکتا ہے۔

14۔ ہم اللہ تعالیٰ کے فضل وکرم سے مسلمان ہیں۔

15۔ اسلام ہمارا دین ہے پر زور دیا ہے۔

16۔ ہم جتنے اچھے مسلمان بنیں گے اُتنے ہی اچھے شہری ثابت ہوں گے۔

17۔ اور ملکی اداروں کے قوانین کا احترام کریں۔

18۔ نظم وضبط کا خیال رکھیں۔

19۔ قومی چیزوں کی حفاظت، سکول کی عمارت، اس کا ساز وسامان، پودے اور درخت سب قومی دولت ہیں۔

20۔ ان کی نہ صرف حفاظت کرنا بلکہ جہاں تک ممکن ہو، اِن میں اضافہ کرتے رہنا بھی ہمارا فرض ہے۔

21۔ جس طرح ہم اپنی ذاتی چیزوں کی حفاظت کرنا ضروری خیال کرتے ہیں

22۔ اِسی طرح دوسرے لوگوں کی چیزوں کا خیال رکھنا ہر شہری کا فرض ہے۔

23۔ بغیر اجازت کسی کی کوئی چیز استعمال کرنا، اِسے خراب کرنا یا چرا لینا گناہ ہے

24۔ ہمیں چاہیے کہ اگر کسی کی گری ہوئی کوئی چیز ملے تو اسے اس کے مالک تک پہنچا دیں۔

25۔ اچھے شہری کا فرض ہے کہ وہ دوسروں کی سہولت کا خیال رکھے۔

26۔ ہسپتال، ڈاک خانہ، بینک اور دوسری جگہوں پر قطار میں کھڑے ہوکر اپنی باری کا انتظار کرے۔

27۔ دوسروں کی حق تلفی کرکے آگے بڑھنے کی کوشش نہ کرے۔

28۔بوڑھے، بزرگ، بیمار اور نابینا کا ہاتھ پکڑ کر اُسے سڑک پار کرنے میں مدد دے۔

29۔کیا خوب ضربُ المثِل ہے

30۔ ''ہمسایہ ماں جایا۔

31۔ '' ہمسائے بھائیوں کی طرح ہوتے ہیں

32۔ اچھے شہری کو پڑوسیوں کے ساتھ اچھا سلوک کرو۔

33۔ عام دِنوں میں قومی پرچم صرف اہم سرکاری عمارتوں، دفاتر، سکولوں اور دوسرے ممالک میں قائم سفارت خانوں کی عمارتوں پر لہرایا جاتا

ہے۔

34۔ قومی پرچم طلوعِ آفتاب کے بعد کسی بھی وقت لہرایا جاسکتا ہے

35۔ لیکن غروبِ آفتاب سے پہلے لازماً اُتار لینا چاہیے۔

36۔ شام کے بعد قومی پرچم کو لہرائے رکھنا اِس کی بے حرمتی کے مترادِف ہے۔

37۔ قومی پرچم ہمیشہ سیدھا اَور سربلند ہونا چاہیے۔

38۔ کسی بھی وجہ سے اُس کا جھکا ہوا ہونا اِس کی بے حرمتی ہے۔

39۔ کسی دوسرے ملک کے پرچم کے ساتھ اپنا قومی پرچم لہرانا ہو تو قومی پرچم ہمیشہ دائیں طرف ہوگا۔

40۔ اگر پرچم زیادہ ہوں تو ہمارا قومی پرچم درمیان میں ہوگا اَور نمایاں نہیں ہوگا۔

41۔ اَور کوئی بھی پرچم، کسی بھی موقع پر ہمارے پرچم سے اُونچا زیادہ پرچم لہرائے یا اُتارے جارہے ہوں

42۔ تو قومی پرچم دوسرے پرچموں سے پہلے لہرایا جاتا ہے

43۔ اَور اُتارتے وقت دوسرے پرچموں کے بعد اُتارا جاتا ہے

44۔ جب قومی پرچم لہرایا یا اُتارا جارہا ہو تو ادب سے کھڑے ہوکر اس کی تعظیم کرنی چاہیے۔

45۔ ایسے موقعوں پر پرچم کشائی کے ساتھ قومی ترانے کی دُھن بھی بجائی جاتی ہے۔

46۔ یومِ آزادی کے موقع پر لوگ اَور خصوصاً بچے اپنے گھروں اَور تعلیمی اداروں کو پرچم والی جھنڈیوں سے سجاتے ہیں

47۔ اِن جھنڈیوں پر آج کل طرح طرح کی تصویریں بنی ہوتی ہیں۔

48۔ چاند ستارے کے علاوہ پرچم پر کسی قسم کی تصویر بنانا جرم ہے۔

49۔ بچوں کو چاہیے کہ اس قسم کی تصویروں والی جھنڈیاں کبھی نہ خریدیں۔

50۔ ماحول صاف، بیماری غائب شہر میں خسرے اور ملیریا کی وَبا پھیلنے کی خبر عام تھی۔

51۔ اخبارات، ریڈیو اور ٹی وی کے ذریعے سے لوگوں کو احتیاطی تدابیر سے رُوشناس کرایا جارہا تھا

52۔ اور اِن پر عمل کرنے کی ترغیب دی جارہی تھی۔

53۔ مائیں ہر وقت دعائیں کرتی تھیں

54۔ ''یااللہ! ہمارے بچوں کو اس موذی مرض سے محفوظ رکھنا۔

55۔ '' محکمۂ صحت کے کارِندے گھر گھر جاکر بچوں کو حفاظتی ٹیکے لگا رہے تھے۔

56۔ اُس دِن مسعود کے محلے کی باری تھی۔

57۔ مسعود کے بہن بھائیوں کو ٹیکے لگانے کے بعد ٹیکے والے دُوسروں کے گھروں پر بھی گئے۔

58۔ ہر گھر سے ماں یا باپ اپنے بچوں کو لے کر باہر آتے اور اُن کو ٹیکے لگوا لیتے۔

59۔ دیکھتے ہی دیکھتے کتنے بچوں کو ٹیکے لگ گئے

60۔ مگر محلے میں کچھ لوگ ایسے بھی تھے، جنھوں نے اپنے بچوں کو چھپا دیا تھا۔

61۔ نجو کی اماں تو ٹیکے والوں کی آمد کا سن کر تھر تھر کانپنے لگیں اور نجو سے کہنے لگیں

62۔ ''تو خالہ کے گھر بھاگ جا'' اور رشیدہ سے کہا:

63۔ ''تو چادر اوڑھ کر لیٹ جا، میں کہ دُوں گی،

64۔ اِس کو بخار ہے، بخار میں ٹیکے نہیں لگ سکتے''

65۔ سب سے زیادہ غضب تو حنیفہ نے ڈھایا۔

66۔ اس نے اپنی تینوں لڑکیوں کو اندر بند کر کے کنڈی لگا دی۔

67۔ تیسرے دِن سننے میں آیا کہ حنیفہ کی تینوں بچیوں کو خسرے کے دانے نکل آئے ہیں

68۔ ماموں جان کہنے لگے: ''حنیفہ! بیماری کا گھر تو تم نے خود ہی بنا رکھا ہے۔

69۔ ذرا دیکھو تو اتنا غلیظ پانی اور اس میں مکھیوں کا مچھروں کی کثرت!

70۔ یہ تو ملیریا، ہیضہ اور انفلوائنزا کا گھر بنا ہوا ہے۔

71۔ جب تک اس نالی کو پاٹ کر پکی نالی نہیں بنے گی

72۔ پانی کا نکاس نہیں ہوگا، ملیریا اور فلو تو خیر، یہاں ہیضہ پھیلنے کا خطرہ بھی رہے گا۔''

73۔ ڈاکٹر کا نام سن کر نجو کی اماں بھی آگئی تھیں۔

74۔ دونوں عورتیں کہنے لگیں:

75۔ ''ڈاکٹر صاحب! ہم غریب لوگ بھلا پکی نالی کیسے بنوائیں اور پھر گندے پانی کا نکاس ہو بھی تو کیسے؟

76۔ کون گوارا کرے گا کہ اس کے گھر کے گے سے گندا پانی بہے۔

77۔ بس ہمارے تو نصیب ہی خراب ہیں

78۔ ' ڈاکٹر نے کہا: ''بھئی تمھارے نصیب کی خرابی تو یہ لڑکے دُور کر سکتے ہیں۔

79۔ '' اِن کا اِشارہ مسعود اور اس کے دوست حامد کی طرف تھا

80۔ جو کالے کالے پانی میں پھدکتے مینڈکوں کو غور سے دیکھ رہے تھے

Appendix E: Corpus 3

1۔ آج بارھویں دسمبر ہے اور موسم بڑا خوشگوار ہے

2۔ کیونکہ کالی گھٹائیں چھائی ہیں اور ٹھنڈی ہوا چل رہی ہے۔

3۔ اچانک بجلی کوندی، مینہ کی باڑھ آئی تو سب کھیتوں کی سنچائی ہو گئی۔

4۔ اب ژالہ باری ختم ہو چکی ہے۔

5۔ پھول اور پودے بارش میں بھیگ رہے ہیں۔

6۔ یار، دوستوں کے سنگ، فکروں سے غافل، جھیل کے عین کنارے بیٹھے موسم کا مزا اٹھا رہے ہیں۔

7۔ شہر سے دور، گھروندوں کے پاس، کھیتوں میں دھند کے درمیان، تھکن سے چور ننھے بچے بھاگ کر ایک دوسرے کو ڈھونڈ رہے ہیں

8۔ سورج کا چہرہ نمودار ہوا تو مہلت ملتے ہی کنویں پر سینکڑوں الھڑ مٹیاریں، کمھار کے بنے مٹکے اٹھائے، بھنور کی صورت، قرارِ جاں لوٹنے چلی آئیں۔

9۔ وہ وہاں کھنچا چلا آیا

10۔ پہاڑوں سے گھرے کہسار میں پرندوں کے چہچہانے کی آوازیں کانوں میں رس گھولتیں

11۔ شبنم سے سنورتے پھولوں کی دھیمی خوشبو، جھرنوں سے چھلکتا اور کنووں کا ٹھنڈا یخ پانی روح کی گہرائی تک تازگی کا احساس پہنچاتا۔

12۔ غروبِ آفتاب اورچڑھتے ماہتاب سے پہلے اور ژالہ باری کے بعد ابھرنے والی قوسِ قزح کے خوبصورت کھلے کھلے رنگ چہرے پر

مسکراہٹ بکھیر دیتے۔

13۔ ڈھلتی رات کے عہد میں گھریوں لگتے جیسے فضا میں ٹمٹماتے جھلملاتے جگنو، جو اس کو ساری تھکان بھلا دیتے

14۔ مستنصر حسین تارڑ المعروف چاچا جی اور ثمر ٹوپی والا مضطربی اور غنودگی کی کیفیت میں ہیں۔

15۔ ژالہ باری کے دوران قسطنطنیہ سے تاشقند کی جانب بحیرہ قلزم کی سیر کی یادوں کے ڈھیروں جم غفیر کے ساتھ اُنھیں دُہراتے اور

بحث کرتے ہوئے عازم سفر تھے۔

16۔ چودھویں رات کی چاندنی اور سمندر کی لہروں کا شور ہے۔

17۔ دھڑا دھڑ برستی برف کے گولے، سیاحوں کا چھوٹے بچوں کی طرح چیخنا چلانا، دوڑنا بھاگنا اور قہقہے لگانا غضب کا نظارہ پیش کرتے ہیں۔

18۔ وہ ایسے اونگھ رہے تھے جیسے گھنے درخت کے نیچے لیٹے ہوں

19۔ اور پورا گاؤں اُن کے گرد پھیریاں لے رہا ہو۔

20۔ اور کوئی الہڑ دوشیزہ درختوں کی ٹھنڈی چھاؤں کے نیچے پینگ جھول رہی ہو

21۔ اور اُس کے پاؤں بلند شاخوں تک پہنچ رہے ہوں اور ہر کوئی کھنچا چلا آرہا ہو۔

22۔ کہتے ہیں ایک دفعہ شہزادہ قمرالدین نے ایک خوفناک اور بھیانک طلسمی جنگل میں پہنچنے کے لیے لاکھوں کروڑوں میلوں کا فاصلہ طے کیا۔

23۔ جیسے ہی وہ منہ اندھیرے جنگل میں پہنچا

24۔ اُس نے وہاں چھوٹے چھوٹے غار نما، سونے چاندی ہیرے زیورات کے بنے رنگ برنگے بے شمار گھر دیکھے

25۔ جو پھل پھولوں سے لدے ہوئے درختوں میں چھپے ہوئے تھے۔

26۔ گھروں کے سامنے بے شمار، کتے، اور گیدڑ جھنڈ بنائے ایک گول دائرے میں اونچی اونچی آواز میں صدائیں لگا رہے تھے۔

27۔ اُس گول دائرے میں ایک خوبصورت دلھن اور بوڑھی عورت بیٹھی ڈھول بجا رہی تھیں۔

28۔ ایک منھیاری دُلھن کو چوڑیاں پہنا رہا تھا۔

29۔ یوں معلوم ہوتا تھا جیسے پورا جنگل کسی طلسم کی گرفت میں ہو۔

30۔ تھوڑی دیر بعد ایک جادوگر سہرا باندھے ایک کنویں سے نکلا۔

31۔ جیسے ہی وہ دُلھن کے پاس پہنچا، ایک لونڈی پندرہ سونے کے تھال لے کر آئی۔

32۔ جادوگر نے ایک ایک کر کے تھال سے کپڑا اُٹھایا۔

33۔ جیسے ہی اُس نے پندرھویں تھال کا کپڑا کھینچا،

34۔ سمندر میں بھنور بننے لگا اور ژالہ باری شروع ہوگئی۔

35۔ جادوگر نے کہا میں آج سے تمھارا بادشاہ ہوں

36۔ اور میرا عہدہ سب سے بلند ہے۔

37۔ شہزادے نے جیسے ہی یہ سنا

38۔، اُس نے اپنی طلسمی تلوار نکالی اور مقابلے کے لیے تیار ہوگیا۔

39۔ کیا بتاؤں، میں پرندہ، انڈے کے ٹوٹے چھلکے سے نکلا

40۔ تو ابتدا سے ہی میری ماں نے مجھے سینکڑوں باتیں پڑھائیں ۔۔۔۔

41۔ وہ دور کے سفر میں کہیں بجلی اور ژالہ باری کوندتی ۔

42۔ مجھے احساس ہے کہ اکثر میں، بارش میں رات گئے تک محض جگنوؤں کے بھروسے طے کرتا رہا۔

43۔ البتہ آج روح پرسکوں ہے

44۔ کہ ایک دفعہ تیز بہاؤ اور بھنور میں غوطے کھاتی ایک چیونٹی کی جان میں نے عین موقع پر پتہ پھینک کر بچالی تھی۔

45۔ ہر ذی شعور اپنی خلقت پر متعجب ہے۔

46۔ خود پر غور کرنے سے بتھیرے سوالات ابھرتے ہیں۔

47۔ کیا انسانی زندگی دو حصوں میں بٹی ہے:

48۔ روح اور جسم۔ کیا فکر انسانی ٹھوکریں کھانے کے بعد روح کی حقیقت کو ڈھونڈ پائی ہے۔

49۔ جس سے فضا میں ننکی بہت بڑھ گئی۔

50۔ مرجھائے ہوئے پھول پودوں میں جان آگئی۔

Appendix F: Durational Analysis of Unstressed and Stressed Vowel

A	B	C	D	E	F	G
VOWELS	Non-Final 0	Non-Final 1	Final 0	Final 1	Final with PAU 0	Final with PAU 1
			Short Vowels			
A	57	81	61	86	75	107
	65	82	67	93	NA	123
	58	NA	69	94	NA	167
AVERAGE	60	82	65	91	75	132
A_N	NA	80	NA	NA	NA	NA
	62	83	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA
AVERAGE	62	82	NA	NA	NA	NA
U	57	85	60	82	89	99
	60	102	NA	111	NA	NA
	62	95	65	97	NA	NA
AVERAGE	60	94	63	97	89	99
U_N	NA	NA	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA
AVERAGE	NA	NA	NA	NA	NA	NA
I	54	85	56	79	77	88
	52	76	59	NA	75	NA
	59	86	7NA	93	NA	NA
AVERAGE	55	82	58	86	76	88
I_N	NA	NA	NA	NA	NA	NA
	NA	69	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA
AVERAGE	NA	69	NA	NA	NA	NA

Low Long Vowels						
A_A	104	132	98	149	133	186
	112	148	108	166	122	191
	96	127	100	143	NA	224
AVERAGE	104	136	102	153	128	200
A_A_N	101	155	78	152	148	211
	NA	145	NA	NA	NA	
	NA	166	100	117	NA	NA
AVERAGE	101	155	89	135	148	211
A_E	88	115	NA	175	159	189
	101	138	NA	197	213	175
	99	117	NA	175	195	236
AVERAGE	96	123	NA	182	189	200
A_E_N	NA	143	NA	145	167	219
	NA	145	NA	NA	183	199
	NA	NA	NA	158	NA	239
AVERAGE	NA	144	NA	151.5	175	219
O	114	143	85	128	141	176
	NA	143	99	111	NA	NA
	98	114	92	145	NA	0
AVERAGE	106	133	92	128	141	88
O_N	NA	99	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA
	NA	117	NA	NA	NA	NA
AVERAGE	NA	108	NA	NA	NA	NA
High Long Vowels						
A_Y	70	116	81	140	135	188
	99	110	97	135	121	152
	87	102	88	127	NA	215

AVERAGE	85	109	89	134	128	185
A_Y_N	NA	NA	93	149	154	213
	NA	NA	112	NA	126	170
	NA	NA	102	135	NA	NA
AVERAGE	NA	NA	102	142	140	192
O_O	94	119	87	138	141	210
	NA	124	88	143	125	NA
			84	124	100	236
AVERAGE	94	122	86	135	122	223
O_O_N	NA	148	89	112	225	192
	NA	NA	115	150	154	214
	NA	110	94	134	NA	NA
AVERAGE	NA	129	99	132	190	203
U_U	80	107	97	134	152	185
	91	118	NA	165	NA	187
	101	107	99	128	NA	NA
AVERAGE	91	111	98	142	152	186
U_U_N	NA	176	104	178	158	231
	NA	143	NA	139	NA	NA
	NA	118	NA	111	NA	NA
AVERAGE	NA	146	104	143	158	231
I_I	78	126	86	131	144	204
	NA	139	95	121	134	177
	91	113	90	121	224	226
AVERAGE	85	126	90	124	167	202
I_I_N	NA	NA	91	135	140	192
	NA	NA	106	159	NA	162
	NA	NA	89	110	NA	235
AVERAGE	NA	NA	95	135	140	196
Medial Vowels						

A_E_H	67	87	57	78	NA	99
	73	73	106	NA	NA	NA
	55	59	NA	NA	NA	NA
AVERAGE	65	73	82	78	NA	99
A_Y_H	57	83	60	96	87	99
	79	84	NA	NA	NA	NA
	56	67	NA	NA	NA	121
AVERAGE	64	78	60	96	87	110
O_O_H	65	114	NA	NA	NA	NA
	98	NA	NA	NA	NA	NA
	65	NA	NA	NA	NA	NA
AVERAGE	76	114	NA	NA	NA	NA

Appendix:G 'Model of Mechanism for determining Urdu Stress Using Acoustic Cues'