*Journal of Language and Cultural Education, 2018, 6(3)*
*ISSN 1339-4584*
*SlovakEdu*

sciendo

DOI: 10.2478/jolace-2018-0023

# Experimental Phonetics and Phonology in Indo-Aryan & European Languages

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**Abstract**

Phonetics and phonology are very interesting areas of Linguistics, and are interrelated. They are based on the human speech system, speech perception, native speakers' intuition, and vocalic and consonantal systems of languages spoken in this world. There are more than six thousand languages spoken in the world. Every language has its own phonemic inventory, sound system, and phonological and phonetic rules that differ from other languages; most even have distinct orthographic systems. While languages spoken in developed countries are well-studied, those spoken in underdeveloped countries are not. There is a great need to examine them using a scientific approach. These under-studied languages need to be documented scientifically using advanced technological instruments to bring objective results, and linguistics itself provides the scientific basis for the study of a language. Most research studies to date have also been carried out with reference to old or existing written literature in poetry and drama. In the current era of research, scholars are looking for objective scientific approaches, e.g., experimental and instrumental studies that include acoustic research on the sound systems of less privileged languages spoken locally in developing countries. In this context, Sindhi is an example of this phenomenon, and un-researched with reference to syllable structure and the exponents of lexical stress patterns.

**Key words: e**xperimental phonetics, phonology, lexical stress, stress patterns

## Introduction

This paper discusses the literature of Indo-Aryan and some of the European languages focuses on the aspects of experimental phonetics and phonology. Very limited research has been carried out on phonetics and phonology with special reference to Acoustic phonetics in Pakistan. Acoustic phonetics comes under the head of speech science, also known as experimental phonetics; this field also includes physiological phonetics. It is the scientific study of human speech sounds, whereas physiological phonetics defines how the nervous system, muscles, and other organs are operated during speech. This science of speech explains how these sounds are made acoustically (Pickett, 1999). Acoustics examines the physical properties of speech sounds with reference to linguistic related acoustic realizations of speech sounds (Davenport & Hannas, 1998).

Fry (1955, 1958) was a pioneering figure and his first ever seminal work on the acoustic correlates of stress in English where Fry applied these factors like duration, intensity, and fundamental frequency. In addition, Gordon's work is merely one of many that explore the phonetic exponents of stress. For instance, Gordon (2004) investigated the phonetic study of stress in Chickasaw through acoustic data from eight speakers of Chickasaw. The study examined duration, fundamental frequency, intensity, and vowel quality as evidence for lexical level stress to determine how primary stress, secondary, and stressed syllables are phonetically distinguished from each other and from unstressed syllables.

Gordon (2004) notes that many aspects effect phonological analysis of stress prominence in a language, e.g., speaker's intonational aspect in the utterance, syllable structure, and morphology, therefore acoustic analysis acts as a tool for examining stress and facilitates factors that help the syllable to be prominent. While many researchers of phonetics and phonology have given various definitions on stress, the present study refers to stress as the prominence of the syllable as compared to adjacent syllables at the lexical level. Stress is a relative factor, unlike aspects such as vowel quality, place, and manner features.

In addition, the part of speech production in which the stressed syllable is more prominent involves the following: length or duration of vowels, vowel quality, loudness, and pitch. Thus, the stressed syllable is longer, louder than its adjacent syllables, and may also be marked by the pitch movement as noted in the literature review. To examine these factors acoustically, several acoustic parameters were examined to determine the stress pattern of a language, e.g., (F0) fundamental frequency, duration of stressed and unstressed syllables, intensity, and vowel quality (F1 and F2). Furthermore, acoustic analysis is often carried out using the Praat. Therefore, the present study also utilized the Praat software (Boersma & Weenink, 2014) to examine 2000 recorded voice samples of Sindhi speech.

The acoustic study of speech provides a scientific method to conduct an objective analysis of speech sounds by measuring physical properties of sounds and their acoustic realizations. As discussed in the literature review, the measurements of these sound properties, i.e., formants (F1 and F2), duration, and intensity, are then used to investigate the sound pattern of a language. Similarly, this study carried out an acoustic analysis of phonetic measurements of lexical stress in Sindhi using the following: (a) Duration of stressed vs. unstressed vowels, (b) Duration of stressed vs. unstressed stop closures, (c) Formant frequency (F1) stressed vs. unstressed vowels, (d) Formant frequency (F2) stressed vs. unstressed vowels, and (e) Formant frequency of stressed vs. unstressed vowels.

In addition, the segmental study of acoustic analysis was conducted on Sindhi by Keerio (2010). The current study has phonetically and phonologically analyzed lexical stress to document this very important aspect in Sindhi. Gordon (2004) argues that, on a supra-segmental level, stress often brings about lengthening (duration), higher F0, and greater intensity, though there are many languages in which these properties do not meet on a single syllable but rather are distributed over multiple syllables.

**Background**

Phonetic analysis of lexical stress is very important where native speakers do not have strong intuition regarding which syllables have primary, secondary, and tertiary stresses at the lexical level. The author argues that Sindhi native speakers do not have strong intuition about the syllable structure and stressed or unstressed syllables in speech. In contrast, English native speakers, whether they are American or British, do have strong intuition about their lexical syllables and stressed or unstressed syllables at the lexical level. This acoustic study of stress patterns, their acoustic realizations, and the perceptual judgments of syllable boundaries by native speakers was developed to explore this issue and address the need for this knowledge. The resulting study findings can be used to enhance learning-ability and teach-ability of syllable structure and stress pattern of Sindhi acoustically for speech therapy and audio-dictionary. Most importantly, the results can be applied to the teaching of phonetics and phonology of other languages, especially English, for Sindhi native speakers and other speakers in general. The paper covers all aspects of experimental phonetic researches have been studied and what are the exponents of lexical stress and how we can study them in terms of its acoustic realizations.

Sindhi is an Indo-Aryan language. It is widely spoken in Sindh, Pakistan and is recognized as the official language by Sindh government (Cole, 2005). There are 22.1 million Sindhi speakers in Pakistan whereas, ethnic population is: 26 million. Total Sindhi speakers in all countries in the world are follows: 23.846 million (2016, as cited in Lewis, M. P, Gary, F. S & Charles D. F. (eds.)).

A written version of Sindhi is used in extended Arabic script in Pakistan; whereas, the script for writing of Sindhi language in India is Devanagari. A little work has been done on Acoustic and Supra-segmental aspects in Sindhi. Sindhi however, has been researched relatively less about the phonological aspects of the language: Syllable structure, syllabifications, and phonological and acoustic stress pattern. Gierison (as cited in Allana, 1996) states that Sindhi consists of six dialects: *Vicholi* which is spoken in central Sindh and considered as a standard dialect of Sindhi, *Utradi (Northern)*, *Lari, Lasi, Kachchi,* and *Thareli*. These dialects have phonetic and phonological variations as noted by many researchers. This research project carried out a phonetic study of the *Utradi (Northern)* dialect only spoken in upper Sindh. The study particularly focuses on stress pattern in terms of phonological and acoustic factors in detail along with syllable structure and the pitch-accent of Sindhi, and work done on general and particular aspects of stress pattern.

### Dialects

The geographically standard dialect of the language is called *Vicholi* (*Central*) dialect in Sindhi. Sindhi is formally taught from the elementary to high secondary level, and formal text is also documented in this dialect of learning-ability and teach-ability for the students and the teachers. This dialect is spoken by educated class of people living in or out of central region of Sindh. The second dialect, *Thareli*, is spoken in Therparker (desert) region of Sindh. This dialect contains fewer sounds overall and several consonantal sounds are modified in their speech by the native speakers. *Kachchi*, the third dialect, is spoken in Cutch, India, after the partition Sindhi-speaking Hindi community left for India. The fourth dialect, *Lari*, is spoken in the Lar region of Sindh. *Lasi,* the fifth dialect, is spoken in the southwest of the Central region of Baluchistan, and sixth dialect *Utradi (Northern)* which is spoken in upper Sindh as reported by the phoneticians and historians of Sindh (Allana, 1996).

### Prior work on syllable structure

This section reviews most of the prior work carried out in phonetics and phonology. The work looks at all related research that has been explored in this field and the main arguments about these important aspects of phonetics and phonology. Ladefoged and Maddieson (1996) note that syllable is very important phonological component which illustrates vague phonetic correlates. Even segmental sonority, a central concept in explaining the organization of the syllable, is highly phonologized (Parker, 2002). The syllable is an aspect of stressed and unstressed prominence of a sound at word level. Ashby and Maidment (2008) state the 'shortest stretch of speech is not the single sound, but rather the syllable; a syllable is like a one pulse of speech'. Syllable has a structure and is observed through phonological features. The syllables may be explained as occupying the center that has little or no obstruction to airflow and which phones relatively loud; there would be greater resistance to airflow before and after the center (Roach, 2004).

Crystal (2008) defines the term of stress as to be the degree of energy used in the production of a syllable. Common description of lexical stress is taken for granted e.g., the alteration between stressed vocalic sound and unstressed vocalic sound on the word level. The syllable prominence is basically based on the factors i.e., loudness of the syllable coupled with wideness of length in duration, in this way, overall pitch supports and is associated with length and higher intensity of the syllable. The key role of stress in Phonology is to distinguish between emphasis and contrastive stress.

A syllable contains the structure, in other words, a few phonemes of a language in a sequence. The syllable structure in the English word *Tom* consists of the phonemes /t/, /ɒ/, and /m/, in that order; the words *ant* and *pen* have the same three phonemes but in different order. Kenstowicz (1994) describes the syllable as a crucial idea to understand phonological factors. The body of the syllable consists of a binding nucleus which involves an optional consonantal onset and follows a consonant coda. The nucleus forms a strong bond with coda and onset plus nucleus, whereas the rhyme is juxtaposed by the nucleus and the coda. Kenstowicz (personal communication, March 2012) argues that loanwords can sometimes reveal restrictions on syllabification, e.g., CC clusters that cannot be fitted by the language, then the syllable structure may be altered by a consonant deletion or vowel epenthesis; which may be a possible source of evidence. The same observation may be interpreted that epenthesis is often employed to aid syllabification (Itô, 1989).

Additionally, the syllable is often described in terms of linguistic as well as phonological theory. This debate is still in vogue for variety of views. As Haugen (1956) argues about syllable all try to research and talk about syllable but no one defines syllable. There were so many attempts to come closer to any solid agreement. However, the aspects of syllable i.e., onset, rhyme, nucleus, and coda are the basic constitutes of syllable, yet nothing can be pointed to invariant acoustic or articulatory evidence. In addition, the syllables do exist, which can be assumed that when language speakers produce them individually. This is an evidence which is often pointed out as to be the syllable with structure. Feinstein (1979) argues about the distinction of speaker's syllable and the phonological syllable. The speaker's syllable is simple and automatic in calculated speech or through experimental studies by looking at external evidences i.e., languages games and through behavioral data. Whereas, the phonological syllable can be defined through empirical data. This sort of question was explored to know the nature of syllable through experiments by eliciting responses and through acoustic properties to syllabification tasks. So far, most of the studies have been carried out to investigate syllable boundaries by looking at syllables placing in an intervocalic consonantal environment (Bosch, 2011).

## Principles of syllabification

Native speakers of various languages, including English, have a strong intuition regarding syllables of English words, and most of them will agree on the numbers of syllables in a word and which syllable is stressed and which one unstressed. Native speakers of Hindi, Urdu, and Sindhi, differ in which syllable is stressed and which is unstressed. They also do not have sound-strong intuition of syllables in the words. Unlike syllabification of a language, is the nativity of the native speaker to break down words into syllables with an implicit intuition in agreement with other native speakers of the same language. In addition to this phenomenon, this study also focuses at the two major principles of syllabification: Sonority Sequencing Principle (SSP) and Maximal Onset Principle (MOP). Most languages follow these principles. However, some languages can violate MOP by breaking CC-clusters. Kenstowicz (1994) contends that the SSP demands onset syllable to ascend in sonority towards nucleus and coda syllables to break down in sonority from nucleus. In the MOP onset is prolonged with consonants if possible, and in this way a legal coda is formed (Gussenhoven & Jacob, 2003). This principle prefers consonants to be on the onset, licensing no coda consonants except for the final word. Evidence of syllables is the restrictions of sounds on onset, medial, and final positions of words, which stays in the minds of native speakers of a language. As noted by Hawkins (1992) that phonotactics is to be the combination of sounds in order. The present study has explored what phonotactic constraints are preferred in Sindhi and which CC clusters and at what syllable positions of the word are licensed; this was also done by Jatoi (1996). This kind of study is known as *phonotactics* (Giegerich, 1998).

Additionally, Hussain (2005) contends that syllabification is done through the application of syllable CV templates and fixing them from either right to left or left to right direction, or by the projection of nuclei through applying SSP and MOP to incorporate some other factors of phonology. MOP prioritizes maximum onset consonants and others to fall on coda. According to Carr (2008), the MOP principal explains that phonotactic restrictions are language-bound. If a consonant may make up a well-formed coda then another consonant can be syllabified as an onset of a word. English word *Appraise* is syllabified as follows: *əp.reiz;* is an English word which fulfils the phototactic constraints of the language since on the first syllable coda /p/ is authentic, as in *cup*; an onset consisting only /r/ is also legitimate, as in *run*; and /pr/ CC is also legitimate, as in *pray.* Therefore, the syllabification of the English word *ə.preiz* is permissible in terms of the phonotactics of English.

### Sonority hierarchy

Parker (2011) argues that it has remained very problematic issue in phonological theory which has brought it to more contending offers than the interior construction of the sonority hierarchy, e.g., natural classes and hierarchical ranks. Parker (2002) claims to have more than 100 distinct sonority ranks in the literature.

**Epenthesis phenomenon**

Many of the languages in the world do not have CC consonant clusters. If native speakers of these languages encounter CC as loanwords in their languages then these CC clusters are broken through epenthesis phenomenon. This is called the phonotactics of the language, because native speakers follow the pattern of their own language. This kind of phonological phenomenon is involved in several languages, particularly when the CC cluster is terminated through the insertion of a vocalic sound, or sometimes insertion occurs at the syllable onset position. Crystal (1997) explains this phenomenon as *epenthesis*, a phonological attribute in which 'an extra vocalic sound is infixed into a word, often categorized as either prothesis (an extra sound is inserted initially in a word) or anaptyxis (an extra sound is inserted between two consonants)' (Crystal, 1997). This is further illustrated by Fleischhacker (2000) as follows: Bharati (1994) argues Hindi native speakers have similar pattern when they produce English words. For Hindi native speakers, syllable onset CC [sm] clusters, like CC st clusters, are resolved through prothesis: e.g., [ɪsmaai:l] 'smile'; whereas, for onset CC [sn] and [sl] clusters, prothesis and anaptyxis are in free variation: [sɪnek] ~[1] [ɪsnek] 'snake', [sɪlo] ~ [ɪslo] 'slow'. Singh (1985) and Broselow (1992) contend that native speakers of Hindi break up CC clusters either by inserting a vowel or by placing a vowel initially, for instance, in *ɪskul* 'school' and in *pɪli: z* 'please' English words.

**Syllable weight**

**Quantity sensitive and quantity insensitive stress**

Hayes (1981) notes that there are two alternative stress rules: quantity sensitive and quantity insensitive. Quantity insensitive rules assign stress to the syllable irrespective of phonological aspect, whereas quantity sensitive rules assign stress to the syllable based on its weight. Syllable weight refers to syllables with long vowels or with consonant clusters, as compared to those with short vowels and one consonant (Hayes, 1985). This study is also designed to investigate whether Sindhi is a quantity sensitive or insensitive language, and how and where primary stress is assigned because of weight (versus some other aspect of syllables).

Gussenhoven and Jacobs (2003) state that the terms *heavy syllable* or *light syllable* do not carry any impression of the construction of the feet. That is why this group of languages is known to be quantity insensitive, while in another group syllable internal structure is considered. In addition, a weak node may not dominate a heavy syllable in quantity sensitive languages. This has long been

[1][~] 'A swung dash means a relation between alternative forms of the same word, i.e., boy ~ boys (Leech, 2007)'.

noted by phonologists that many languages differentiate between heavy and light syllables by certain phonological processes (Allen 1973; Hayes 1989, cited in Gordon, 2002a; Hyman 1977, 1985, 1992; Jakobson 1931; McCarthy 1979; Trubetzkoy 1939, Zec 1988). Recent theories focused on syllable weight and broadened its prosodic phenomenal factors by encompassing aspects of syllable weight as weight-sensitive to stress. In languages which carry a weight-sensitive stress, where the heavy syllables are stress attractor; whereas, light syllables do not attract stress (Hayes 1995, cited in Gordon; Hyman 1985; Levin 1985; Zec 1988).

**Lexical stress**

In fact, this entire study revolves around lexical stress. Therefore, before various researches in this field are discussed, it is important to explain both lexical stress in general and how the current study deals with the research query of lexical stress. Lexical stress has the same meaning as the word stress. For example, stress here means a relatively prominent syllable in a word or different words. Many languages differ in terms of the stress occurring on various positions of words, and the prominence may be a function of loudness, pitch, and duration, as noted by many researchers. However, the change in pitch, along with other aspects, is most important and this prominence of syllables is referred to as stress (Harrington & Cox, 1984b). Most languages behave in one of two ways: They have fixed stress at pen-initial (second from the left), initial, final, penultimate (second from the right), or ante-penultimate (third from the right) position of words, or have variable stress location (i.e., stress falls sometimes on the rightmost/ leftmost, or sometimes heavy syllables attract stress in words). In addition, this literature review looks at important works which have been carried out on lexical stress in other languages to inform the present research and incorporate aspects of these works.

Languages vary in two degrees of stress, i.e., stressed and unstressed. A difference can be made between primary and secondary stress regarding stressed syllables, which is very common. Alternatively, some languages differentiate between primary, secondary, and tertiary stress levels (De Lacy, 2007). Stress is the most phonetically elusive phonological factor and is realized through the offices of other phonetic features. The analysis of stress has been carried out from the beginning of generative grammar (Chomsky, Halle & Lukoff, 1959) and has really played a vital role in theory (Kenstowicz, 1994).

Reetz and Jongman (2009) argue that the stress is a property of a syllable, which makes it relatively prominent. Generally, there are three levels of stress which vary from strongest to weakest, e.g., primary stress (the strongest), secondary stress, and unstressed. Gordon (2004) investigated the phonetic study of stress in Chickasaw through acoustic data from eight speakers of Chickasaw.

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

**Typology of lexical stress**

Languages differ in their stress system of locating primary stress at lexical level. Some languages have predictable and some have unpredictable lexical stress systems. This section will look at the typology of fixed and variable lexical stress systems in different languages. For example, in bounded languages, primary stress is assigned at a fixed distance from the boundary of a word, whereas in unbounded stress languages stresses cannot be identified at a fixed distance. Proto-Indo-European languages have stress patterns as follows: The finest proof for the exact location of stress in Proto-Indo-European (PIE) originates from Vedic (Classical Sanskrit established its own stress system, like that of Latin). The position of pitch accent in Classical Greek (especially in Greek noun paradigms) also reflects the PIE stress pattern. In the Germanic languages the original location of stress is sometimes re-constructible Germanic spectacularly bears out the testimony of Vedic and Classical Greek. Finally, the evolution of pitch-accent systems in Balto-Slavic makes most sense if we adopt the stress system reassembled based on Vedic, Greek and Germanic as its starting-point (PIE, 2000). Proto-Indo-European (PIE) stress was free – it does not mean that no one cared where it fell, but because it was determined neither by phonological factors, nor by counting syllables from the beginning or the end of a word. Its location depended on the inflectional type to which a given word belonged. PIE patterns may be classified as static or mobile. In a static paradigm the stress of each inflected form was fixed on the same syllable of the stem, while in a mobile pattern the stress fell on the stem in some forms, and on the inflectional ending in others (PIE, 2000).

**Fixed stress**

Ashby and Maidment (2008) state some languages have a fixed stress pattern, which means that most of the words in a language bear stress on the same syllable. Typically, the syllables, i.e., the first syllable, last syllable, or penultimate syllables, are stressed in fixed stressed languages. Hyman (1977) illustrates that there are 306 fixed lexical stress languages, including 114 first syllable stress languages, 12 second syllable stress languages, 77 ante-penultimate syllable stress languages, and 97 final syllable stress languages. There are several languages with variable stress patterns, like Catalan and many others, which have fixed stress patterns. Ashby and Maidment (2008) illustrate stress fixed languages as follows: First syllable of a word in Czech, final syllable of a word in Turkish; penultimate syllable of a word in Welsh; Variable syllable of a word in Catalan. Turkish is known to have a simple stress assignment rule that places primary stress on the final syllable of a word irrespective of the length of the word and weight of the syllables (Lees, 1961; Lewis, 1967; Sezer, 1983, as cited in Kabak & Vogel, 2001). Sapir and Swadesh (1960) illustrate that stress falls in Yana on the first syllable in a word that is either closed or contains a long vowel or diphthong. If there are no such syllables in the word, stress falls on the first syllable.

Languages differ in terms of which syllables are heavy. In contrast Yana, considers both CVV and CVC as heavy syllables. For example, the word [si'búmk'ai] 'stone' the stress falls on the rightmost heavy syllable in a word; where heavy syllables include those containing a long vowel (CVV) or a coda consonant (CVC). In words lacking any heavy syllables, stress falls on the initial syllable (Gordon, Carmen J, Carlos N, & Nobutaka T., 2008). Gordon (1999) argues that the leftmost syllable attracts stress with a long vowel or closed syllable (Sapir & Swadesh, 1960). Gordon contends that the syllable with no long vowels and closed syllables attract stress on the first syllable in words. Thus, the syllables with long vowels (CVV) and closed syllables (CVC) are heavier than open syllables with short vowels (CV).

In addition, another example of bounded quantity sensitive pattern is found in Yidiny, as noted by Dixon (1977). Stress falls on all odd-numbered syllables and on even numbered syllables without long vowels in words. When a long vowel occurs in an even-numbered syllable, stress falls on even-numbered syllables. Whereas, in the case where an odd number of syllables occurs, the second to last syllable is lengthened and stress falls on even-numbered syllables. In other words, quantity-sensitivity manifests an agreement between quantitative structure (patterns of light and heavy syllables) and metrical structure (groupings into weak and strong syllables) (Kager, 1992a; Alber, 1997).

**Variable stress**

Free stress languages are those which do not have fixed stress pattern. This means stress is not predictable at one place, but rather different words have different stress places in different words. Word stress is lexically contrastive in free stress languages, resulting in minimal stress pairs that differ in terms of stress alone (e.g., Russian *'bagrit*$^{j}$ 'to spear fish' and *ba'grit*$^{j}$ 'to paint crimson'). Stress is phonologically predictable in fixed stress languages; however, a morphological structure of a word may affect the location of stress or suffixes may attract stress (Kager, 1989b).

**English stress**

Jones (1972) contends that 'there are no rules that determine which syllable of English words bears the stress'. In contrast, Hayes (1982) argues significant output with reference to the treatment of English stress is to have two stress rules rather than one. First, the English Stress Rule is sensitive to rime structure and determines the placement of primary stress. Second, Strong Retraction is not sensitive to rime structure and determines the placement of subsidiary stresses: completely in non-derived words, and partially in derived stresses. Hayes observes that 'the English Stress Rule must precede Strong Retraction' (Halle & Vergnaud, 1990).

### Stress patterns

The term stress pattern is repeated in this study, so it should be defined in terms of both current research and how the term is treated here. The present study looks at stress patterns in terms of how native speakers perceive primary stress in words differently. For example, in a three-syllable word, some native speakers of Sindhi can differ from other native speakers in stressing the first, second or third syllable in a word. This means that three syllable words have three different stress patterns, as perceived by native speakers of the language.

Duanmu et al. (2005) argues that that lexical stress is assigned on the first syllable in *Canada* (CVCVCV) and second in *banana* (CVCVCV). This English stress assignment offers no any explanation why on first in *Canada* and why second stressed syllable in *banana,* nor is there any reason why stress in such words cannot be all on the first, or all on the second syllable. English utilizes both ways to assign English words e.g., an English word can be a VC, such as *Ann*; CVC, such as *sit*; or CCCVC, such as *strike.*

Ladefoged (2001) contends that the stressed syllables are produced with relatively more muscular energy and more airstream is driven out of lungs. In contrast, pitch accents are viewed in the first instance as building blocks of pitch contours, and stress is treated as a distinct aspect of the phonological utterances (Ladd, 1996). English is a stress accent language where the accent is expressed by a combination of pitch, duration, intensity, and vowel quality (Fry, 1955; Gay, 1978; Kochanski et al., 2005), whereas Japanese is a pitch accent language where the accent is dominantly realized by a fall in the fundamental frequency (F0) from an accented high-pitched mora to the following mora (Fujisaki & Hirose, 1984).

### Phonetic correlates of stress

Phonetic correlates of stress means that there are some phonetic factors which are the features of stress, or that the stress is realized through these factors-for example, loudness of syllable or greater duration of sound and these can be analyzed by their frequency of sounds, i.e., F0, F1 and F2. While this study has also analyzed phonological tasks for syllable structure and stress (a subjective approach), this chapter will focus on acoustic manifestations of stress in Sindhi, that is, a totally objective approach. Moreover, stress is explained in detail in terms of prior works on this aspect and considering how other researchers have treated the aspects of stress.

Fry (1955, 1958) was a pioneering figure to research the acoustic correlates of stress in English on the acoustic factors of duration, intensity, and fundamental frequency. Fry selected the vowels in noun-verb minimal stress pairs as follows: *con*vert (noun) vs. con*vert* (verb) and *im*port (noun) vs. im*port* (verb). Fry figured out that the stressed vowels were correlated with greater duration and higher intensity and fundamental frequency as compared to unstressed tokens, with these acoustic factors as the most reliable cues to stress (Gordon, 2011).

Fry (1955, 1958) found that loudness had the least effect on stress perception, despite its intuitive status as the most natural correlate of stress. Duration changes had a greater effect, with longer syllables more likely to be perceived as stressed. The strongest effects on stress perception were achieved by altering the pitch contours, as shown. Thus, pitch and duration, rather than loudness, seem to be the principal perceptual cues for stress.

There are three significant aspects signaling the main stress: (a) Stressed syllables are produced with higher F0; this causes vocal folds to vibrate rapidly, and sounds as higher pitch; (b) The duration of stressed syllables is greater and its perception is longer as well; and (c) The production of stressed syllables causes greater intensity which makes them louder than the unstressed. (McMahon, 2002).

Gordon (2004) states that stress is a more prominent syllable, as compared to other syllables in a word. These syllables have heightened fundamental frequency, longer duration, amplified loudness, and more outlying vowel qualities, i.e., English and other languages have different stress realizations acoustically (Beckman, 1986; Fry, 1955), Polish (Jassem et al., 1968), Tagalog (Gonzalez, 1970), Russian (Bondarko et al., 1973), Mari (Baitschura, 1976), Indonesian (Adisasmito-Smith & Cohn, 1996), Dutch (Sluijter & Heuven, 1996), and Pirahã (Everett, 1998). Hussain (2010) contends that stress may be verified by examining F0 pattern of a word. Almost certainly there is higher or lower pitch or abnormal behavior of fundamental frequency, where stress can be located.

Gordon (2004) argues that Chickasaw has a stress system which is normally bigger the level of stress, the longer the duration, the higher the intensity of vowels and F0. Most consistent factor of vowels is the duration of stressed syllable in comparison to intensity. In addition, De Lacy (2007) argues: Stress has no specific phonetic factor; however, it is very generic cross-linguistically speaking for the unstressed to have lower pitch, short duration, and lower intensity than stressed syllables. Tones are more inclined to be attracted to the syllables, which are stressed.

Reetz and Jongman, (2009) state that English assigns stress in disyllabic words as follows: English disyllable verbs are stressed on the second whereas, nouns in English is often assigned stress on the first, e.g., the minimal stress pairs: (n) record *ɹɛ.kɚd* and (v) record *ɹə.kɔɹd*. When the stressed syllables are compared to the unstressed syllables, it causes an increase in fundamental frequency, longer duration, and increase in intensity, and a change of formant frequency pattern in English. This indicates that there is a clear difference in phonetic quality. In addition, F0 fundamental frequency change in any direction is a correlate of stress. Which means the stressed syllable can have either a higher or lower fundamental frequency than its unstressed syllable. Thus, the perceptual experiments indicate that the fundamental frequency and duration may be stronger cues to stress than intensity (Reetz & Jongman, 2009).

Gordon (2011) argues that stressed syllable or unstressed syllable is linked with supra-segmental and segmental aspects. Stress typically activates lengthening, higher F0, and greater intensity, however, the syllable features of several languages do not come together at one syllable but it rather spread out on several syllables.

Stress in several languages spread over many neighboring syllables, and does not meet on any syllable. For instance, in Welsh an unstressed penultimate syllable has lower F0 and short vowel duration than an unstressed final syllable. In such situations, the stressed vowels become the most authentic correlate of stress, which are preceded by lengthening of the consonants (Williams 1985, as cited in Gordon, 2011).

**Duration**

Lexical stress leaves an influence on speech production as an acoustic signal. Researchers argue that most consistently trustworthy examination of lexical stress is duration as the acoustic correlates of stress. Dogil (1995) and Jessen, Marasek, Schneider, & Claßen (1995) and Dogil and Williams (1999), consider the acoustic property i.e., duration as the most important correlate of word stress, since this factor of syllable was found in stressed syllables to be greater in duration than the unstressed. Thus, the present analysis includes the duration as the most important property of lexical stress by measuring duration the stressed and unstressed syllables acoustically.

Gordon (2004) states that phonetic dimensions for investigation of stress in several languages are closely linked with duration, loudness, and weight. Phonetic factor the duration or intensity are the acoustic correlates of stress between longer duration or intensity, which has been analyzed experimentally for the languages as noted by Beckman (1986) and Fry (1955) as follows: French (Rigault, 1962), Tagalog (Gonzalez, 1970), Russian (Bondarko et al., 1973), Polish (Jassem et al., 1968), Mari (Baitschura, 1976), Indonesian (Adisasmito-Smith & Cohn, 1996), and Dutch (Sluijter & Heuven, 1996). The work delivers more evidence for a correlation between the phonetic aspects of duration and weight as noted by

Maddieson (1993), Hubbard (1994, 1995), and Broselow, Chen, and Huffman, (1997).

**Quality of vowels (F1 and F2)**

Perceptual difficulty and articulatory complexity may cause intensity to be an ineffective cue to stress, as reported by Sluijter and Heuven (1996) for Dutch. The work of various researchers, including Jones, Raphael, and Rosner, indicate that the form of the vocal tract, it is open and closed end, shape the articulation and the vowel quality of vocalic sounds (Keerio, 2010). Basic articulatory characteristics of the first two formants are: the tongue body displacement in mouth (the height and back-ness) and the lip rounding (Ladefoged, 1993; Pfitzinger, 2003). The first and second formants frequencies are regarded as enough for acoustic-phonetic analysis, although for speech recognition and synthesis F3, F4, and F5 are needed (Parsons, 1987). For male adult speakers, the formants can be described in terms of their 'range of frequencies, for example, F1 ranges between 200-800 Hz, F2 ranges between 600-2800 Hz, and F3 ranges between 1300-3400 Hz' (Parsons, 1987). The phoneticians argue the vowel quality can be quantified acoustically by examining F1 and F2 of the vocal tract.

The articulatory aspects that correspond to F1 and F2 are as follows: the tongue body displacement in mouth (the height and back-ness) and the lip rounding (Ladefoged, 1993; Pfitzinger, 2003). The higher the tongue position and the lower the value of F1, it narrowly correlates of the height of vowel (Raphael, Gloria, & Katherine, 2006). The more backward is the body of tongue, the lower the value of F2 which manifests that value of F2 are closely linked with back-ness of the tongue body and the lip rounding. Whereas, the more forward the tongue body in mouth, the higher value of F2, and the lips remain either in spread or in neutral position.

German language regards vowel quality as an acoustic correlate of lexical stress (e.g., Dogil, 1995 & Jessen et al., 1995). The space of the vowel inventories of German and other languages is assumed to extend under stress, i.e., F1 and F2 either increase or decrease under stress depending on their position in the vowel quadrilateral (e.g., Crosswhite, 2001a; Lindblom, 1963; Flemming, 2002). However, Jessen (1993) found only vowel quantity to be a reliable correlate of word stress in German.

Wang and Heuven (2006) argue that the quality of vowel can be measured by analyzing sound frequencies with accuracy. First formant is calculated through the central frequency of the lowermost resonance of the vocal tract; connecting narrowly to the perceptual measurement of vowel height or articulatory (close vs. open vowels or high vs. low vowels). First formant values range for male between 200 Hz for a high vowel /i/ to some 800 Hz for a low vowel /ɑ/. Second formant exposes the place of utmost constriction while the vowel is produced, e.g., the front vs. back dimension, such that the Second formant values range from roughly 2200

Hz for front /i/ down to some 600 Hz for back /u/. Whereas, the formant frequencies of female are 10 to 15 percentage higher, because the small size of female vocal track than a male speaker relatively.

In Chickasaw long vowels and closed syllables with final syllables (as heavy syllables) are assigned stress. Final syllable is marked as primary stress if it is a long vowel. Even non-final position can be stressed for the existence of long vowel as primary stress. In addition, the words with two long vowels can assign primary stress with free variation either on one or on both in (Weijer & Los, 2006, cited in Gordon, 2004).

**Fundamental frequency (F0)**

The complete number of cycles made by the vocal folds in one second is fundamental frequency (F0); this is measured in Hertz (Ogden, 2009). Fundamental frequency is primarily used to differentiate primary stressed vowels from other vowels (Gordon, 2004). The average F0 values are 120 Hz for men, 220 Hz for women, and 336 Hz for children when they are about ten years old. This resonance frequency varies because of the vocal tract of each person is different from every other human being. The vocal tract is approximately 17 cm in length for male adults (Parsons, 1987).

Isačenko and Schädlich (1970) argue that fundamental frequency is an essential aspect of lexical stress. The studies on correlates related to sentence and word stress, has shown that fundamental frequency is an important correlate of sentence stress rather than word stress (cf. e.g., Dogil 1995, 1999; Möhler & Dogil 1995). However, Jessen et al. (1995) argues that fundamental frequency is correlate of stress, and with the durational aspect is the most dominant correlate. De Jong, K. Beckman, M. and Edwards, J. (1993) put forward that the properties of co-articulatory in English are substantial correlate of word stress: There is less tendency for the segments bearing main stress are affected by co-articulatory aspects. These effects are usually measured through articulatory analyses (e.g., Jong et al., 1993). Vowel quality was detailed in terms of co-articulation based formant target undershoot theory which also included co-articulatory effects (Lindblom, 1963).

The words containing long vowels are encompassed in the analysis, then F0 surfaces as an important factor of stress (Gordon, 2004). For the determination of vowel quality as a role of stress level in Chickasaw, the first two formants frequencies were also analyzed for a subset of the speakers. Languages have tendency cross-linguistically to centralize the vowels which are unstressed, e.g., Maithili (Jha, 1940-44, 1958), English (Bolinger, 1958, Fry, 1965), Tauya (MacDonald, 1990), and Delaware (Goddard, 1979, 1982; cited in Gordon, 2004).

Fundamental frequency is a very robust correlate of word stress on account of F0 prominence in stressed syllables as noted by Claßen, K., Dogil, G., Jessen, M., Marasek, K. and Wokurek, W. (1998). Average fundamental frequency manifests inclinations to vary from secondary stress and syllable location in a word. Vowel durational factor and fundamental frequency substantiated consistent correlates of word stress in terms of control comparison (as cited in Kleber & Klipphahn, n.d.).

Stress is defined as a prominence of syllables relative to other syllables in the metrical structure, which arranges segments into larger prosodic units like feet and words (Pierrehumbert, 1980). Different languages use different acoustic cues for stress; speakers may lengthen segments to indicate stress in English, but may shorten the segments to indicate stress in Estonian (Lehiste, 1970). As noted in the literature survey, lexical stress can be defined as the prominence of stressed relative to other syllables in the same word string. The prominence of a stressed syllable over an unstressed may be because many factors, i.e., loudness, duration, and pitch. In other words, the vowel quality (F1 and F2), F0, and duration are the most important acoustic cues for examining lexical stress in any language. All these aspects correlate of phonetic properties. The current research investigates stressed and unstressed syllables in Sindhi to look at how lexical stress influences other acoustic properties of the syllables. This variable aspect is investigated in, to document the acoustic properties of stress patterns in Sindhi.

Abbasi (2015a) argues the evidence for higher frequencies of stressed vowels and lower for unstressed vowels in Sindhi. Statistically significant acoustic differences between short and long vowel values of stressed and unstressed syllables were discovered. The duration and stop closure of stressed vowels were greater than the unstressed, while F1-F2 and F0 values were higher in stressed and lower in unstressed vowels which is a quite evident that phonetic correlates of lexical stress in Sindhi. Thus, the phonetic exponents of stress were discovered through its strong evidence of modification of acoustic aspects which explicitly supports the theory developed by Abbasi (2015a) that Sindhi is a stress accent language.

**Pitch accent-languages**

This section begins with the discussion of stress accent and non-stress accent languages and will be followed by the discussion of Hindi and Urdu because their generic proximity to Sindhi, which might lead to predictions about properties expected in Sindhi.

**Lexical pitch accent**

Beckman (1986) distinguishes between stress accent and non-stress accent or in other words pitch-accent languages. Languages with stress accent are those which show accentual prominence in terms of phonetic factors, e.g., pitch, intensity, and duration, versus the phonetic cue, i.e., pitch correlates of accent, in non-stress accent languages.

Hualde (1991, 1999) states that the typology of Beckman can be tested with a language like Northern Bizkaian (NB) Basque. This language shares some features with the Tokyo, a dialect of Japanese language, which lacks durational contrasts. An important feature NB Basque dialect has in common with Tokyo is a lexical distinction between accented and unaccented words, and most words are related to the unaccented class. In addition to that, in both languages often surface lexically accented words, with the H*+L pitch-accent on a syllable. The third aspect is that accentual phrases are marked by the initial rising boundary % LH, with the high target loosely related to the second syllable.

Gordon (2012) argues in terms of the pitch accents in Chickasaw, if such syllables are acoustically noticeable in words where syllables lack a pitch accent, then how can acoustic properties of prominently be manifested. There may be two possibilities one Chickasaw has less prominent stress in words which lack pitch accents, and as many words lack a pitch accent in Japanese language. This may be possible that along with pitch accent system, the stress system also exists.

The role of different acoustic dimensions in exhibiting stress must be described, if this possibility exists. It may be possible that Chickasaw copies other in terms of function more 'prototypical' pitch accent languages like Japanese in its acoustic reliance on F0 over duration and intensity to signal prominence (Beckman, 1986).

Hayes (1995) argues that function words and morphemes are often decreased in speech. Therefore, it would be very difficult to argue that the verb stems in Navajo have metrical prominence. If so, then there will be at least to extricate the aspects for stress from the attributes of morphemes and content words. However, if the verb stem contains similar attributes, which does not mean to have the existence of stress system. Though most of the verb stems are prominent morphemes semantically, they are also inclined to have more phonetic contrast, longer duration and a wider pitch range, yet these are content morphemes. In addition, the phonetic data which illustrate their properties make them more distinct for prominence, but these seem not to be so uniform to claim that the stress falls on the final syllable.

Gordon (2012) argues it needs to be differentiating between properties of phrasal pitch and word-level stress since both are closely related to each other. Pitch accents are characteristically allotted to bottom-up fashion depending on word-level stress patterns. In this context, the languages have stressed syllables and unstressed syllables at word level may have a pitch accent. The sentence i.e., *Rabbits like giraffes,* in which first syllable is stressed in *Rabbits*, while, the final syllable of giraffes may consist of a pitch accent. Languages can differ, in terms of compactness of their pitch accents. One case of this kind exists in Egyptian Arabic

(Hellmuth 2006, 2007, as cited in Gordon, 2012), in Egyptian Arabic most words are linked to a pitch accent that tails the second mora of the foot with primary stress.

**Intonational pitch accent**

Intonation aspect of speech is closely related to pitch and duration, these aspects of speech play significant parts in intonation. Intonation is defined in terms of being alike to tone, however, is only realized in the domain of the utterance rather than on the level of word or syllable. These aspects i.e., stress or accent play a major role in intonation of speech, since peaks and valleys in contours are often expected to go together with the stressed syllables on a word level (Beckman and Pierrehumbert, 1986). Kidder (2008) argues about intonation as it is basically linked to its internal structure in the construction of discourse chunks and the understanding of pragmatics of human speech. This topic has remained as a subject matter of interest for researchers to have insights of syntactic and pragmatic meanings for human speech.

The system of the Tones and Breaks Indices (ToBI) is involved in the analysis of Intonation. The ToBI is basically a system of transcription which was developed by Beckman, M., and G. Ayers Elam (1993). This system is based on the work by Pierrhumbert (1980), which provides a basic tool for transcription of intonation contours through breaking up phrases into discrete units of high and low pitch accents and these are systematically constructed. Through this model a computer can analyze physical speech signal for the pitch track to have intonation analysis, and similarly this may be of F0 over the utterances in intonation pattern.

Tashlhiyt carries phrase-final syllables which are linked with greater fundamental frequency. On the other hand, their counterparts occurring in other syllables which indicate a phonological pitch accent placing on the final syllable of a large intonational unit (Pierrehumbert 1980, as cited in Gordon, 2012). The pitch accent is associated to voiced obstruent nuclei, which is almost present in phrase-final sonorant nuclei. This pitch accent is most consistently present in phrase-final sonorant nuclei and is variably associated with voiced obstruent nuclei. A virtue of assuming a phrase-final pitch accent in Tashlhiyt is that it is consistent with hypothesis for Intonational Phrase carrying one metrically prominent syllable.

**Stress in Indo-Aryan languages**

This section will conflate first Hindi-Urdu generic discussion in view of different researchers, and then separate sub-section for each variety followed by Sindhi. Basically, Hindi-Urdu is an Indo-Aryan, a major sub-branch of Indo-European. National language of India is Hindi whereas, the national language of Pakistan is Urdu. Hindi differs from Urdu in terms of literary styles and linguistic aspects as noted by Masica (as cited in Nayyar, 2000-2001). Hindi-Urdu can be described as two sides of the same coin in terms of quite similar behavior about phonetic and phonological aspects.

In addition, Urdu words are not differentiated with reference to stress alone since stress is not distinct in Hindi-Urdu. Stressed syllables are related to syllable weight, such as in the word, *kəla* 'art'; whether stressed as *kə'la* or unstressed as *kəla'*, it has the same meaning. The phonetically long syllables are basically the stressed syllables and their length is retained without any position in a word as argued by Nayyar (2000-2001).

Dyrud (1997) argues that stress is a relatively prominent syllable than the neighboring syllables at word level. The location of stress is marked in some Hindi and Urdu dictionaries i.e., Fallon (1879) and Qureshi (1992). Stress pattern in Hindi-Urdu verse was noted by Fairbanks (1981, as cited in Dyrud, 1997) which shows that the word stress is predictable on syllable weight. In addition, Hussain (1997, as cited in Dyrud, 1997) argues that when there are light syllables in a word string then the penultimate syllable is stressed and if final syllable is heavy, then the stress is assigned on final heavy. Assuming extrametricality phenomena, where the final mora carries no weight and is not counted in assigning the stress location. Furthermore, Dyrud (1997) states that Mohanan (1979) was the first person who utilized extrametricality nation for defining stress patterns in Hindi. Dyrud continued saying that the correlates of stress are durational factor, intensity and fundamental frequency. F0 was analyzed as a reliable cue for stress assignment in several languages. However, some languages can differ in terms of acoustic realizations.

According to the analysis of Moore (1965, as cited in Dyrud, 1997) that every foot in Hindi word is described by a tendency of rising pitch through its durational aspect and further it is argued that the neutral division of the foot is a single foot on single word. In addition, few words which are compounds or derivatives may be divided into two feet or a single foot may be divided into two words. Moore (1965) further argues in terms of intonational factor 'where utterances are distinguished from one another about prosodic realizations of pitch, intensity and quantity' in Hindi. In Hindi intonation pitch is not the only cue for associated aspects which may transfer meaning, but some other important aspects are involved depending on intensity alone or on quantity alone.

### Hindi syllable structure

Hindi contains eleven vowels: /ɪ, e, ɛ, æ, ə, a, u, ʊ o, ɔ/, along with nasalized counterparts. Hindi has three short vowels, /ə/, /ɪ/, /ʊ/, and seven long vowels, /a, i, u, e, o, ɛ, ɔ/. The ash vowel /æ/ occurs only in English loanwords of Hindi. The short vowels do not occur word finally (Ohala, 1992, as cited in Puri, 2013). Pierrehumbert & Nair (1996) argue that Hindi with prosodic structures has complex elements. Hindi may have three moras. Syllable onsets can be minimized

ISSN 1339-4584
SlovakEdu

to a single consonant. Hindi licenses a nuclear on glide and an extra consonant at word boundary.

Hindi syllables can have three moras; the third mora can be used to parse segments. Secondly, stress provides a test for how medial consonantal clusters are syllabified, for example, the word *mʊdra* 'position'. Two syllabification alternatives, *mʊ.dra* and *mʊd.ra*, would rise to the foot and word structures as shown in Figure 1.

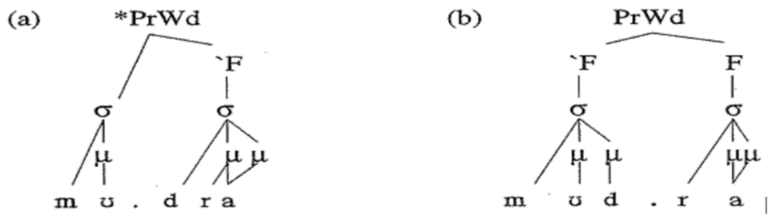


Fig. 1: Illustrates two different syllable patterns of Hindi word

**Hindi lexical stress**

Nair (1999) argues that lengthened syllable and relative extreme (F1 and F2) vowel formants are strong acoustic correlates of stress in Hindi (as cited in Dyrud, 1997). About formant variations, these variations are not reliable acoustic cues in comparison to durational factor (Nair, 1999). Nair (1999) states the unstressed syllables are more schwa-like vocalic than stressed syllables. In addition, she argues despite of Hindi stress as being non-contrastive, vowel/syllable durational variations and variations in formant values specify Hindi language has lexical stress, and therefore, this can conclude that as also reported by other authors, Hindi carries lexical stress which consists of acoustic aspects as follows: Extreme vowel formants which is, however, less significant and syllable lengthening (Nair, 1999).

Nair (1999) states that several linguists argue about the existence of stress in Hindi but they describe the rules of stress in Hindi (e.g., Hays 1991, 1995; Pandey 1989; Mehrotra 1970; Kelkar 1968) (as cited in Nair, 1999). However, Ohala established basic work on Hindi words to determine some of its acoustic analysis, while the few other phonologists studying the language mainly relied on intuition (as cited in Nair, 1999). Ohala (1977, 1986 & 1991) made two strong claims in favor of lexical stress in Hindi as follows: Stress may be a favored location in a word for the placement of pitch contour. Interpretation of some words where the wrong syllable is stressed, are judged by the native speakers of Hindi as unacceptable and these judgments vary depending on whether the word is inserted in a sentence or in state of separation.

Kachru (2006) argues that stress in Hindi is not distinctive but is related to the syllable weight. The syllables are classified as light, medium, and heavy. Stress is assigned through vowel quality and duration of sound (weight of syllable) (Kachru, 2006). Nair (2001) found a less consistent amount of supporting results of Hindi stress, which made her believe that Hindi has pragmatic stress rather than lexical stress. In addition, Nair argues that there is substantial acoustic evidence to have lexical stress in Hindi, as also noted by Ohala (1977, 1986, & 1991 as cited in Puri, 2013). Kelkar (1968) argues that Hindi has syllable weight, e.g., light, medium and heavy. Lexical stress is assigned in a bi-syllabic word to the heavy syllable, if there is a single heavy syllable. In cases where both syllables are light or both heavy, the penultimate syllable is stressed. In tri-syllabic words, primary stress is marked on heavy syllable the penultimate, when there are two heavy syllables in a word. Dehli Hindi has initial stress where Kelkar's Hindi has it elsewhere.

**Urdu lexical stress**

In addition, 10 syllable structures were reported and as in other languages, Urdu contains only a single stress in a word. However, in some places multiple stresses were also reported. Syllables are classified as follows: heavy medium and light. The greater the weight of syllable, the stronger the possibility of primary stress on lexical level (Nyyar, 2000-2001). Much work has been conducted on Urdu in terms of phonetics and phonology. An acoustic work was done with reference to lexical stress in Urdu by Hussain (2010), who investigated the acoustic realizations of phonetic correlates of lexical stress in Urdu. As a result, the study found that the lexical stress alters the phonetic properties of both vowels and consonants in Urdu. This was the first such acoustic study of lexical stress in Urdu. Other research on the phonology of Urdu has included Phonemic Inventory, Urdu templates, and the Urdu sound system.

Hussain (2010) conducted an acoustic analysis of Urdu stress using recordings of Urdu native speakers as its measurement for determining the lexical stress in Urdu. He applied acoustic realizations of vowel duration, their fundamental frequency, relative intensity, and first two formant frequencies of six long and three short vowels of Urdu. Hussain argues that Urdu has lexical stress, which is often marked on a final heavy syllable. However, the final heavy syllable does not contribute to the weight of a final syllable because extramatricality. Urdu is a fixed stress language since syllable weight determines the primary stress in a word. Phonetic analysis shows that the quality of vowels is not only affected by stress, but also that phonetic properties of stop closures are modified by the stress. Masica (1991) regards Urdu and Hindi as the same language whereas, Hussain's, (1997), the analysis in terms of vowel quality he measured for Urdu is different from Hindi.

**Sindhi phonetics**

Much work has been done about descriptive phonetics and phonology in Sindhi by Nihalani (1995), Jatoi (1996), Bughio (2001), Cole (2001) and Allana (2009). Allana (2009) described Sindhi articulary phonetics and phonology, while Jatoi has also contributed a great deal in phonetics and phonology of Sindhi. Bughio (2001) worked on the sociolinguistic aspects of Sindhi, while Cole (2001-2002) has written encyclopedic research papers on Sindhi phonetics and phonology, as has Nihalani (1995).

**Sindhi vocal system**

The division of the Sindhi vocal system according to Bughio (2001) is as follows: long vowels, short vowels, and diphthongs. The long vowels are /ɑ:, i:, u:/. The short vowels are / e, o, ɪ, ʊ, ʌ/, coupled with two diphthongs /ʌo, ʌe/. Whereas, Allana (2009) illustrates ten vocalic sounds: /ʌ, ɑ:, ɪ, i:, ʊ, u:, e, o, ʌo, ʌe/. Nihalani (1995) and Allana (2009) contend that each oral vowel has a nasalized counterpart and areshown with some examples as follows: *əsi:* 'eighty', *əsĩ:* 'we'; *adʱi* 'half rupee', *ɑ̃dʱi* 'storm'; *ɗəhi* 'yogurt', *ɗəhĩ* 'tenth'. Nihalani (1995) argues that vowels /ɛ/ and /ɔ/ have a tendency of being diphthongized, as follows: [ɛə] and [əʊ]. He further explains that closed vowels tend to be shorter than the vowels in an open syllable and most of the vowels are longer than these short vowels e.g., /ə, ɪ, ʊ /.

In addition, Keerio (2010) claims to have ten vowels as follows: /i/ /ɪ/ /e/ /ɛ/ /ə/ /ɑ/ /ɔ/ /o/ /ʊ/ /u/, whereas, Bughio (2001) and Allana (2009) contend only eight mono-thongs along with two diphthongs. Sindhi diphthongs were in a bit of a controversial position, which has been solved through the acoustic study of diphthongs in Sindhi by Keerio (2010). The eight diphthongs [ɪi:, əʊ, eɪ, əe, əo, ʊu, ʊu:, əi:] in Sindhi were predicted by Jatoi (1996) and the acoustic study was carried out and examined by Keerio (2010) as follows: [əy, ɪə, oɪ, ɑɪ, əw, uə, ɑʊ, iʊ].

**Sindhi consonantal system**

Jatoi (1996), Allana (2009), and Keerio (2010) illustrate Sindhi consonants as follows: /p, pʰ[2], b, bʱ[3], t, tʰ, d, dʱ , ʈ, ʈʰ, ɖ, ɖʱ, tʃ, tʃʱ, dʒ, dʒʱ, k, kʰ, ɡ, ɡʱ, ɓ, ɗ, ʄ, ɠ, [ɖr, ɖʱr, ʈr ʈʰr][4], m, [mʱ], n, [nʱ], ɳ, [ɳʱ], ɲ, ŋ, f, v, s, z, ʃ, q, x, ɣ, ħ, h, r, rʱ, ɽ, [ɽʱ], w, j, l, [lʱ]. While Cole, (2001) contends stops, affricates, nasals, and liquids have aspirated or breathy voiced counterparts and has a full series of stop consonants, showing

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2 [ʰ] Superscript diacritic for voiceless aspiration.
3 [ʱ] Superscript diacritic for voiced aspiration.
4[ɖr, ɖʱr, ʈr ʈʰr] are allophonic sounds pronounced instead of /ɖ, ɖʱ, ʈ, ʈʰ/ in Sindhi *Utradi (Northern)* dialect, also noted by Prem (1995).

contrasts between voicing and un-voicing, aspirating and non-aspiration, and plosives and implosive articulations in Sindhi. It has five places of articulation: labial, dental, retroflex, palatal, and velar, and the prominent aspects of Sindhi are implosive stops (Cole, 2001).

Considering prior work, this study will help to break new ground in the study of Sindhi syllable structure and stress patterns by applying objective methods. To explore the stress patterns of any language, the study needs to investigate lexical items carrying all targeted sounds in minimal stress pairs occurring at the same positions of lexemes without being affected by neighboring sounds acoustically. If the sounds are influenced by the neighboring sounds then these may be controlled by such words, preventing them from affecting the token sounds.

**Sindhi syllable structure**

Languages can have different numbers of syllabic templates; Sindhi language contains eight syllable templates as reported by Jatoi (1996).

Gordon (2014)[5] states that Sindhi syllable structure is interesting that CCVCC is unattested given that onsets and codas are in most theories assumed to function independently of each other, i.e., complexity in the onset should not impact complexity in the coda (or vice versa). But the absence of CCVCC syllable structure in Sindhi seems to suggest a relationship between the two margins.

Cole (2001) states about Sindhi syllable as follows: 'Syllable structure in Sindhi is maximally CCVC in word-medial position and CCV word finally. The onset consonant is optional, words may begin in vowel hiatus within words is frequently resolved through glide insertion or glide formation. Word-medial -CC- clusters may consist of any combination of obstruent and/or sonorant consonants. In -CC- clusters with an initial obstruent, there is typically an alternative pronunciation with a vowel inserted between the two consonants i.e., the word *hikɽo* 'one' and *jʰupɽi* 'shack' can be alternatively pronounced as *hikəɽo* and *jʰupɪɽi* by inserting intrusive short vowels /ə /, and /ɪ/ respectively'.

CC clusters can occur at any three positions of words i.e., at syllable onset, medial and coda; syllables are closed with vowels-semi-vowels in Sindhi (Jatoi, 1983). Sindhi words can have syllables from one to six in a word (Jatoi, 1996),

**Consonant clusters at onset**

Jatoi (1996) contends that CC consonant clusters can occupy initial position when the trill, rolled or flapped /j, r, or ɽ/ consonants or glide follow any initial consonant, for example, kya 'did', *pri:təm* 'love', *pɽi:*' cattle market'. While Cole

[5] Matthew Gordon (2014) reviewed the dissertation. Gordon's comments have directly been quoted here on CCVCC syllable structure referencing to Sindhi syllable structure.

(2006) argues that word-initial consonant clusters carry the consonant+ glide (y, w), as do CC of retroflex stop + ɽ (flapped).

Sindhi may be characterized by its free variation features as follows: Onset CC-clusters (*prem* and *pro.li*) are sometimes broken as alternatively *pırem* and *pıroli* by insertion of an intrusive short vowel. There are compound consonantal sounds occurring on onset words medially like *po.ɽho*, *sən.nho*, and *mã.ɳhũ.* They are compound individual phonemes and are not part of the Sindhi alphabet (Allana, 2009; Keerio, 2010). This was also noted in the current study, that no participant inserted a vowel between the sounds, i.e., [ɽh], [lh], [nh], [ɳh], and [mh].

Both Bughio (2001) and Cole (2006) attribute this variation to the social background of the person. In addition, Cole (2006) argues that the deletion of word-final vowel as follows: Frequent deletion or loss of final word vowel may be distinguished by old and new varieties in Sindhi. Bughio (2001) further notes that the tendency of vowel deletion and insertion on the word-final environment is perceptibly noticed, particularly in *Lari,* as in *Kachchi* or *Lasi* (dialects of Sindhi); this illustrates the impact of Urdu-English on Sindhi, with especial reference to vowel variable occurrences in English loanwords.

Catford (1988) argues that lexical stress is an aspect of syllable, so is treated as to be a prosodic rather than a segmental phenomenon. Nihalani (1995) contends that lexical stress is not distinctive and the first syllable is assigned a stress of the morpheme. If special emphasis is given then the contrastive stress may be utilized for pointing any contrast idea in Sindhi. Jatoi (1983) argues lexical stress in Sindhi, has no phonemic role, whereas, English plays phonemic role by stressing different syllables in words. This specifies that the word meaning is modified in English by stressing first or second syllable of English words, whereas, this phonological modification in meaning does not occur in Sindhi.

## Conclusion

This study explored the research works carried out on the experimental phonetics of speech science of lexical stress patterns in Indo-Aryan and European languages through empirical evidence from the native speakers. Sindhi language which is less-studied language in terms of its phonetic and phonological aspects has also been explored through this review that Sindhi word stress in comparison to English, is a weakly quantity sensitive, in which the lexical stress is assigned on the so-called heavy syllable (Abbasi & Hussain, 2015; Abbasi, 2017; Abbasi et al. (2017). Additionally, Abbasi (2015a) reports logistic mixed effects regression models on the perceptual judgments of stress assignments show that syllable (light vs. heavy) is a small but significant predictor of stress perception in Sindhi. Whereas, Abbasi (2017) further reports that acoustic realizations of the exponents of lexical stress is much less in Sindhi relative to English language. Lexical stress in Sindhi is phonological distinct from English in terms of word stress and, is phonetically distinct from English in the acoustic correlates of stress. Abbasi (2015b) argues on Sindhi as a language in which intonation contours appear to be independent of stress. It suggests that stress is completely orthogonal to F0 contours unlike in most stress languages in which pitch accents dock on stressed syllables. Sindhi pitch accent rises from the first syllable string in disyllable words, regardless of syllable heaviness, and the rise is trailed by a fall at end of the word. Thus, the study suggests that Sindhi seems to behave like a stress accent language.

**Acknowledgement**
The author is much indebted to Higher Education Commission of Pakistan for funding the entire project.

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