AN ACOUSTIC STUDY OF TONE AND PHONATION IN PUNJABI

TAHIR GHAFOOR MALIK
(Regd. No. 2009-UMDB-11920)

Session 2009-2012

Department of English
Faculty of Arts
The University of Azad Jammu and Kashmir, Muzaffarabad.
AN ACOUSTIC STUDY OF TONE AND PHONATION IN PUNJABI

by

TAHIR GHAFOOR MALIK
(Regd. No. 2009-UMDB-11920)

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CERTIFICATION

It is certified that the thesis entitled "An Acoustic Study of Tone and Phonation in Punjabi" submitted by Tahir Ghafoor Malik, Registration No. 2009-UMDB-11926, in the partial fulfillment of the degree of Doctor of Philosophy, at the University of Azad Jammu & Kashmir, Muzaffarabad, has been satisfactory for the requirement of the degree.

Supervisor: 
Dr. Abdul Qadir Khan

Member: 
Prof. Dr. Nadeem Haider Bukhari

Member: 
Prof. Dr. Ayesha Sohail

External Examiner: 

Chairman
Department of English

Dean
Faculty of Arts

Dated: 

Director
Advanced Studies and Research

28 FEB 2018
DECLARATION

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To my wife
Abstract

This study investigates, by means of acoustic and statistical analyses, the nature of Punjabi tones and the interaction of tone and phonation, with a particular focus on exploring the contribution of the phonation configurations to the tonal contrasts in the language. Punjabi is an Indo-Aryan language which is a tone language with three tone types, namely low tone, mid tone and high tone. The study also explores as to what extent the Punjabi tones co-exist with the phonation types, so as to discover the contribution of phonation types to each of the three tones. The stimuli consisted of three sets of mono-syllabic words of Punjabi with each set containing three tonal words different from one another only due to their different tone. In this way each set of stimuli contained three tonal words representing the three tone types in the language. All the words were recorded in a silent room. A good quality WAV file recorder was used for the purpose of recording the words. Each word was recorded for five times by ten (five male and five female) native speakers of the language. The Punjabi speakers were selected conveniently from Lahore, the capital city of Punjab province of Pakistan. The recordings were analyzed acoustically with the help of software including Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The acoustic correlates of tone and phonation including fundamental frequency (F0), duration, intensity, final velocity, H1-H2, H1*-H2*, and CPP were measured for all the three tones in the language. SPSS was also used for the statistical analyses in order to see their statistical significance. One way ANOVA test was applied; which was followed by post-hoc Bonferroni test in each case in order to see the comparisons.
between any two of the three tone types in the language. The results of the study, on the basis of the acoustic and statistical analyses conducted, confirm that there are three tone types in the language, namely low tone, mid tone and high tone. The findings of the study also indicate that three out of the seven acoustic measures, i.e., duration, final velocity and CPP distinguished the three tonal contrasts in Punjabi with statistical significance. The remaining four acoustic measures in the study including F0, intensity, H1-H2, and H1*-H2* did not distinguish the three tone types with statistical significance. The results also showed that the Punjabi tones are contour tones in nature which change their pitch while moving from their onset to their offset of the TBU. Regarding the role of phonation in the Punjabi tonal contrasts, the findings in the study suggest that tone and phonation co-exist in the language in a significant way. The low tone in Punjabi co-exists with the breathy phonation type and the high tone in the language co-exists with the tensest phonation configuration of the three tones.
Chapter 1

INTRODUCTION

1.0. INTRODUCTION

This study investigates as to what extent two important and related phenomena, i.e., tone and phonation, co-exist in Punjabi. Punjabi is an Indo-Aryan language, spoken mainly in Pakistan and India, which has got tonal contrasts. Bussmann (2006: p. 1204) describes the terms tone and toneme as: “phenomena of pitch that refer to morphologically defined segments (morphs, words) to the extent that different pitches in a language are distinctive. Such languages are known as tonal languages. In phonology, the term ‘toneme’ (in analogy to ‘phoneme’) is used to denote phonetically distinctive tones.” So, in tone languages tone is a phonemic unit, i.e., along with vowels and consonants, tone languages have tonemes (tone units) to distinguish between words. A change of tone (pitch) changes the meaning of a word. Tone features in tone languages are segmental and phonemic in function (Pickett, 1999), i.e., tone is a permanent part of words just like consonants and vowels. Baart (2003) suggests that in tone languages, tone is an important feature of a word which should be written in the script of that language in the same way as the vowels and consonants of a word are written. The Chinese Mandarin and the Punjabi spoken in Pakistan and India are good examples of tone languages. Whereas English is a stress timed language but not a tonal language because it does not differentiate words on the basis of tonal contrasts.
The second phenomenon to be explored in the study is phonation which is supposed to play an important role in creating tonal contrasts in a language and so explored side by side with tone in many languages. Crystal (2008: p. 361) describes the term phonation as referring to: “any vocal activity in the larynx whose role is one neither of initiation nor of articulation. The various kinds of vocal fold vibration (voicing) are the main phonatory activities, and the study of phonation types is aimed at accounting for the various laryngeal possibilities, such as breathy and creaky voice.” Heinz (2011: p. 3) suggests that: “In terms of articulation, phonation refers to the proportion of time the glottis is open and this is called the open quotient.” As both the phenomena to be explored in the study, i.e., tone and phonation are controlled mainly at the point of larynx, so this study is an attempt to find out as to what extent they co-exist in the language and affect each other, with some particular focus on the role of phonation configurations in creating tonal contrasts in the language.

The most important acoustic cue for observing the tonal contrasts in a language is considered to be the fundamental frequency (F0), which is produced and controlled majorly at larynx. Similarly, phonation is also referred to as how the larynx is set up in the production of different voice qualities. As both of them, i.e., tone and phonation share the same physiological source of energy, i.e., larynx, so there are high chances that they interact and affect each other in the process of their production. An important example of this interaction and inter-dependence of tone and phonation comes from Mandarin. Kuang (2013: p. 61) explores Mandarin and states that: “different pitch
ranges affect the voice quality in both low targets and high targets of Mandarin tones: low targets become breathier when pitch range is raised, but creakier when pitch range is lowered; by contrast, high targets become tenser when pitch range is raised, but breathier when pitch range is lowered.” Like Mandarin, Punjabi is also a tonal language, therefore, this effect of tone and phonation on each other might exist in this language also which is explored in this study.

There are considered to be three tone types in Punjabi, namely, low tone, mid tone, and high tone. Lata and Arora (2008) suggest that in the language there are three phonemically distinct tones, i.e., high tone ( / ), low tone ( \ ) and mid tone ( - ), and there are five tonal characters, i.e., (bh) is produced as /p/ with a tone, (dh) is produced as /t/ with a tone, (dh) is produced as /ʈ/ with a tone, (gh) is produced as /k/ with a tone, and (Jh) is produced as /tʃ/ with a tone. It can be noticed here that the voiced aspirated consonants are replacing their voiceless un-aspirated neighbouring consonants in the IPA along with a tone. That is what is happening in the language in the case of low tone which is explored and discussed in detail in the subsequent sections of this dissertation.

This study is an attempt to investigate the nature of the tone system in Punjabi, the interaction of tone and phonation, and the role of phonation contrasts in making the tonal contrasts in the language. The study is conducted by means of scientific analyses
using some latest software like PRAAT (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014).

1.1. OBJECTIVES

This study aims to:

1. Explore the nature and the acoustic properties of Punjabi tones;
2. Investigate the phonation configurations which affect tone in the language; and
3. Analyze as to which acoustic correlates specific to phonation facilitate and so can be used in addition to the acoustic correlates of tone in investigating the tonal contrasts in the language.

1.2. RESEARCH QUESTIONS

This study is an attempt to find the answer to the following questions:

1. What is the nature of the tone types in Punjabi?
2. How many phonation configurations interact with tone in the language? And
3. Which acoustic correlates specific to phonation along with the acoustic correlates of tone can be used in investigating the tonal contrasts in the language?

1.3. SIGNIFICANCE OF THE STUDY

Most of the earlier studies on tone have investigated the phenomenon of tone in different languages all around the globe by focusing only on the traditional acoustic
correlates of tone which include: fundamental frequency (F0), duration and intensity. Those studies did not explore the role of phonation which could provide important cues in the tonal contrasts in a language. Anyhow, now there are many studies available in literature which explored tone and phonation together and got much better understanding of the tonal systems in different languages. Keating and Esposito (2006: p. 89) suggest that “there are languages where tone and phonation co-vary, either on all tones or on some. In such cases it may not be clear if it is the F0 or the phonation that is contrastive, and whether listeners rely on one, the other, or both.” Therefore, today many studies suggest that both tone and phonation should be studied together in order to have a better understanding of their occurrence and interaction. Keating and Esposito (ibid) further state that “even when the nature of the contrast is clear, it is possible, indeed likely, that listeners attend to secondary dimensions as well. For example, Mandarin clearly uses F0 contrasts, but the low dipping third tone, and even the falling fourth tone, is often produced with creaky voice (Davison 1991, Belotel-Grenie & Grenie, 2004)”. So, the role of phonation configurations in contributing to the tonal contrasts is obvious and should not be ignored in analyzing a tonal language like Punjabi.

Some studies have investigated both the phenomena, i.e., tone and phonation together in different languages. Kuang (2013) discusses some studies as examples of co-occurrence of tone and phonation which are discussed as follows. One of the studies is by Garellek and Keating (2011) which investigates Jalapa Mazatec with three
phonation types and three level and contour tones. Brunelle (2009) studies Vietnamese language which has got six tones and reports that some of the tones are produced with creaky or breathy voice features. Belotel Grenie and Grenie (1994) report that Mandarin Tone 3 is produced with creaky voice features. Gruber (2011) investigates Burmese language which has got four tones and reports that: “a purely tone or register analysis of Burmese is inappropriate, in the sense that pitch contours or phonation type cannot alone serve as the basis of contrast. Instead, the present state of affairs is argued to represent an intermediate stage of tonogenesis, where multiple phonetic properties exist side by side to reinforce supra-segmental categories.” (pp. iii-iv)

Therefore, keeping in view the current level of available and ongoing research in the area of discovering supra-segmental and especially prosodic features in a language, it becomes important that the phenomena of tone and phonation should be studies together. Punjabi is a rich language, spoken by a good number of people all around the world, especially in Pakistan and India. Some research has been conducted and reported on the tonal aspect of this language but no comprehensive study is available on the co-occurrence of tone and phonation or their effect on each other. Moreover, if some work is available on the phenomenon of tone in this language, that is highly insufficient and lack proper systematic and acoustic analysis. So, this study helps in documenting the phonological system of Punjabi with a primary focus on its tonal and phonation contrasts through an acoustic investigation with the help of some latest software like PRAAT (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014).
Furthermore, it will encourage other researchers to work on other tone languages in the region.

1.4. LIMITATIONS OF THE STUDY

This study is limited to the acoustic analyses of tone and the interaction of tone and phonation in the Punjabi language with the help of some software like PRAAT (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The perceptual or manual aspect of tone analysis is not a key part of it. It is limited to the monosyllabic words of Punjabi language having tonal contrasts. The study is limited to measuring the acoustic correlates of tone and phonation including fundamental frequency, duration, intensity, final velocity, H1-H2, H1*-H2*, and CPP. The study is conducted in Lahore and all the participants are from Lahore with their mother tongue as Punjabi. All the participants reported to have Punjabi as their dominant language in their daily lives.

1.5. TONE AND PHONOLOGICAL THEORY

There are many theoretical frameworks in linguistics that address the phonological system of a language but not all of them deal with the supra-segmental phenomena in a language. A few of the theoretical frameworks are discussed here. In their theoretical framework of Sound Patterns of English (SPE), Chomsky and Halle

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1 H1-H2 represents amplitude of the first harmonic minus the amplitude of the second harmonic, whereas, its formant corrected counterpart is denoted by H1*-H2*.
2 CPP (Cepstral Peak Prominence) is a measure of peak harmonic amplitude normalized for overall amplitude.
(1968) present a phonological theory which is linear in nature, i.e., the words are connected to one other in a linear relationship. The connection of words in this framework is linear in such a way that it is described with the help of an analogy of beads which are connected to one other on a string. In this theoretical framework, segments are given whole of the attention and there is no attention given to the supra-segmental phenomena which is equally important in describing phonological system of a language. Therefore supra-segmental phenomena of a language could not be described in this theoretical framework.

In order to describe supra-segmental phenomena of a language, Selkirk (1981) presents a theory of prosodic hierarchy which provides an important framework which is non-linear in nature. According to this theory, all the units have a hierarchical structure, i.e., segments are organized to make syllables and words which can then be organized to make larger constituents like noun phrases or sentences. Therefore, this model is important and useful in describing supra-segmental phenomena like syllabification, stress, tone, intonation etc in a language.

Goldsmith (1976) introduces autosegmental phonology in his thesis. One of the famous models for describing supra-segmental phenomena is also given by Goldsmith (1990) who gives the idea of auto-segmentalism which is also non-linear in nature. This model of phonological representation does not take segments as units for ultimate analysis; rather it prefers the role of distinctive features over segments for a
phonological representation. In this framework, distinctive features do not have direct bonds with their carrier segments and so are independent in nature. Likewise, features of tone, such as low, mid, high, rising, falling, etc. are proposed by distinctive feature theory of phonology. This model is considered to be of key importance in describing supra-segmental phenomena like tone because in this model tone has also got its own separate tier which gives tone full attention. According to this model, the phenomenon of speech comprises many independent components that may coordinate or interact with one another. All the components of speech, i.e., segments or supra-segmental units like tone, have their independent tiers and they are linked to their host segments by means of association lines. A set of well-formedness conditions control and govern these associations. According to this model given by Goldsmith (ibid) the well-formedness conditions regarding the phenomenon of tone are as under:

1. Every tone bearing unit (TBU) must have a tone;
2. Every tone must be associated to some TBU;
3. Association proceeds one - to - one, left - to - right; and
4. Association lines must not cross.

1.6. ORGANIZATION OF THE THESIS

The thesis is organized in six chapters. The first chapter of the thesis introduces the area and topic of research. The objectives of the study, the research questions, the significance of the study, the limitations of the study, and organization
of the thesis are discussed in the first chapter. Then there is a brief summary of the first chapter.

The second chapter of the thesis defines and discusses the phenomena explored in the study, i.e., tone and phonation and their acoustic correlates, in the light of already available literature and research related to the current study. Also, it discusses the interaction of tone and phonation based on the acoustic analysis of some of the acoustic correlates of tone and phonation; as it is evident from many studies on different languages that tone and phonation co-exist in many different ways. The second chapter also presents some information regarding the Punjabi language along with a brief discussion on its phonology, which includes the syllable system in Punjabi, the consonant and vowel sounds in the language, and the tone system in the language etc. This is also followed by a brief summary of the second chapter.

The third chapter of the thesis discusses the methodology part of the study. How the participants are selected, which stimuli are used, which software are used and which SPSS tests are conducted, all these things are discussed in this chapter. Then there is a brief summary of the third chapter.

The fourth chapter of the thesis presents the results and findings of the experiment conducted in the study which is also followed by a summary of the results.
The fifth chapter of the thesis presents a discussion on the results and findings of the experiment. Also, it compares the results of the present research with some results of the already published research on some other languages.

The last, sixth chapter concludes the study. At the end, there is a summary of the whole work followed by some suggestions for future research, references to the cited works and finally appendices.
SUMMARY OF CHAPTER 1

This chapter introduces the research topic of this study as well as the key terms used in the topic. It starts with the description of the two phenomena mentioned in the topic, i.e., tone and phonation. It explains that tone is a phonemic unit in tone languages just like consonants and vowels. This phonemic unit, i.e., tone shows its existence mainly by pitch variations on otherwise similar words and creates lexical contrasts among those words. The second phenomenon introduced in this chapter is phonation which describes how the larynx is set up in producing different speech sounds. As both the phenomena, i.e., tone and phonation, involved in the study share the same power source for their production, i.e., larynx, there are expected to be high chances that they may affect each other. Furthermore, this chapter tells us that Punjabi is an Indo Aryan language which is tonal. This chapter tells us about the main objectives of this study including finding the acoustic properties of Punjabi tones, exploring the role of phonation in the language tonal contrasts, and measuring different acoustic correlates of tone and phonation. Afterwards, this chapter introduces the research questions for the current study that focus on exploring the nature of Punjabi tones, the interaction of tone and phonation, and the usefulness of different acoustic correlates in analyzing Punjabi tones. Then this chapter tells us about the significance of this study and highlights the importance of studying tone and phonation jointly for a better understanding of the tone system in a language. Then this chapter introduces some limitations of the study like it is limited to mono-syllabic Punjabi words and limited to the area of Lahore etc. After that a brief introduction is
given to the phonological theory with reference to tone. It discusses the importance of
goldsmith’s (1990) idea of auto-segmentalism for describing supra-segmental
phenomenon like tone because in this framework tone has got a separate tier due to
which tone gets full attention. Lastly, this chapter presents organization of this thesis
and tells us that it comprises six chapters.
Chapter 2

LITERATURE REVIEW

2.0. INTRODUCTION

In order to conduct an acoustic study of tone and the interaction of tone and phonation in the Punjabi language, we need to know how tone and phonation can be measured in a language and which acoustic correlates of tone and phonation types should be measured. For that purpose extensive literature and related published research is reviewed where some acoustic correlates for both tone and phonation are tested, discussed and reported, which could help in analyzing the phenomena of tone and phonation in Punjabi in this study. The selected acoustic correlates, particularly for tone in this study are fundamental frequency (F0), duration of the TBU, intensity, and final velocity. Whereas, the selected acoustic correlates particularly for phonation to investigate the role of phonation in tonal contrasts are H1-H2, H1*-H2*, and CPP. However, all the seven selected acoustic correlates described both the tone system and the phonation types in the language either in a significant way or at least to the extent of showing contrastive trends. After defining and discussing the phenomena of tone and phonation at length, the above mentioned acoustic correlates of tone and phonation are explained in this chapter with the help of examples from the latest published research. Some information and facts regarding the Punjabi language along with its brief phonology is also discussed in this chapter.
TONE

Tone can be defined and described primarily in terms of variation in pitch or fundamental frequency (F0) of a segment of speech which results in lexical contrasts in a language. In this regard, Kuang (2013) rightly states that most of the phonological theories have defined tone with only one phonetic dimension, i.e., pitch. Pike (1948) also states that pitch distinguish the meanings of words in a tone language. Clark, Yallop and Fletcher (2007: p. 331) refer to pitch as: “the perceived correlate of fundamental frequency.” Hyman (2010) defines tonal contrasts in terms of a “pitch scalar system”. Similarly, Catford (1988) is of the view that tones are pitch variations which are used in short stretches of syllable length, such as in small grammatical units like words. In tone languages, tone is a fixed and permanent feature just like vowels and consonants which cannot be removed from its carrier words or segments.

According to Pike (1948) the tone languages can be of two types, i.e., level tones languages or contour tones languages. Both types of tone, i.e., level or contour are permanent part of the segments they are attached to. Regarding the contour tones, Baart (2003) states that the shape of the pitch contour with which a word is pronounced in a tone language is also tied to the word. So, a word will be changed if its pitch contour is changed. This change in pitch is perceived very accurately by the humans even when there is a fraction of variation in F0. Human ear is very sensitive to distinguish among pitch differences. In this regard, Flanagan (1972) states that we can perceive a change in pitch of as little as 0.3-0.5 percent. That is perhaps why pitch has
a very good contribution to the development of phonology of any language of the world, especially the tone languages, and most of the studies on tone focus primarily on F0 (fundamental frequency) for the tonal investigation; a very few studies address the role of phonation in tonal contrasts (Kuang, 2013) which has proved to be of great importance in analyzing a tone language.

2.2. TONE LANGUAGES

Pike (1948: p. 3) refers to a tone language as: “a language having lexically significant, contrastive, but relative pitch on each syllable”. The minimal contrastive units of speech sound are referred to as phonemes; similarly, the minimal contrastive units in tonal analysis are called tonemes (Pike, 1948). In addition to having vowels and consonants, tone languages have another phonemic unit which is tone, and merely the tonal contrast can make semantic changes in the same words (with respect to vowels and consonants) in these languages. Ladefoged (2000) emphasizes that these languages use pitch to signal difference in meaning between words.

Many languages around the globe are tonal. Some major East Asian languages such as Chinese, Vietnamese, Burmese and Thai along with a good number of the languages of Africa, the Americas and the Papua Guinea are tonal languages (Clark, Yallop and Fletcher, 2007). These languages are so many in number that Crystal (1987: p. 172) claims that more than half of the languages in the world are tone languages. Whereas, Maddieson (2008) asserts that almost 41.8% of all the languages of the world are
tonal. Yip (2002) gives the example of Chinese Mandarin as the top most tonal language with nearly 885 million speakers. Baart (2003) presents Punjabi as a classic example of a tone language which is an Indo-Aryan language and spoken mainly in Pakistan and India with some other parts in the world.

2.3. PIKE’S TYPOLOGY OF TONE LANGUAGES

Pike (1948) gives two way typology of tone languages and divides them into two groups, i.e., ‘register tone languages’ and ‘contour tone languages’.

2.3.1. Contour Tone Languages

Pike (1948: p. 8) states that: “a pure contour tone language is one in which glides are basic to the system, with no level tonemes whatever, each contrastive pitch unit is a glide.” In contour tone languages, the pitch of the segments carrying tone rises or falls, or there can be, in some languages, some combinations of rise and fall, such as rising falling or falling rising in the course of a tone bearing unit (TBU). Punjabi and Mandarin are good examples of contour tone languages in which the tones have pitch variation, i.e., the pitch shifts in the course of a lexical unit even when that unit is a monosyllabic word. If the pitch of a tone bearing unit in a tone language first shows rise and then there is a fall it is called peak, whereas if the pitch of a tone bearing unit in a tone language first shows a fall and then there is a rise it is called as dipping of pitch.
The contour tone languages show that the F0 of the segments with rising tones is increased from the onset of the tone to its offset. Similarly, they show decrease in F0 of the tone bearing units with falling tones from their onset to the offset in the course of their occurrence. As the pitch rises or falls in contour tones, some researchers believe that these tones should be analyzed by breaking them into levels tones so that each level is analyzed independently like it is done in the case of level tones. In this regard, Woo (1969) proposes that the contour tones can better be analyzed by dividing them into levels because they are longer than level tones, therefore, the syllables carrying them must be bimoraic or trimoraic. Leben (1978) also finds that the contour tones in Mende are actually sequences of H (high) and L (low) tone features, so they should be analyzed accordingly. This approach of looking at the contour tones requires proper acoustic investigation so as to determine whether or not the contour tones are the combinations of the level tones in Punjabi also. Regarding the variations in the contour tones, Sarmah (2009: p. 71) suggests that: “Contour tones in tone languages demonstrate a plethora of variations in terms of the difference between the offset and onset of the pitch contour. Languages like Mandarin Chinese and Thai show large differences between the onset and offset of contour tones.” Pike (1948) also discusses a good number of variations in terms of the difference between the offset and onset of the pitch contour which is presented and discussed in the following paragraphs.

Pike (1948: p. 9) highlights some of the characteristics of contour tones along with their graphic representations which are discussed as under:
In the contour tone languages, there can be a contrast among the contour tones on the basis of their direction, i.e., tones can have rising trend, falling trend, falling - rising trend, rising - falling trend, falling - rising - falling trend, or even level in some cases as shown below with the help of diagrams:

\[
\begin{array}{cccc}
/ & \_ & \^ & \_ \\
/ & \_ & \_ & \\
\end{array}
\]

According to Pike (ibid), there can be another contrast among the contour tonemes in a language due to the height of their beginning point as, i.e., there can be a fall beginning low, fall beginning higher, or rise beginning in between the two as indicated below:

\[
\begin{array}{c}
/ \\
/ \\
/ \\
\end{array}
\]

Pike (ibid) suggests that there can be another contour tonal contrast in a language which can exist due to the beginning and the end points of tonemes where none of the tonemes can be equated in height to any other or to the level toneme as shown below:

\[
\begin{array}{c}
/ \\
/ \\
\end{array}
\]

According to Pike (ibid), the contour tones can also have a contrast in a language on the basis of distance that they cover in the direction of their movement, i.e., there can be a slight fall, greater fall, or greatest fall as shown below:

\[
\begin{array}{c}
/ \\
/ \\
/ \\
\end{array}
\]
Pike (ibid) proposes that there can also be a contrast due to the time duration of the tonemes, i.e., the tonemes can be of shorter time, longer time or longest time as indicated below:

\[ \text{\textbackslash} \quad \text{\textbackslash} \quad \text{\textbackslash} \]

According to Pike (1948), another contrast can occur in a contour tone language in the form of a correlation between the time and distance of rise, i.e., there can be fast beginning rise with slow ending or slow beginning rise with fast ending as shown below:

\[ \text{\textbackslash} \quad \text{\textbackslash} \]

Pike (ibid) further suggests that the stress placement in a language can also make a contrast among the contour tonemes, i.e., there can be greater intensity at the beginning of the rise or greater intensity at the end as shown with the help of diagram:

\[ \text{\textbackslash} \quad \text{\textbackslash} \]

According to Pike (ibid), there can also be a contrast in a contour tone language in the form of a correlation with glottal stop, i.e., there can be a rise arrested abruptly with glottal stop or rise not so arrested as under:

\[ ? \quad \text{\textbackslash} \quad \text{\textbackslash} \]
The above mentioned different possibilities and characteristics of contour tones in contour tone language as given by Pike (1948) provides a deeper understanding of the contour tones.

Sarmah (2009) conducts an acoustic study on the contour tones of Dimasa and Rabha. The average values of different F0s can only tell us about the level tones because there is no indication of rising or falling of tones in these values; whereas, for the contour tones, the average F0 values are not enough because the direction of the tones is very important. Therefore, in order to investigate about the direction of a tone, different ways and means are adopted. Sarmah (ibid: p. 43) makes descriptive statistical analysis of F0d by using ANOVA and post hoc Bonferroni tests, where “F0d is the difference between the 39th point (78%) and the 11th point (22%) of an extracted pitch track that indicates the direction of the pitch contour”. Sarmah (ibid: p. 54) further asserts that: “The F0d is expected to be of positive value in case of a rising tone, negative for a falling tone and near zero for a register tone”. In the current study the measure of final velocity has been included for the purpose of exploring the direction of Punjabi contour tones because this measure gives the direction of contour tones by measuring their velocity at the point of tone offsets. A positive final velocity shows that the tone is rising; whereas, a negative final velocity shows that the tone is falling.
2.3.2. **Register Tone Languages**

As given by Pike (1948), the second category of tone language is a register tone language. In a register tone language, the tones are level which means their pitch does not change in the course of tone bearing units. The tones are either high or low. Yoruba is considered as a good example of a register tone language. There are many languages in the world which have register tones, especially the languages of West Africa. Pike (1948, pp. 5) defines registers as: “when a language has a small, restricted, number of pitch contrasts between level tonemes, these contrastive levels are conveniently called registers.” The pitch of register toneme does not rise or fall during the course of the syllable on which it occurs.

2.3.3. **Comparison between Contour and Register Tone Systems**

Pike (1948: p. 8) discusses the difference between contour tone systems and register tone systems which is presented in the form of a table in this work as follows:

<table>
<thead>
<tr>
<th></th>
<th>Contour tone system</th>
<th>Register tone system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic phonemic unit</strong></td>
<td>Gliding</td>
<td>Level</td>
</tr>
<tr>
<td><strong>Morphemes boundaries</strong></td>
<td>Cannot be interrupted</td>
<td>Interrupted (non phonemic compounded types)</td>
</tr>
<tr>
<td><strong>Beginning and end points</strong></td>
<td>Cannot be equated with level tonemes in the same system</td>
<td>All glides are to be interpreted phonemically in terms of their end points.</td>
</tr>
<tr>
<td><strong>In the printed materials examined</strong></td>
<td>Only one toneme per syllable</td>
<td>May have two or more tonemes per syllable (e.g., Mazateco)</td>
</tr>
</tbody>
</table>
The above table gives a good comparison between a contour tone system and a register tone system. Pike (1948) suggests that in contour tone systems there can only be one toneme per syllable, whereas in register tone systems there may be two or more tonemes per syllable. Clark, Yallop and Fletcher (2007: p. 344) also suggest that “the crucial difference between the two kinds of tone system may be that in contour systems tone is a property of syllables and in register systems tone is a property of larger units such as words.” Punjabi is also considered a contour tone language which shows that the tone is placed on the stressed syllables (Baart, 2003).

2.4. PITCH ACCENT OR ACCENTUAL LANGUAGES

There are other ways also in which pitch plays a significant role in making phonetic and phonological distinctions among tonal languages. One of the ways is the use of pitch in pitch accent or accentual languages. These languages may not be considered as prototypical tone languages but they have got some sort of restricted tone systems and have been referred to as ‘word-pitch’ systems (Pike, 1948). Many languages in the world are pitch accent languages, e.g., Norwegian, Swedish and Serbo Croatian languages (Clark, Yallop and Fletcher, 2007). Pike (1948: p. 14) puts it in this way: “a number of European languages have been described as utilizing pitch in the differentiation of the meaning of various lexical items, but with the placement of the pitch limited to certain types of syllables or to specific places in the word.” McCawley (1978: p. 113) gives the following example of Japanese as a pitch accent language:
<table>
<thead>
<tr>
<th>Word</th>
<th>Tone</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>ka'ki ga</td>
<td>HLL</td>
<td>(first syllable accented) ‘oyster’</td>
</tr>
<tr>
<td>kaki\ ga</td>
<td>LHL</td>
<td>(second syllable accented) ‘fence’</td>
</tr>
<tr>
<td>kaki ga</td>
<td>LHH</td>
<td>(unaccented) ‘persimmon’</td>
</tr>
</tbody>
</table>

2.5. **TONE SANDHI**

Tone sandhi is also an important phenomenon which is described as the effect of adjacent tonemes on each other in certain contexts. It should also be kept in mind while exploring a tone language but it should not be confused with contour tone systems because tone sandhi is not directly involved in making lexical contrasts on the basis of tone as is the case with contour tone systems. Pike (1948: p. 77) describes it as: “tonemes which come together in adjacent morphemes can interact and cause a mechanical perturbation of the other”. These mechanical perturbations do not cause any change in meaning directly but, sometimes, their indirect result is difference in meaning. Pike (1948) gives the example of Mixteco in which the word for 'mountain' is zuku, 'today' is blna and both the words have mid level tonemes on each syllable but when the words are placed adjacently, the toneme of the first syllable of the second word is perturbed (changed) from mid to high as shown below:

\[
\begin{align*}
&\text{kl?ln-na z\text{"uk\text{"}}} & \text{’I'm going to the mountain’} \\
&\text{ki?ln-na bl-na-} & \text{’I'm going today’} \\
&\text{but} & \\
&\text{kl?ln-na z\text{"uk\text{"} bl\’na-} & \text{‘I'm going to the mountain today’}
\end{align*}
\]
On the surface level it appears as if tone sandhi does not take place in Punjabi because the tones in the language are fixed and do not change in any context. But for a deeper understanding, whether or not the phenomenon of tone sandhi occur in the language can be an interesting research that can be conducted with a suitable framework and stimuli which is chosen specifically for that purpose but it is beyond the scope of this study.

2.6. **TONE LEVELS**

A tone language can have many levels on the basis of tonal contrasts it has. Levels here refer to the number of tones in a language. Maddieson (1978) finds that most of the tone languages have two or three levels, whereas, four and five level tone languages are extremely rare. Kuang (2013: p. 76) also claims that: “A two level contrast is the most frequently attested type among tonal languages.” Chao (1948) suggests that there are at most five level tones, and transcribed them as 1, 2, 3, 4 and 5 (1 for Low to 5 for High). Black Miao is one of the languages having highest number of tonal contrasts with five tones. However, Punjabi, the language under investigation in this study, is known for its three tone types.

Yip (2002: as cited in Sarmah, 2009: p. 26) gives an example from Cantonese in which the syllable [yau] can have six different pitches with six different meanings as shown below:
Syllable [yau] from Cantonese with six pitch contrasts:

<table>
<thead>
<tr>
<th>Pitch</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>high level</td>
<td>‘worry’</td>
</tr>
<tr>
<td>high rising</td>
<td>‘paint’</td>
</tr>
<tr>
<td>mid level</td>
<td>‘thin’</td>
</tr>
<tr>
<td>low level</td>
<td>‘again’</td>
</tr>
<tr>
<td>very low level</td>
<td>‘oil’</td>
</tr>
<tr>
<td>low rising</td>
<td>‘have’</td>
</tr>
</tbody>
</table>

Bussmann (2006: p. 1204) gives an examples of Punu, a Miao Yao language, which has eight distinctive tones as: cu33 ‘together,’ cu22 ‘the last of all,’ cu12 ‘bridge,’ cu43 ‘wine, alcohol,’ cu42 ‘order,’ cu31 ‘hook,’ cu21 ‘just,’ and cu231 ‘drought.’ Now, viewing this example, one might expect that there could be another language somewhere in the world with even more distinctive tones but might not have been documented so far.

In order to analyze a tonal language which has got so many tonal contrasts the pitch cues may not be sufficient, so there should be some other supporting cues also which could be used in analyzing these tonal contrasts. Here comes the role of phonation with even greater importance, which is proved to be of great importance in many studies in this regard because it shares the same energy source of its production with
tone, i.e., larynx. Kuang (2013: pp. 106-107) also finds and suggests that: “When level tone inventories are large, pitch cues are no longer sufficient, requiring too much perceptual and articulatory effort to maintain the crowded contrasts….there are two possible ways to optimize the tonal spaces with large size of inventories: expand the pitch space for tonal contrasts or add an additional contrastive dimension… Pitch cues are sufficient to distinguish small tonal inventories, but larger tonal inventories require more complicated dimensions.” So, the addition of phonation related measures in analyzing a tone language with so many tones could easily provide those extra cues required for distinguishing a good number of tonal contrasts.

2.7. TRANSCRIPTION OF TONE

How to transcribe tone is an important question having many answers but a single answer to the question has not been agreed upon so far. Many systems for the transcription of tone are at work and all are equally good. Clark, Yallop and Fletcher (2007) state that there is no particular symbol or diacritic to indicate tones in the traditional Chinese orthography, rather tones are implicit in the characters; and in African and American tone languages also, the tone is indicated by some kind of diacritic within an alphabetic writing system. In this regard, as mentioned earlier, Baart (2003: p. 2) proposes that: “In tone languages, tone is an integral feature of the word and in principle deserves to be written in the script of such a language, just as the vowels and consonants of a word should be written.” Anyhow, now IPA has introduced tone symbols in the IPA chart for the transcription of tones. In this system
there is a vertical bar and an iconic symbol is attached to it which represents the tone as indicated below:

<table>
<thead>
<tr>
<th>Tone</th>
<th>Tone Symbols (IPA)</th>
<th>Tone Diacritics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid level tone</td>
<td>˧</td>
<td>３</td>
</tr>
<tr>
<td>Rising tone</td>
<td>˩˧</td>
<td>ˊ</td>
</tr>
<tr>
<td>Falling tone</td>
<td>˥˧</td>
<td>ˋ</td>
</tr>
</tbody>
</table>

Chao (1930) gives another system for tone transcription by means of which tones are transcribed using at least two numbers from 1 to 5 to describe the pitch contour, where 1 shows the lowest pitch level and 5 shows the highest pitch level. In this system rising tones can be transcribed as [15], [35], [13] etc, and falling tones as [51], [42] etc. Level tones in this system can be transcribed as [55], [33], [11] etc. Complex tones can also be transcribed as [214], [353] etc. This system is quite famous and used for its simplicity.

Gussenhoven (2004) discusses the formal representation of tone in terms of some diacritics along with H and L letters, where H stands for high tone and L for low tone, as shown below:

<table>
<thead>
<tr>
<th>Diacritic</th>
<th>Tone</th>
<th>Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>′</td>
<td>High</td>
<td>H</td>
</tr>
<tr>
<td>`</td>
<td>Low</td>
<td>L</td>
</tr>
</tbody>
</table>
The above mentioned diacritics are also very useful in representing different tone types in a language. The tones in the Chinese Mandarin language are transcribed in many ways (McCawley, 1978) as follows:

<table>
<thead>
<tr>
<th>Word</th>
<th>Tone</th>
<th>Letter</th>
<th>Number</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma1</td>
<td>high level pitch</td>
<td>H</td>
<td>55</td>
<td>‘mother’</td>
</tr>
<tr>
<td>Ma2</td>
<td>high rising pitch</td>
<td>LH</td>
<td>35</td>
<td>‘hemp’</td>
</tr>
<tr>
<td>Ma3</td>
<td>falling rising pitch</td>
<td>L</td>
<td>21(4)</td>
<td>‘horse’</td>
</tr>
<tr>
<td>Ma4</td>
<td>falling pitch</td>
<td>HL</td>
<td>51</td>
<td>‘scold’</td>
</tr>
</tbody>
</table>

There are some other systems also for the identification of tone in the text which are and have been in use. For example, in Pinyin, which is an official phonetic system for transcribing Chinese characters, an iconic bar is used above or below a segment or vowel carrying tone to indicate mid tone, rising tone, falling rising tone or falling tone as follows: [mā], [má], [mǎ], [mà] etc (Du, 2010). Another system for transcribing tones has been in use in different languages in which numbers are assigned to tones.
and then the segments carrying tones are marked with the tone number, e.g., [ma1], [ma2] etc (ibid).

2.8. **TONE BEARING UNIT (TBU)**

As the above heading suggests, a tone bearing unit is a unit that bears tone. Yip (2002) defines tone bearing unit (TBU) as an entity to which tones associate. In the framework of auto-segmental phonology given by Goldsmith (1990), a tone bearing unit refers to a segment on the segmental tier which is linked with a tone. A tone bearing unit can have a single tone or multiple tones based on the type of the tonal system it belongs to. In some tone languages, one tone bearing unit is associated with one tone; whereas, in some other tone languages, one tone bearing unit is associated with more than one tone.

A tone bearing unit can be a word, a syllable or a mora. Dutcher and Paster (2008: p. 123) discuss this idea in detail and state that: “A common pattern is one in which contour tones are permitted on long vowels but not on short vowels; this is explained in the traditional model by assuming that the mora is the tone bearing unit (TBU) and there is a one tone per mora restriction that prohibits contour tones on short vowels.” Yip (2002) also suggests that languages differ in their phonology as to whether the tone bearing unit is a syllable or a mora. Baart (2003) investigates some of the tone languages of northern Pakistan and proposes that they show tone features associated
with a stressed syllable. The TBU in Punjabi is a stressed syllable in monosyllabic or bisyllabic words.

Cruttenden (1997: pp. 8-9; as cited in Clark, Yallop and Fletcher, 2007: pp. 342-343) presents an account on tone languages and states that: tone is a “feature of the lexicon, being described in terms of prescribed pitches for syllables or sequences of pitches for morphemes or words”. A stereotypical tone is permanently linked to its tone bearing unit and is not affected by any kind of affixation. Anyhow there are some languages where tone is affected by any change in the structure of a word. Cruttenden (ibid: p. 9) discusses it and states that in many African languages tone is sensitive to word structure and affixation can be referred to as “characteristic tone”, i.e., tone can be an affix in these languages, whereas in languages like Chinese the tone is linked to the specific word segments and this kind of tone can be referred to as “lexical tone”. Punjabi also belongs to the second type, i.e., lexical tone. So there are lexical tones linked to the specific word segments in the language.

Sometimes, in a given context, an L (low) tone loses its anchor (TBU) because the tone bearing unit is deleted; that tone which is now without a TBU is called a floating tone. Anyhow this kind of floating tones associate themselves with the next possible TBU, i.e., they are linked to the next possible segment which can bear them. This kind of re-association of a floating tone with another nearby TBU is referred to as persistence under deletion or tone stability.
The second phenomenon to be explored in the study with reference to the Punjabi language is phonation. Keating and Esposito (2006: p. 85) define phonation as: “Phonation is the production of sound by the vibration of the vocal folds.” Different phonation configurations are determined by the way vocal cords vibrate which result in different voice qualities. Keating and Esposito (ibid) propose that the most common phonation types are breathy voice, modal voice and creaky voice. Garellek (2010: p. 1) suggests that: “These phonations are often termed lax, or slack for phonation types tending towards breathy, and tense, stiff, or laryngealized for phonation that tends towards creaky.” In the light of above statements it is clear that breathy voice is produced when the vocal cords are lax whereas creaky voice requires tense vocal cords. Modal voice lies in between the two, i.e., it is produced with vocal cords neither lax nor tense.

Heinz (2011: p. 4) describes different phonation types in terms of their articulation and open quotient as under:

1. “When the glottis is closed (tensed) most of the time in the course of one cycle, this is called creaky;
2. When the glottis is open (loose) most of the time in the course of one cycle, this is called breathy; and
3. When the glottis is open and closed for approximately equal amounts of time in the course of one cycle, this is called modal.”
Heinz (2011: p. 9) gives the following figure which clearly distinguishes among the three phonation types with reference to the open quotient as under:

![Figure 2.1. Phonation types by Heinz (2011: p. 9)](image)

The above figure shows that the value of open quotient for creaky voice is lowest, i.e., 0.3; for the modal voice is intermediate, i.e., 0.5; whereas, for the breathy voice is 0.65 which is highest among the three. That means that the proportion of time while the glottis is open during breathy phonation is longest, i.e., breathy phonation is produced when the vocal cords are in abducted position for the most time than the other two tones. The mid tone is produced when the vocal cords are in abducted position for the intermediate time duration. The high tone, or in some cases creaky tone, is produced when the vocal cords are in abducted position for the least time period.
There are many possibilities in which vocal cords can adjust their posture and positions in producing different voice qualities. For example, whether the vocal cords are adducted (close) or abducted (open), whether they are lax or tense, which portion of the cords is adducted or which part is tense, etc all these configurations contribute to different phonation types. Gordon and Ladefoged (2001) refer to breathy phonation as having the vocal folds fairly abducted (relative to modal and creaky voice) along with slight longitudinal tension. Kuang (2013: p. 11) refers to modal phonation as “the most usual and default voice quality in speech, typically involving full closure and full opening of the glottis in each cycle of vibration.” Ladefoged (1971) suggests that creaky phonation (also termed vocal fry) is produced when the vocal folds are tightly adducted but open enough along a portion of their length to allow for voicing. Whereas, Gordon and Ladefoged (2001) propose that a typical creaky phonation is defined as having the vocal folds tightly adducted which vibrate irregularly. Gordon and Ladefoged (ibid: p. 15) further state that: “Creaky phonation is characteristically associated with aperiodic glottal pulses.”

Fung (2014) describes the three phonation configurations in terms their relative rate of closure of vocal cords (voice pulse), which are presented in the form of a table in this study as follows:
Table 2.2. Phonation types by Fung (2014)

<table>
<thead>
<tr>
<th>Breathy Voice Pulse</th>
<th>Modal Voice Pulse</th>
<th>Creaky Voice Pulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>A less sharp closure</td>
<td>Closing phase is shorter than the opening, but two are nearly the same.</td>
<td>A sharp quick closure of glottis</td>
</tr>
<tr>
<td>Have much of the energy in the F0 (= H_1), and is composed semi random noise produced by the turbulent glottal airflow</td>
<td>H2 is slightly lower than H1</td>
<td>Have a great deal of energy in the higher formants, such as F1 (= A_1)</td>
</tr>
</tbody>
</table>

To show the difference among the three phonation types, Fung (2014) gives the following image:

Figure 2.2. Phonation types by Fung (2014)

It is clear from the image above that the creaky voice shows a sharp quick closure of glottis. In the modal phonation the closing phase of the vocal cords is shorter than its
opening, but the two are nearly the same. Whereas, there is a less sharp closure of the vocal cords while producing a breathy voice.

Ladefoged and Johnson (2011) discuss the following phonation types with respect to the position of vocal cords which can be adjusted by the movements of the arytenoid cartilages. The vocal folds are close together and vibrate for a voiced sound like in all the vowels or in voiced consonants like /b/, /g/ etc and they are pulled apart for a voiceless sound like in /p/, /k/ etc. If the vocal folds vibrate when they are apart and there is a significant air flow the breathy sounds (also called murmur) are produced like in Urdu voiced aspirates /bh/, /gh/ etc. Ladefoged and Johnson (ibid) propose that when the arytenoid cartilages are closed tightly together and the vocal folds vibrate only at the anterior part, the creaky sounds (also sometimes called laryngealized) are produced. Ladefoged and Johnson (ibid) further suggest that the creaky sounds are very low frequency sounds which are produced like at the end of falling intonation for some speakers of English.

Human speech sounds can be explained in a better way by paying some attention to the source by means of which they are produced, i.e., the human speech apparatus. All the speech organs from lungs to lips including all the articulators are responsible for the production of different speech sounds. Ohala (1978: p. 5) discusses the importance of physical mechanisms in explaining human speech sounds and states as: “It is reasonable that widely attested sound patterns, tonal or not, can be explained
to a great extent, if not totally, by reference to the only thing that is common to
different linguistic communities, though they be geographically, chronologically, or
genealogically remote from each other, namely, the physical mechanisms used in the
transmission and reception of speech: the human articulatory and auditory
mechanisms, including associated neurological structures.”

Similarly, different phonation configurations can also be explained by focusing on the
state and position of vocal cords. Keating and Esposito (2006: p. 85) refer to some
studies (Ladefoged, 1971; Ladefoged and Maddieson; 1996, Gordon and Ladefoged,
2001) and suggest that there is “a simplified model of possible phonations, the glottal
constriction continuum”, which could be used for a better description of phonation
types in a language as under:

Figure 2.3. Model of phonation types by Keating and Esposito (2006: p. 85)

Most open
Voiceless Breathy Modal Creaky Glottal closure Most closed

In the above model, Keating and Esposito (2006: p. 85) highlight that most commonly
there are three phonation configurations in a language, i.e., creaky phonation which is
produced with a constricted glottis, breathy phonation which is produced when the
glottis is more open, and modal phonation which lies in between these two. Keating
and Esposito (ibid) further suggest that there are degrees of creakiness and of
breathiness in a language because glottal constriction is a continuum and it varies not
only across languages but also across speakers which means that what counts as breathy voice in one language or for one speaker might count as modal in another or for another. Therefore, there are no absolute values to determine breathiness or creakiness in a language, rather they are relative and every language or even every speaker has its own set of values for different phonation configurations. Keating et al. (2010: p. 188) state that: “when each within language phonation category was then compared across languages, each category was found to differ from language to language on multiple acoustic measures, e.g. breathy in Hmong is distinct from breathy in Gujarati. This unexpected result suggests that language / speaker differences in voice quality are larger than phonation category differences.”

Garrellek and Keating (2011: p. 186) also discuss the model of the continuum of glottal stricture (Ladefoged, 1971; Gordon & Ladefoged, 2001) as shown above and state:

“This model only refers to the average aperture between the vocal folds in accounting for the major differences across voice qualities. Modal voice is characterized by an average opening that allows complete closure during glottal periods (e.g. Titze, 1995); breathy voice is characterized by a greater average opening, typically with only incomplete closure of the vocal folds during glottal periods; creaky or laryngealized voice is characterized by a smaller average opening, typically with a very small maximum opening during glottal periods.” Garrelkek and Keating (ibid: p. 186) further propose that: “the major reasons for the popularity of this model are first, its simplicity; second, that breathy, modal, and creaky phonation types can usually be
ordered along the various acoustic measures of voice (an argument made explicitly by Blankenship 2002); and third, that a direct relation has been found between measures related to average glottal opening and the acoustics.”

Gordon and Ladefoged (2001) give a good acoustic analysis of different phonation contrasts including breathy, modal, glottalized, pharyngealized, and strident sounds in different languages. Also, there are many examples of languages having different phonation types along with tonal contrasts, i.e., the phenomena of tone and phonation co-exist in these languages. Garellek and Keating (2011: p. 186) discuss the example of Mazatec and state that: “Jalapa Mazatec is rare in contrasting three phonation types and three tones independently…. The independent tone and phonation type contrasts in Jalapa Mazatec make the language particularly suited for investigating how phonation type contrasts may vary by tone, speaker sex, and time.” This interaction of tone and phonation is explored in detail with the help of some acoustic correlates of tone and phonation later in this chapter.

It is already discussed that the most common phonation types in a language are considered to be breathy, creaky and modal phonations. These phonation contrasts along with some other possible contrasts could exist in a language. However, whichever phonation contrasts are there in a language, voicing plays an important role in these contrasts. Voicing plays an important role in tonal contrasts as well which makes it a common measure in analyzing tonal and phonation contrasts in a language.
Gordon and Ladefoged (2001: p. 2) state that: “Certain languages contrast breathy voiced and regular modal voiced sounds. Some of these languages, e.g. Hindi, Newar, and Tsonga make this contrast among their nasals.” Gordon and Ladefoged (ibid: p. 3) further state that: “Languages with contrastively breathy voiced obstruents are relatively rare cross linguistically, although they are common in Indo-Aryan and other languages spoken in Asia, e.g. Hindi, Maithili, Telugu, in addition to Newar”. Over a period of time, Punjabi which is also an Indo-Aryan language is reported to have lost its voiced aspirates in favor of the low tone which is discussed in detail in the last section of this chapter.

As it is also discussed earlier in this chapter that tone can be placed on the whole of a word or on a part of it, i.e., on a syllable or a mora. Similarly, there is a good discussion on the placement of non modal phonations as to what extent they are localized to a carrier vowel, i.e., they are placed to the whole of the vowel or to just a part of it. Esposito (2012: p. 468) refers to some studies and proposes that non modal phonation is often localized to a part of a vowel, especially in tonal languages which have contrastive phonation configurations. Esposito (ibid) gives the examples of Jalapa Mazatec wherein non modal phonation is placed on the beginning of the vowel (Blankenship, 2002; Silverman, 1997), whereas in Santa Ana del Valle Zapotec, non modal phonation is placed on the end of the vowel (Esposito, 2003).
There are many common acoustic correlates between tone and phonation that could be analyzed for describing both the phenomena in a better way. Fundamental frequency (F0) and duration are the most basic among the common measures found in tonal and phonation contrasts. They are considered primary measures in tone investigations and their role in non modal phonation types has also been reported. Gordon and Ladefoged (2001: pp. 17-18) suggest that: “Non-modal phonation types are commonly associated with lowering of fundamental frequency… and non modal phonation types are in some languages, though not all, associated with increased duration.” Intensity is also an important measure in tone analysis and different phonation types have also been reported to be influenced by intensity. Therefore, it is also a common measure in tonal and phonation contrasts. Gordon and Ladefoged (2001) put forward that the breathy and creaky phonation configurations are associated with a decrease in overall acoustic intensity in many languages. Gordon and Ladefoged (ibid: p. 17) further propose that: “In the breathy vowel, the harmonic closest to the first formant has much lower amplitude than the fundamental. In the creaky vowel, on the other hand, the harmonic closest to the first formant has much greater amplitude than the fundamental. The modal vowel is intermediate, characterized by very similar amplitude values for the fundamental and the first formant”.

There are studies which show that duration of TBUs is also an important measure in determining tonal contrasts. Faytak and Yu (2011) investigate this relationship between tone and duration and reveal a negative correlation between tone height and
duration. Faytak and Yu (ibid) find that the syllables with low tone tend to be longer than the syllables with high tone. Faytak and Yu (ibid; as cited in Kuang, 2013: p. 17) state that: “There is a robust negative correlation between duration and pitch height.” Kuang (2013: p. 17) adds: “the lower the tone, the longer the duration.” Gill (1960) investigates Punjabi and suggests that Punjabi has three level tones where the duration of L tone is longer than H tone and M tone is longer than H tone. This study is an attempt to measure and compare the duration of tone bearing unit of the three tones in Punjabi and find if all the tones in the language show different lengths of duration, which is discussed later. These measures along with some other acoustic measures are discussed at length in the subsequent sections in this chapter.

2.10. ROLE OF VOCAL CORDS

The vocal cords are of key importance when it comes to describing both the phenomena explored in the study, i.e., tone and phonation. Tone is a variation of pitch produced by the vibration of vocal cords and phonation is all about setting up of larynx in the production of speech sounds. This setting up of larynx includes opening and closing the cords, and / or status of the cords as being tense and lax.

Discussing the co-existence of pitch and phonation, Ohala (1973: p. 8) refers to an earlier study (Ohala and Ohala, 1972) and quotes as: they “have speculated that the lowered pitch accompanying Hindi breathy voiced stops could be due to the lessening
of the tension of the vocal cords primarily intended to achieve lowered glottal resistance in order to produce the rapid air flow through the glottis and consequently the noisy quality of the breathy voice phonation.” In response to the earlier description of the breathy phonation by Ohala and Ohala (1972), Ohala (1973: p. 8) responds and states that: “however, there is no evidence for this as yet”, perhaps because it was not investigated through proper acoustic analysis. Ohala (1973: as cited in Ohala, 1978: p. 26) further suggests that: “An early explanation for it was that the aerodynamic conditions created by the voiceless / voiced obstruents, i.e., high air flow after voiceless, especially voiceless aspirated, obstruents, and low air flow after voiced obstruents caused the high and low pitches, respectively.” That means in spite of the lessening of the tension of the vocal cords, low air flow after voiced obstruents could be causing low pitches in breathy phonations. Later, Ohala (1978: p. 26) admits that: “This was an appealing hypothesis in part because it explained why these consonants should affect the following, not the preceding vowel. However, there are serious problems with the hypothesis.” Anyhow the whole of the argument by Ohala (1978) referring to the earlier studies also provides us with the deeper understanding of the breathy phonation which is accompanied by a low tone. All this explains the physiology of the vocal cords along with the overall functioning of the related parts which is very relevant to the current study also.

Regarding the role of vocal cords in producing tonal and phonation contrasts, Gordon and Ladefoged (2001) propose that glottis is an organ which can be controlled to
produce speech sounds with not only regular voicing vibrations at a range of different pitches, but also different phonation configurations, i.e., harsh, soft, creaky, breathy etc. Both air flow from the lungs and the adjustment of the vocal cords are involved in controlling the pitch and phonation configurations in a language. Ladefoged (1971, as cited in Ohala, 1973: p. 5) notes that: “an extra expiratory pulse (which can be detected as a momentary increase in the EMG of the internal intercostals muscles) does occur during some stressed syllables and there is a momentary increase in sub glottal air pressure (Ps) during stressed syllables (which all investigators of Ps have noted).” In response to that, Ohala (1973: p. 6) suggests that “no doubt a good part of this momentary rise in Ps is due to this expiratory pulse, but part of it may be due to a momentary increase in glottal resistance which would result from the vocal fold adjustment for increased pitch and intensity.”

Ladefoged and Johnson (2011) highlight some physical mechanisms which determine or control pitch of voice. They include the tension of the vocal cords as the most important, the flow of air out of the lungs, and variations in the position of the vocal folds in different phonation types. So, both pitch and phonation are produced and controlled at the point of larynx. Therefore, there is a high probability that they affect each other. In this regard, Khan (2012: p. 782) states: “as phonation and pitch are both primarily manipulated by many of the mechanisms within the larynx, systematic changes in F0 are often seen in non modal phonation cross linguistically.”
The voiced aspirates in Punjabi are reported to have lost their aspiration in favor of their voiceless unaspirated counterparts along with a low tone. In order to have a review of the phenomenon of voicing, physiology of the vocal cords during voicing becomes important to be discussed briefly. In that context, Ohala (1978: p. 28) discusses some hypotheses related to the phenomenon of voicing which somewhat reveal physiology of the vocal cords. First one is by Halle and Stevens (1971) that suggest that the degree of stiffness of the vocal cords can determine whether or not voicing will occur, i.e., there is stiffness of vocal cords during voiceless stops and slackness of vocal cords during voiced stops. Ohala (1978: p. 28) refers to some studies (Jespersen, 1889; Hudgins and Stetson, 1935; Ewan and Crones, 1974) and discusses the second hypothesis as: “A second hypothesis suggests itself from the fairly well established fact that larynx height is slightly higher for voiceless than voiced stops).” Ohala (ibid) suggests that “other thing being equal, vocal cord tension varies with larynx height; the different pitch on vowels following the different obstruents is accounted for. Presumably the lower larynx during voiced stops is a consequence of the need of the vocal tract to expand in order to accommodate more air in the oral cavity so that it can contain the positive trans-glottal pressure drop necessary for voicing.”

Ohala (1973: p. 9) suggests that “breathy voiced stops such as Hindi (bh, dh) etc. and voiced “h”, [ɦ], are complex cases. Upon release of the breathy voiced stops and throughout the [ɦ] the air flow is very high and thus one might expect them to raise
pitch, yet they depress pitch.” Ohala (ibid) goes on and gives the following expected reasons for this:

- “The vocal cords have to be rather closely adducted for the high rate of air flow to cause increased pitch (this is reasonable, given that we know of how the Bernoulli effect works; cf. Lagefoged, 1973), and as the vocal cords are somewhat abducted during these sounds, the high air flow has little effect on pitch.

- The vocal cord tension may be lowered in the process of abducting the vocal cords, particularly by the lateral cricoarytenoid muscles, known to play a secondary role in pitch regulation. A brief period of inhibition of the lateral cricoarytenoid muscle during [ɦ] is evident in the EMG records presented by Ohala (1970: p. 72).

- Most of the air flowing through the glottis during these sounds is escaping through the arytenoidal portion, not the ligamental portion of the vocal cords (Ladefoged 1973). Thus, although the average transglottal air flow may be high during breathy voice, the air flow through the ligamental portion may be lower than normal. As it is only or mainly the ligamental portion of the vocal cords which is vibrating in this case this lower-than-normal air flow may cause the lowered pitch.” (pp. 9)

2.11. INTERACTION OF TONE AND PHONATION

It is already discussed earlier in this dissertation that tone and phonation share the same power source of their production, i.e., larynx, due to which there are high chances that they interact with each other while co-existing in a language. Garellek and Keating (2011) suggest three possible ways by means of which the phenomena of tone and phonation may interact in a language. First one is that both tone and phonation could interact through their F0 and different phonation categories can differ in their F0; secondly, on the other hand, different F0s can differ in their voice quality;
or thirdly, different tone categories can differ in their voice quality. Yoon et al. (2005: p. 2) suggests that: “It has been widely noted that there is a relationship between F0 and voice quality. For example, Hindi breathy voiced stops are distinguished by a lowered F0 at voice onset following release (Ohala, 1973).” Kuang (2013) also explores the co-existence of tone and phonation and finds that the phonation contrasts are better distinguished when the pitch is low and they gradually lose their contrasts as pitch increases.

Esposito (2012) discusses some studies on Jingpho, Lahu, and Yi (Madiesson & Hess, 1987) and Chong (DiCanio, 2009; Thongkum, 1991) and suggests that tense phonation is associated with a higher F0 than its non tense counterparts. Kuang (2013: p. 106) discusses some studies and gives a good account of different pitch ranges and their relation with the phonation types for the male speakers and states that: “the mean F0 of the highest tone is around 220 Hz, which is a remarkably high pitch for male speakers, much higher than the average 175 Hz upper limit of the male speech range across languages (Baken and Orlikoff, 2000). If not doing anything to reduce the longitudinal tension in the vocal folds, then these high pitches must be produced with tense voice (Kong, 2007). This tension results in a greater CQ in EGG signals. Likewise, when pitch goes to the lowest end, e.g. below 75 Hz for males, speakers have to produce these pitches with creaky voice (e.g. vocal fry), which also leads to a greater CQ.” That means the CQ value in EGG signals is higher for the highest pitch range as well as for the lowest pitch range for male speakers. Probably the results
would be same for the female speakers also because this measure shows longitudinal tension in the vocal folds; anyhow it would be required to be analyzed acoustically because female speakers have much higher values on F0 and there are studies which suggest that phonation types vary when there is much change in the values of F0.

The measure of CQ (contact quotient) and OQ (open quotient) are also very important in describing the phonation types in a language. The measure of CQ gives higher values if there is longitudinal tension in the vocal cords, i.e., in the case of tense phonation configuration. Whereas, for the lax phonations CQ values are lower. Kuang (2013: pp. 33-34) suggests that: “The tense phonation consistently has a greater CQ than the lax phonation suggesting a smaller open quotient in the vocal folds…. In general, the glottal articulations involved in the tense vs. lax contrasts are not extreme, and they are controlled independently from pitch so that speakers are able to keep pitch constant when producing different phonation types.” Therefore, in comparison with the other values in a language, the higher CQ (contact quotient) values refer to the tense phonation in that language; whereas, the higher OQ (open quotient) values refer to the lax phonation in that language. Alternatively, in comparison with the other values in a language, the lower CQ values refer to the lax phonation in the language; whereas, the lower OQ values refer to the tense phonation in that language.

In some languages, some tone and phonation contrasts co-exist in a fixed pattern, i.e., they occur simultaneously and in the same manner even in different environments and
contexts. Garellek and Keating (2011: pp. 188-189) discuss some tonal languages including Mandarin as an example of a case where a tone co-exists with a non modal phonation in a fixed pattern, i.e., the Mandarin dipping Tone 3 is produced with an audible creak (Davison, 1991; Belotel Grenie and Grenie, 2004). Anyhow, Garellek and Keating (2011) themselves respond to this and further propose that phonation configurations can be constrained to co-exist only with certain tone categories. Referring to this co-existence of tone and phonation, Kuang (2013: p. 18) also suggests that: “there are natural constraints on pitch ranges which are good for phonation contrasts, and phonation types which are good for pitch contrasts. That is why phonation contrasts and tonal contrasts happen in certain ways.” Therefore, it can be stated that all the possible tonal contrasts in a language cannot co-exist with all the possible phonation types in that language. Only a few tone types may co-exist with a few phonation types in a language and these possibilities are purely based on the phonotactic constraints related to tone and phonation in the given language.

Therefore, it can be also stated that the interaction of tone and phonation is mainly dependent upon the phonology and structure of a language due to which one language behaves differently from another language. Another thing to remember is that every language has a different set of phonotactic constraints which cannot be applied to any other language. For example, Khan (2012: p. 782) refers to some studies like Nyah Kur (Thongkum, 1987), Western A-Hmao (Johnson, 1999), and Khmu’ Rawk (Abramson et al., 2007) and suggests that F0 is lower during breathy vowels. At the
same time, Khan (2012) gives another example of a language Chanthaburi Khmer (Wayland & Jongman, 2003) which shows higher F0 on breathy vowels. Furthermore, Khan (2012) discusses Jalapa Mazatec which shows no effect of phonation on F0 (Garellek and Keating, 2010). All these examples indicate that there is no uniform effect of F0 and phonation on each other and their correlation varies across languages.

Consider some cases which show no effect of tone and phonation on each other, there is evidence available in literature provided by some cases of different languages where F0 and phonation do not have any effect on each other. For example, Gruber (2011) suggests that phonation and pitch contrasts can exist in a language without intersecting each other like in White Hmong which contrasts five tones (High, Low, Mid, Falling, Rising) and two phonation types (creaky, breathy) and the phonation types function side by side with the pitch contrasts without any overlap. Gruber (ibid) goes on and proposes that phonation and pitch can intersect also and their intersection can be independent or dependent. Gruber (ibid) refers to Yip (2002) for her examples of two languages: Bai (citing Edmondson and Li, 1994) and Jingpho where the interaction between pitch and phonation is intersective and independent. Gruber (ibid) further points out that there can also be intersective and dependent interaction of pitch and phonation like in Sgaw Karen, a language spoken in Myanmar; furthermore, he refers to Brunelle and Finkeldey (2011) study on Sgaw Karen which demonstrate six tones bearing a combination of three phonation types and at least three pitch contours. In this regard, Brunelle and Finkeldey (ibid: p. 25) also suggest that: “Preliminary
acoustic analysis of recorded Karen speech indicates that each of the 6 written tones is acoustically distinct in terms of pitch, voice quality, and duration.”

In the same way, now consider some cases which show that phonation and pitch contrasts influence and intersect each other in a number of ways. In this regard also, Kuang (2013: p. 2) discusses some studies including a study on Vietnamese by Brunelle, 2009 which suggests that: “For Mandarin and Cantonese, phonation is only an allophonic cue to tonal contrasts. However, sometimes a phonation cue is more important than pitch for a tonal contrast.” Kuang (ibid: p. 72) further suggests that, in Mandarin, “voice quality co-varies with pitch in a wedge shaped way, with breathiest voice quality in the mid range, and creakier and tenser voice quality as pitch moves lower or higher.” Therefore, this side of the argument is equally strong due to the available evidence provided by different languages that tone and phonation influence and affect each other.

As proposed by Gruber (2011) which is discussed earlier, Kuang (2013) also suggests that there are two possible types of non modal phonation configurations, i.e., pitch independent phonation and pitch dependent phonation. Kuang (ibid) studies three Yi languages Southern Yi, Hani, and Bo and finds that their phonation configurations are independent from tonal production because tone and phonation contrasts use different phonetic dimensions in these languages. Kuang (ibid: pp. 108-109) states that: “Crucially, the phonation contrast has no effect on F0, the most important phonetic
correlate of tone; and the tone contrast has no effect on Contact Quotient (CQ), the most important phonetic correlate of phonation for these languages. In addition, these two key dimensions, CQ and F0, are not correlated. That is, in these languages, tone and phonation are not only phonologically contrastive, but phonetically completely independent. Tone is purely pitch, and phonation is purely voice quality.”

On the other hand, discussing a strong correlation between F0 and phonation, Esposito (2012) presents the examples of breathy voiced stops in Hindi (Ohala, 1973) and breathy and creaky vowels in Santa Ana del Valle Zapotec (Esposito, 2010) which are produced with a lower F0 than their modal counterparts. Therefore, proper acoustic evidence from different studies on many languages proves this point that the interaction of tone and phonation is primarily language specific and most of the tone languages have unique phonological structure in this regard.

Kuang (2013: p. 32) measures certain acoustic correlates of tone and phonation and presents a summary of the main effects of tone (low, mid) and phonation (tense, lax) in three Yi languages as under:
Table 2.3. Main effects of phonation and tone by Kuang (2013: p. 33)

<table>
<thead>
<tr>
<th></th>
<th>Tone</th>
<th>Phonation</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1*</td>
<td></td>
<td>Tense &lt; Lax (8.32)</td>
</tr>
<tr>
<td>H1*-H2*</td>
<td></td>
<td>Tense &lt; Lax (10.69)</td>
</tr>
<tr>
<td>H1*-A1*</td>
<td>Mid &lt; Low (4.71)</td>
<td>Tense &lt; Lax (8.77)</td>
</tr>
<tr>
<td>H1*-A2*</td>
<td>Mid &lt; Low (4.15)</td>
<td>Tense &lt; Lax (8.16)</td>
</tr>
<tr>
<td>H1*-A3*</td>
<td>Mid &lt; Low (2.47)</td>
<td>Tense &lt; Lax (6.78)</td>
</tr>
<tr>
<td>CPP</td>
<td>Mid &gt; Low (8.6)</td>
<td>Tense &gt; Lax (3.19)</td>
</tr>
<tr>
<td>H2*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H4*</td>
<td>Mid &lt; Low (4.04)</td>
<td></td>
</tr>
<tr>
<td>H2*-H4*</td>
<td>Mid &lt; Low (2.28)</td>
<td></td>
</tr>
<tr>
<td>F0</td>
<td>Mid &gt; Low (10.5)</td>
<td></td>
</tr>
<tr>
<td>CQ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIC</td>
<td></td>
<td>Tense &lt; Lax (4.06)</td>
</tr>
</tbody>
</table>

Only significant effects (p < .05) are reported and direction is noted, t-values are in parentheses.

Kuang (2013: p. 33) comments on his table in the following way: “The table shows that phonation and tone have some distinctive effects on pitch and voice measures, and some shared effects.” Therefore, Kuang (ibid: p. 45) proposes that “for Yi languages non-modal phonation is a primary cue for distinguishing lexical meanings, and phonation cues are independent from pitch cues.” Also, Kuang (2013: p. 41) conducts a series of Spearman correlations between F0 and phonation related voice measures in order to understand the relationships between pitch and phonation with the following results:

Table 2.4. Correlation coefficients (r values) between F0 and phonation related measures by Kuang (2013)

<table>
<thead>
<tr>
<th></th>
<th>H1*</th>
<th>H1*-H2*</th>
<th>H1*-A1*</th>
<th>H1*-A2*</th>
<th>H1*-A3*</th>
<th>CQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>0.26</td>
<td>0.14</td>
<td>-0.15</td>
<td>-0.14</td>
<td>-0.1</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Again, Kuang (2013: p. 41) himself explains his findings as: “It can be seen that none of these phonation related measures have good correlations with F0… This means that the control of glottal opening is generally independent from pitch control.”

Kuang (2013: pp. 109-110) investigates another case where pitch and phonation are inter-dependent by examining Mandarin and suggests that Mandarin speakers’ voice quality co-varied with pitch in a wedge-shaped function. Kuang (ibid: pp. 109-110) states that: “In sum, voice quality in general, and use of creaky voice in particular, seems to be quite systematically tied to F0 in Mandarin. Voice quality varies across the different tones because they differ in their F0s. While the present study does not go so far as to provide a function predicting all aspects of voice quality from F0 in Mandarin, it seems likely that voice quality is indeed highly predictable from F0 in this language. Mandarin, then, appears very different from the Yi languages. Because of its apparently tight coupling between pitch and phonation, tone in Mandarin involves laryngeal differences in addition to pitch.”

Also, Kuang (2013) investigates and discusses Black Miao, a language having five tones, which is considered among the languages having highest number of tonal contrasts (however a language with eight tones is also reported earlier in the thesis), and finds that this language shows both kinds of systems, i.e., pitch dependent phonation contrasts and pitch independent phonation contrasts. Kuang (ibid: p. 107) concludes that: “non modal phonations are very important cues for these tonal
contrasts. A model is proposed in which two different kinds of non modal phonations
that either enhance pitch contrasts or provide an additional contrastive cue divide tonal
levels into several registers so as to optimize the distinctiveness of the tonal space.”
Furthermore, Kuang (ibid: p. 111) presents a new tonal model for this mixed system
language and states: “In this schema, the five level tones are divided into different
quadrants based on different phonations. The tones with the highest pitch and the
lowest pitch form their own quadrants, and the tones with mid range pitches can be
further divided into two quadrants: T33 in the breathy quadrant, and T22 and T44 in
the modal quadrant. With these dimensionalities, the burden of pure pitch contrasts
reduces to T22 vs. T44 only. This model sheds light on many important issues
concerning tonal contrasts, but needs to be extended beyond Black Miao to tone
systems more generally.”

Therefore, it can be stated that every language is unique in its phonological system
which can favor or not the above discussed effect of tone and phonation on each other.
Or even it may show partial effect of tone and phonation on each other which is also
entirely based on the laryngeal and glottal activities in that particular language.

2.12. ACOUSTIC CORRELATES OF TONE AND PHONATION

There are certain acoustic correlates by means of which the phenomena of tone
and phonation can be explored and measured scientifically. Pickett (1999) suggests
that the acoustic patterns of the prosodic features are found in the fundamental
frequency (F0), duration, and intensity. These three, i.e., F0, duration, and intensity are considered as traditional and primary acoustic correlates for measuring prosodic features in a language including tone. These terms can be defined in the following way: Fundamental frequency (F0) is the rate of vibration of the vocal cords during speech sounds. Its unit is Hertz (Hz). Duration is the time taken by a segment under consideration during speech. It is measured in millisecond (ms). Intensity is the force or energy by which a segment under consideration is produced. Trask (1996: p. 181) defines intensity as: “The amount of energy carried by a sound wave, measured in decibels. The perceptual correlate of intensity is loudness, but the relationship is far from linear.”

Gandour and Harshman (1978) also suggest that in a tone language, fundamental frequency (F0) as a primary acoustic cue along with syllable duration and intensity contour as secondary cues are used to contrast lexical meanings. For example, Mandarin has four contrastive tones on the basis of difference in F0 (Howie, 1976) as under:

<table>
<thead>
<tr>
<th>Tone</th>
<th>Word</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tone1</td>
<td>ma [High]</td>
<td>‘mother’</td>
</tr>
<tr>
<td>Tone2</td>
<td>ma [Rising]</td>
<td>‘hemp’</td>
</tr>
<tr>
<td>Tone3</td>
<td>ma [Low]</td>
<td>‘horse’</td>
</tr>
<tr>
<td>Tone4</td>
<td>ma [Falling]</td>
<td>‘scold’</td>
</tr>
</tbody>
</table>
It is clear from the example above that the four Mandarin tones are distinguished primarily due to their distinctive F0. “While the four tones are mainly distinguished by fundamental frequency, other acoustic characteristics such as overall intensity and duration tend to vary systematically with tone” (Howie, 1976; Zee, 1978; Blicher et al., 1990; Tseng, 1990; Whalen and Xu, 1992; Fu and Zeng, 2000; as cited in Kuo et al., 2008). Therefore, F0 has proved to be the main acoustic correlate in the analysis of a tone language along with the acoustic correlates of duration and intensity which also depend on the value of F0 and change if there is any change in F0.

Fundamental frequency (F0) also gives information about other prosodic features. Yuan (2004) suggests that fundamental frequency (F0) also gives information regarding intonation in a tone language; and Lehiste (1970) proposes that F0 gives information regarding intonation in a non tone language also. Anyhow, the present study is concerned about exploring the nature of tone and the interaction of tone and phonation in Punjabi; whereas, studying the role of intonation in the language is beyond its scope.

Other acoustic correlates of tone and phonation like duration and intensity also have shown their importance in the tonal and phonation analyses as mentioned in the published research conducted so far. Anyhow some other acoustic measures for tone along with some phonation measures have also been included in the current tonal analyses in this area of research. Ohala (1973: p. 4) refers to some studies (Pike, 1948;
Hinton, 1970; Matisoff, 1973) and states that: “although the primary physical correlates of what has been labeled ‘tone’ are the level, direction, and / or rate of change of the ‘pitch’ or fundamental frequency (F0) of vibration of the vocal cords, secondary correlates may in some cases be the mode of vibration (lax, breathy, tense, creaky voice), vowel duration and quality, and manner of termination of the vowel bearing the tone, i.e., with vs. without glottal stop”.

As it is discussed earlier that the phenomena of tone and phonation should be explored simultaneously for a proper and deeper tonal analysis in a language, so along with the acoustic correlates of tone, the acoustic correlates particularly of phonation or voice quality become important in the discussion. Phonation measures are important so as to explore as to which phonation types are playing their role in creating tonal contrasts in a language. In this regard, Khan (2012: p. 782) states that: “additional acoustic measures, including intensity, duration, pitch, the frequency of the first formant (F1), and the effects of tracheal coupling are less reliable in distinguishing linguistic voice quality categories in a consistent way.” So, there should be some other acoustic measures with better reliability in distinguishing voice quality in a language. However, there are some common acoustic correlates of tone and phonation including the traditional measures, i.e., F0, duration, and intensity which may not be ignored when analyzing the tone and phonation types in a language.
It is already discussed earlier that the role of duration in making tonal and phonation contrasts is quite important. The measure of duration has a significant contribution to creating tonal and phonation contrasts in a language. Wayland and Jongman (2003: p. 187) refer to some studies (Gordon & Ladefoged, 2001; Samely, 1991; Kirk et al., 1993; Silverman, Blankenship, Kirk, & Ladefoged, 1995; and Wayland et al., 1994) and state that non-modal phonation configurations are associated with increased vowel duration like in Kedang, Jalapa Mazatec and Javanese. However, at the same time, Wayland and Jongman (ibid) give two more examples of languages where this trend is not found, i.e., Hmong (Huffman, 1987) and Lucas Quiavini Zapotec (Gordon & Ladefoged, 2001). Again, keeping in view the above cited examples, the point to remember is that every language follows a unique phonological system with its own set of rules.

Huffman (1987) studies the phenomena of tone and phonation in White and Blue Hmong by measuring the acoustic correlates F0, duration, spectral tilt, H1-H2, and two related measures of inverse filtering, i.e., glottal pulse symmetry and relative closed phase duration, and finds that measure of spectral tilt and the inverse filter glottal pulse symmetry do not distinguish phonation types, whereas, H1-H2 and inverse filter of closed phase duration successfully distinguished modal from breathy phonation configurations. Whereas, Gordon and Ladefoged (2001: p. 15) state that “One of the major acoustic parameters that reliably differentiates phonation types in many languages is spectral tilt, i.e. the degree to which intensity drops off as
frequency increases.” So, the measure of spectral tilt, like most of the acoustic measures, is also language specific and distinguishes phonation types in only some languages.

Esposito (2012) also examines tone and phonation in White Hmong by using the acoustic measures which include primarily fundamental frequency (F0) and then there are eight spectral measures and two EGG measures. Esposito (ibid) finds that many of the acoustic measures are correlated with F0 and out of the eight spectral measures, cepstral peak prominence (CPP) is a measure of periodicity (also called noise measure) and the other seven measures are H1, H2, H1-H2, H1-A1, H1-A2, H1-A3, and H2-H4 which are described as follows:

- Amplitude of the first harmonic (H1);
- Amplitude of the second harmonic (H2);
- Amplitude of the first harmonic minus the amplitude of the second harmonic (H1-H2);
- Amplitude of the first harmonic minus the amplitude of the first formant peak (H1-A1);
- Amplitude of the first harmonic minus the amplitude of the second formant peak (H1-A2);
- Amplitude of the first harmonic minus the amplitude of the third formant peak (H1-A3);
- Amplitude of the second harmonic minus the amplitude of the fourth harmonic (H2-H4).

The above mentioned acoustic spectral measures can well be used for distinguishing phonation types in a language. In the area of acoustic phonetics, the above mentioned terms including amplitude, harmonic and formant are defined in the following way:

Crystal (2008: pp. 23-24) describes the term amplitude as: “referring to the extent to which an air particle moves to and fro around its rest point in a sound wave. The greater the amplitude, the greater the intensity of a sound, and (along with other factors, such as fundamental frequency and duration) the greater the sensation of loudness.” Therefore, amplitude is very important in the analyses of tone and phonation because both of these phenomena occur with varying values of amplitude which depend on the strength of the acoustic signals.

Crystal (2008: p. 224) describes the term harmonic as: “Harmonics are whole number multiples of the fundamental frequency; for example, if the fundamental is 200 Hz, the harmonics will be at 400 Hz, 600 Hz, and so on… The combination of a fundamental frequency and the amplitude of its various harmonics combine to give a sound its characteristic tone and quality.” Therefore, the values of different harmonics and the differences between different harmonics clearly indicate the phonation configurations
in a language because harmonics show the adduction or abduction of the vocal cords due to an increase or decrease in the values of adjacent amplitudes.

Bussmann (2006: p. 425) describes formants as: “Bundle of sound elements that together form the quality of a sound and are made visible through the frequency stripes of a spectral analysis (spectrograph)… Formants are defined according to their frequency, amplitude, and width.” Therefore, all these measures are much related to one another and of great importance in describing phenomena like tone and phonation in a language.

By taking the above mentioned measures separately, i.e., in singles (like H1, H2 etc) and / or by subtracting the value of one measure from another (like H1-H2), the actual position, posture and shape of the vocal cords and overall larynx during tonal and phonation contrasts can be realized. Garellek and Keating (2011: p. 187) suggest that: “Higher frequency energy is usually measured as the amplitude of H1 relative to the amplitudes of F1 (A1), F2 (A2), and F3 (A3), as H1-A1, H1-A2, and H1-A3. These formant amplitude measures also reflect the bandwidths of the corresponding formants, and Hanson et al. (2001) interpret H1-A1 in particular as reflecting the effect of a posterior glottal opening.”

There are many different ways by means of which these acoustic measures are used in different acoustic analyses. Some of the uses of these acoustic measures as mentioned
in the published research are discussed here. Esposito (2006) finds that the measures of H1-A3 and H1-H2 distinguished well the phonation configurations within languages. Blankenship (2002) investigates Chong and finds that the measure of H1-A2 is better in distinguishing breathy from modal phonation. Therefore, mostly a set of acoustic measures is used in order to analyze different features corresponding to tone and phonation in a language. Wayland and Jongman (2003: p. 188) state that: “a conglomerate of cues may convey the breathy and clear phonation distinction. Besides spectral noise, dynamic spectral cues, namely the difference in amplitude between the first two harmonics (H1-H2); the first harmonic and the most prominent harmonic in the F1 region (H1-A1); and the difference in amplitude between the first harmonic and the most prominent harmonic in the F3 region (H1-A3) emerge as the most likely cues.” Referring to spectral analysis, Crystal (2008: p. 445) states that: “A spectral analysis is a graph in which one axis displays the frequency of each harmonic and the other displays amplitude.”

Among the above mentioned acoustic cues, H1-H2 is considered one of the most important cues in distinguishing phonation types in a language. Holmberg, Hillman, Perkell, Guiod, and Goldman (1995) suggest that the measure of H1-H2 is correlated with the time period of the glottis opening during each glottal cycle, which is referred to as open quotient (OQ). Therefore, during breathy phonation configurations, the value of H1-H2 is higher due to the dominance of the amplitude of the first harmonic, i.e., H1. Andruski and Ratliff (2000) investigate three of the seven tones of Green
Mong along with its phonation configurations and find that the breathy phonation gives higher values on the measure H1-H2 than non breathy phonation types. Whereas, DiCanio (2007: p. 475) finds that: “The H1-H2 values are the most closely correlated with the pitch changes.” Therefore, this measure can be of good importance in investigating interaction between tone and phonation in a language.

Heinz (2011: p. 8) suggests that: “The difference between the first and second harmonic are a good indicator of the phonation type.” Heinz (ibid: p. 9) further describes the three phonation types in the following way:

“H1 > H2 → breathy
H1 ≈ H2 → modal
H1 < H2 → creaky”

That is, for a breathy phonation the value of H1 would be higher than H2, for modal phonation the value of H1 would be nearly equal to H2, and for the creaky phonation type the value of H1 would be lower than H2.

Earlier, Bickley (1982) introduces the acoustic measure of H1-H2 that was considered important in the perception of breathiness. “Low range measures like H1-H2 have a close correlation to OQ values and are therefore good measures of the degree of glottal tension present in different phonation types (Stevens & Hanson 1995, Holmberg et al. 1995, Sundberg et al. 1999; as cited in DiCanio, 2007: p. 463).” Garellek and Keating (2011) claim that H1-H2 is the most widely used acoustic measure of phonation and it
has been found to distinguish among contrastive phonation types in many studies. Giving examples, Garellek and Keating (ibid) discuss Esposito (2006, 2010) which found that H1-H2 distinguished phonation types in eight out of the 10 languages in a cross linguistic sample of breathy versus modal phonation. However, Blankenship (2002) studies Mpi and suggests that the measure of H1-H2 is more reliable on a high tone than on a mid or low tone. Fung (2014) discusses the following image in order to show the measure H1-H2 on a graph:

Figure 2.4. Measures of H1 and H2 by Fung (2014)

Garellek (2010: p. 14) refers to some studies and propose that: “A higher value of H1-H2 is thought and often found to be correlated with greater glottal open quotient (Holmberg, Hillman, Perkell, Guiod, & Goldman, 1995; Stevens & Hanson, 1995; Sundberg, Andersson, & Haltqvist, 1999; DiCanio, 2009; but cf. Kreiman, Iseli, Neubauer, Shue, Gerratt, & Alwan, 2008). Open quotient (OQ) is the proportion of a
glottal period during which there is no contact between the vocal folds. H1-H2 as a correlate of OQ should be a good measure for differentiating non modal phonations from modal, since breathy phonation often has a greater OQ than modal, whereas creaky phonation can involve a more closed glottis. Indeed, for languages with contrastive breathy phonation, H1-H2 (or its formant corrected counterpart, denoted by asterisks: H1*-H2*) has been shown to be greater in breathy phonation than in modal for a variety of languages (Bickley, 1982, for Gujarati; Huffman, 1987, for Hmong; Blankenship, 1997, for Mazatec; Wayland & Jongman, 2003, for Khmer; Miller, 2005, for Ju’hoansi; see Esposito, 2006, for others).”

Esposito (2010) finds that the four measures, i.e., H1*-H2*, H1*-A1*, H1*-A2* and CPP (where the asterisk indicates that the measure is corrected for vowel formants), all distinguished well breathy from modal phonation configurations in Mazatec. Fung (2014: p. 23) states that: In the measure H1*-H2*, “Asterisks indicate that the harmonic amplitude were corrected to recover the source spectrum of the vocal fold pulses by reducing the influence of formant resonances.” Garellek (2010: p. 31) states that: “The higher the value of H1*-H2*, the breathier the phonation. Conversely, the lower the value of H1*-H2*, the creakier the phonation.”

DiCanio (2007: p. 460) proposes that: “H1-H2 significantly distinguishes registers with increased glottal tension from those lacking it.” DiCanio (ibid: p. 473) further state that: “Since H1-H2 distinguishes the phonation types containing glottal tension
from those without it, OQ is by extension also a good predictor of the degree of glottal tension.” Keating and Esposito (2006: p. 86) also suggest that the measure of H1-H2 is related to the Open Quotient (OQ) which in turn relates to overall glottal stricture; so: “H1-H2 is an acoustic measure well suited to characterizing differences along the glottal constriction continuum, and has been applied to many languages.”

Keating and Esposito (2006) discuss different acoustic measures used in distinguishing different phonation configurations and find that these measures reflect different aspects of production and so: “may or may not all distinguish the phonation categories of a given language” (pp. 87); and for that, the ANOVA tests are used to determine which measures give contrastive values for different phonation configurations. Keating and Esposito (ibid) give some related examples which give a good account of acoustic measures used in some studies. First one is by Wayland and Jongman (2003) who used five measures in Khmer, and found that H1-H2, H1-A1, and vowel RMS amplitude successfully distinguished breathy and modal vowels.

Second example is by Blankenship (2002) who used ten (10) measures in studying Mazatec and found that the measures of H1-H2, H1-A2, and CPP all distinguished well breathy from modal phonation configurations in Mazatec. Last example is by Esposito (2006) who tested 10 languages that contrast breathy and modal phonations, and found that Cepstral Peak Prominence, H1-A3, H1-H2, and H1-A2 are the measures which give voice quality contrasts.
There could be some other acoustic measures also which are used in the identification of tone and phonation in a language; whereas, in the current study fundamental frequency (F0), duration, intensity, final velocity, CPP, H1-H2, and H1*-H2* are measured for the description of interaction of Punjabi tones and phonation configurations. Out of them, H1-H2, H1*-H2* and CPP are the acoustic measures which are considered more relevant to distinguish different phonation configurations in a language.

2.13. ACOUSTIC MEASURES OF BREATHY VOICE

A very important phenomenon which plays a significant role in creating tonal and phonation contrasts in a language is breathy phonation which is produced with abducted vocal folds. Many studies like (Fairbanks, 1940; Zemlin, 1968; Klatt & Klatt, 1990; Hillenbrand, Metz, Colton, & Whitehead, 1990; Hillenbrand, Cleveland, & Erickson, 1994; Hillenbrand & Houde, 1996; as cited in Wayland and Jongman, 2003: p. 183) prove this point that breathy phonation is produced by incomplete and non simultaneous glottal closure during the closed phase of the phonatory cycle.

In many languages of the world breathy phonation is considered to be associated with a low pitch (Gordon and Ladefoged, 2001; Kong, 2001). Khan (2012: p. 781) suggests that: “Breathy phonation is also associated with a steeper spectral tilt; this is typically measured as the difference between the amplitude of the first harmonic and that of one of the first three formants.” Hombert, Ohala, and Ewan (1979) also report that the
breathy phonation type appears to be consistently associated with lowered tone in many languages. Durvasu (2011) suggests that in the process of breathy phonation, the folds are open longer in comparison to the amount of time that they are closed during a period which result in an open quotient that is greater than 0.50. Wayland and Jongman (2003: p. 187) state that: “During the production of breathy phonation, to allow the vocal folds to vibrate while they stay relatively far apart, the vocal folds have to be relatively less taut. Thus, the fundamental frequency of a breathy vowel is expected to be lower than that of a clear vowel.”

Khan (2012: p. 784) discusses the case of Gujarati and proposes that breathy phonation can reliably be distinguished by a higher value of H1-H2, a lower value of F0, a higher value of H1-A1, H1-A2, and H1-A4, lower RMS energy, possibly lower vowel height, and occasional aspiration. Khan (ibid: p. 791) further suggests that the breathy vowels in Gujarati can be distinguished by significantly higher values of H1–H2, H1–A1, H1–A2, and H1–A3 averaging across their entire duration; whereas, the measure of CPP gives lower values in breathy vowels.

Gordon and Ladefoged (2001: p. 15) discuss some studies like on Gujarati (Fischer-Jorgensen, 1967), Kui and Chong (Thongkum, 1988), Tsonga (Traill and Jackson, 1988), Hupa (Gordon, 1998) and suggest that breathy phonation is associated with a decrease in overall acoustic intensity in many languages. Wayland and Jongman (2003: p. 187) also refer to two studies first on Gujarati (Fischer-Jorgensen, 1967) and
second on Kui, and Chong (Thongkum, 1988) and suggest that breathy voice is associated with a decrease in acoustic intensity in many languages. However, Wayland and Jongman (2003) further refer to a study Wayland et al. (1994) which shows that breathy vowels in Javanese are associated with an increase in overall acoustic intensity. Again it is proved that the phonation types in a language are very much specific to that particular system and there are no absolute values by which these types can be determined. Rather they are relative and language specific.

Keating and Esposito (2006: p. 86) suggest that: “The strength of higher frequencies in the spectrum is thought to be related to the closing velocity of the vocal folds and perhaps to muscle tensions. This property can be quantified in many ways, including the amplitude of H1 relative to some higher frequency component, such as one of the formant frequencies (or the strongest harmonic near it).” Keating and Esposito (ibid) propose that the acoustic measure H1-H2 suits well to measuring different configurations along glottal constriction continuum. Keating and Esposito (ibid) further suggest that there are other acoustic measures like Cepstral Peak Prominence, H1-A1, H1-A2, and H1-A3 which distinguish the modal and breathy categories of the languages where H1-H2 does not work.

In the same way, Garellek and Keating (2011: p. 185) also find and suggest that: “spectral measures like H1-H2 and midrange spectral measures like H1-A2 best distinguish each phonation type, though other measures like Cepstral Peak Prominence
are important as well.” So CPP has also proved to be of great importance in distinguishing phonation contrasts in a language.

Hillenbrand et al. (1994) mention two studies (Hillenbrand, Cleveland, and Erickson, 1994; Stevens, 2000) and define CPP (Cepstral Peak Prominence) as a measure of peak harmonic amplitude normalized for overall amplitude; which gives lower values in breathy phonation due to the additional noise of increased airflow. Noise is produced when air coming from the lungs passes through a persistent and narrow glottal gap while producing breathy vowels. Esposito (2006) finds that the measure of CPP is proved to be a good measure at distinguishing modal from breathy phonation configurations. Hillenbrand, Cleveland, and Erickson (1994) also suggest that the measure of CPP which gives harmonics to noise ratio is an important measure in distinguishing between the breathy and other phonation categories. Keating and Esposito (2006: p. 86) state that: “The stronger the cepstral peak, the stronger the harmonics above the floor, noise or otherwise, of the Fourier spectrum, and the more periodic the signal.”

Some other related acoustic measures have also been used in various studies. Garellek (2010: pp. 14-15) refers to some studies and suggests that the measure of “H1-A1 is correlated with the bandwidth of the first formant, which is also thought to reflect posterior glottal opening at the arytenoids (Hanson, Stevens, Kuo, Chen, & Slifka, 2001). Taking these studies into account, higher H1-A1 should be an indication of
whispery voice, which is produced by means of air flowing through the arytenoids (Laver, 1980), whereas the higher spectral tilt measures like H1–A2 and H1-A3 should correlate with speed of closure.” Blankenship (2002) also mentions H1–A1 as considered to be correlated with posterior glottal opening.

Stevens (1977) comments that the measures of spectral slope, i.e., H1–A2 and H1–A3 are considered to be correlated with the abruptness of vocal fold closure. Therefore, the vocal folds close slowly during breathy phonation configurations and the higher harmonics are lower in amplitude than H1. Khan (2012) suggests that H2–H4 should only be taken as an auxiliary measure of breathiness. Creakier sounds have smaller H1-H2 values than breathier sounds (Kuang, 2013).

Analysis of interaction of tone and phonation is a complicated process because there are many factors involved which can affect pitch of a particular toneme. Pike (1948) highlights two features which could affect tonal contrasts in a language, i.e.,: “(1) the relative, rather than absolute, nature of tonal contrasts, and (2) tonemes that change (a) non-phonemically when conditioned by segments, stress, quantity, intonation, or position in word or phrase, or (b) phonemically in morphology, or phonemically but mechanically in sandhi, or phonemically in syntactic constructions.” (pp. 164)
2.14.  **TONE AND CONTEXT**

One of the factors that affect pitch is the context of a toneme. Varying context can bring some sort of change in that particular toneme. Therefore, controlling the context of tonemes could be a suitable solution to the analysis of a tonal language. For that, carrier phrases are used wherein the target tonemes are placed so that all the contrastive tonemes in the language are analyzed in the same environment and so in a better way. As Pike (1948: p. 164) suggests: “Tonemes may best be analyzed by controlling the context of utterances so as to control phonemic and non-phonemic change.” In this study, the stimuli consisted of mono-syllabic Punjabi words which fit to the syllable template of ‘CV’, where the vowel was [a] in all the words. That was how an attempt was made to control the contextual effects on tone.

2.15.  **THE PUNJABI LANGUAGE**

Punjabi is an Indo-Aryan language. It is spoken by more than 130 million people mainly in West Punjab in Pakistan and in East Punjab in India. There are also significant numbers of Punjabi speakers in the UK, Canada, the UAE, the USA, Saudi Arabia, and Australia (Punjabi: omniglot.com). McWhorter (2004: p. 35) states that: “Ninety six percent of the world’s people speak one of the 20 most spoken languages (Chinese, English, Spanish, Hindi, Arabic, Bengali, Russian, Portuguese, Japanese, German, French, Punjabi, Javanese, Bihari, Italian, Korean, Telugu, Tamil, Marathi, and Vietnamese).” According to this list Punjabi is the 12th most spoken language in the world.
Shackle (1979; as cited in Lothers and Lothers, 2010: p. 3) state that: “In linguistic literature, Pahari and Pothwari are classified with some other Indo-Aryan languages in a group called “Lahnda.” Grierson gave this name “Lahnda” to Western Punjabi. “Lahnda” is the Punjabi word for “western.” Other linguists preferred the Indo-Aryan convention of using feminine forms for languages so they called it “Lahndi.” However, only linguists have used the terms “Lahnda” or “Lahndi.”” Nigram’s (1972, as cited in Lothers and Lothers, 2010: p. 4) classification of the Indo-Aryan languages (central northern group) is as under:

Figure 2.5. Nigram’s (1972) classification of the Indo-Aryan languages (central northern group)

Punjabi is the most spoken language in Pakistan. Zaidi (2014: p. 2) states as: “Punjabi is the majority language of Pakistan. The province of Punjab is Pakistan’s largest
political administrative unit whose population is more than 60% of the country’s population. Punjabis are not just the most numerical group in Pakistan, they are also the most powerful ethnolinguistic entity in the country... The population of the Punjabis within the province of Punjab is well over 80%.”

In Pakistan, Punjabi is under the influence of Persian and Arabic (Perso-Arabic); whereas, in India, this language is influenced by Sanskrit. It has three main text scripts, namely, Shahmukhi, Gurumukhi and Devenagari. In Pakistan, it is written in Shahmukhi script, whereas, in India, it is written in Grumukhi and Devanagari scripts. The Punjabi language has got many dialects. Some of the major dialects include: Majhi, Pothohari, Lehandi, Multani, Doabi, Malwai and Puwadhi. Majhi dialect is spoken in Lahore, Sheikhupura, Kasur, Gujranwala, Sialkot, Narowal, Gujrat, and Jhelum regions in Pakistan; and in Amritsar, Gurdaspur regions of the Indian state of Punjab. (Punjabi: language.iloveindia.com)

Punjabi has a unique phonological system and has got all the phonological features of the region it belongs to. It uses pulmonic egressive airstream mechanism in all of its sounds as Bhatia (1993: p. 330) suggests that: “Pulmonic egressive airstream mechanism is involved in the production of all phonetic segments of the language.”
2.15.1. **Syllable Structure of Punjabi**

Bhatia (1993: p. 342) discusses the sound system of Punjabi language and comments on the syllable template in the language as: “The canonical syllable type is (C) (C) V (V) (C) (C), where V is one of the vowels, /a/, /e/ and /o/.” Therefore, Punjabi can have syllable structure with complex onsets, i.e., more than one consonant, and complex codas also. These complex onsets and codas can have a maximum of two consonants. So, a Punjabi syllable is sensitive to its structure and can have long or short vowels and different number of consonants at its onset and coda positions. Anyhow, more research is needed to determine the phontactic constraints regarding the syllabification in the language.

Syllable templates in Punjabi are as under:

<table>
<thead>
<tr>
<th>Syllable Template</th>
<th>Word</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>/aa/</td>
<td>come</td>
</tr>
<tr>
<td>CV</td>
<td>/pa/</td>
<td>put</td>
</tr>
<tr>
<td>CCV</td>
<td>/hla/</td>
<td>shake</td>
</tr>
<tr>
<td>VC</td>
<td>/ik/</td>
<td>one</td>
</tr>
<tr>
<td>CCVC</td>
<td>/ṭlab/</td>
<td>pond</td>
</tr>
<tr>
<td>CCVCC</td>
<td>/ṭṟəx/</td>
<td>tree</td>
</tr>
</tbody>
</table>

Exploring the syllabification rules in Punjabi, Kabir (Crulp report / CR02_20E: p. 173) suggests that: “The phonetics of Punjabi allows complex consonant clusters in
both the onset and the coda of syllables (might use extra syllabification as in /ʃkæt̪/.
The maximum number of consonants in the onset is 2 whereas it allows up to 2 coda consonants. Thus, the maximum number of consecutive consonants across syllable boundaries is 4.” Kabir (ibid: p. 174) further states that: “Certain restrictions exist as to which consonants, or classes of consonants, can occur in which position within the onset or coda of a syllable. For instance, in Punjabi no phones other than obstruents can occur before an obstruent in the onset. In codas, after the first obstruent no phones other than obstruents can occur in the coda.”

Kabir (Crulp report / CR02_20E: p. 174) gives the following examples to support his point:

Table 2.5. Consonant clusters in onset by Kabir (Crulp report)

<table>
<thead>
<tr>
<th>Class</th>
<th>Cluster</th>
<th>Example</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop + trill</td>
<td>d̪r</td>
<td>d̪rəx̌t̪</td>
<td>Tree</td>
</tr>
<tr>
<td>Fricative + stop</td>
<td>f̪k</td>
<td>f̪kæt̪</td>
<td>Complaint</td>
</tr>
</tbody>
</table>

Table 2.6. Consonant clusters in codas by Kabir (Crulp report)

<table>
<thead>
<tr>
<th>Class</th>
<th>Cluster</th>
<th>Example</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fricative + stop</td>
<td>x̌t̪</td>
<td>d̪rəx̌t̪</td>
<td>Tree</td>
</tr>
<tr>
<td>Nasal + stop</td>
<td>nd</td>
<td>f̪ʒənd</td>
<td>Slap</td>
</tr>
<tr>
<td>Trill + stop</td>
<td>rk</td>
<td>kʰ ork</td>
<td>Itch</td>
</tr>
<tr>
<td>Retroflex + stop</td>
<td>rk</td>
<td>kʰə rk</td>
<td>Noise</td>
</tr>
</tbody>
</table>
2.15.2. Consonant Sounds in Punjabi

There are 32 consonant sounds in the language (spoken in Lahore) as Karamat (2002) finds in her study of phonemic inventory of Punjabi. There are five voiceless plosives (four stops and an affricate), i.e., /p, t̪, t, ʧ, k/. There are five aspirated versions of voiceless plosives, i.e., /pʰ, t̪ʰ, tʰ, ʧʰ, kʰ/. There are five voiced plosives (four stops and an affricate), i.e., /b, d̪, d, ʤ, ɡ/. There are no voiced aspirates in the language. “Voiced aspirates series is absent in Punjabi” (Karamat, 2002: p. 182). There are four nasals, i.e., /m, n, ɳ, ŋ/. Punjabi has five voiceless fricatives, i.e., /f, s, ʃ, x, h/. There are three voiced fricatives, i.e., /v, z, ɣ/. There is one trill sound, i.e., /r/, and one flap, i.e., /ɾ/. There are three approximants in the language, i.e., /l, l, j/. The table of Punjabi consonants is as under:

Table 2.7. Consonants of Punjabi by Karamat (2002 : p. 182)

<table>
<thead>
<tr>
<th></th>
<th>Bilabial</th>
<th>Labiodental</th>
<th>Dental</th>
<th>Alveolar</th>
<th>Retrflex</th>
<th>Palatal</th>
<th>Velar</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plosive</td>
<td>p</td>
<td>t̪</td>
<td>t</td>
<td>ʧ</td>
<td>k</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pʰ</td>
<td>t̪ʰ</td>
<td>tʰ</td>
<td>ʧʰ</td>
<td>kʰ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>d̪</td>
<td>d</td>
<td>dʒ</td>
<td>g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasal</td>
<td>m</td>
<td>n</td>
<td>ɳ</td>
<td>ŋ</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fricative</td>
<td>f</td>
<td>s</td>
<td>ʃ</td>
<td>x</td>
<td>h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>v</td>
<td>z</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trill</td>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approxi-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mant</td>
<td>l</td>
<td>ɭ</td>
<td></td>
<td>j</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.15.3. Vowel Sounds in Punjabi

There are ten vowel sounds in the language (spoken in Lahore) as Karamat (2002) finds in her study. There are seven long vowels, i.e., /i, e, ɛ, a, ɔ, o, u/, and
there are three short vowels, i.e., /ɪ, ə, ʊ/. Zahid (2012) mentions in her study that Punjabi language has oral as well as nasal vowels and suggests that there are ten oral vowels with three short / ɪ, ǝ, ʊ / and seven long / i, e, æ, a, ɔ, o, u / vowels. Zahid (ibid) notes that Punjabi has /æ/ vowel instead of /ɛ/ vowel as suggested by Karamat (2002). Being a native speaker of Punjabi, the author of this study also feels that Punjabi has /æ/ vowel instead of /ɛ/ vowel. Gill and Gleason (1969; as cited in Zahid, 2012: p. 32) suggest that all the oral vowels in the language have their nasal counterparts as well. The Punjabi vowel quadrilateral as given by Karamat (2002) is as under:

Figure 2.6. Vowels of Punjabi by Karamat (2002 : p.182)
2.15.4. Tonal Contrasts in Punjabi

Baart (2003) states that Punjabi is a tone language and the words of Punjabi are grouped into three tone classes: words with low rising tone, words with high falling tone, and words with mid or unmarked tone. Baart (2003) gives the following example of Punjabi as a tone language:

‘horse’ (rising)  ‘leper’ (falling)  ‘whip’ (level)

kooɽa:  kooɽa:  kooɽa:

L H  H L  H

Bailey (1915: ix; as cited in Baart, 2003: p. 2) comments on the above mentioned example as: “The pitch patterns of these Punjabi words can be described as level in the case of ‘whip’, low rising in the case of ‘horse’, and high falling in the case of ‘leprosy patient’.” Whereas, Masica (1991: p. 118) is of the view that: “There are two distinctive tones in Punjabi contrasting with the neutral tone: the High (or High Falling) /`/ and the Low (or Low Rising) /´/. (Some would say there are three tones, including the neutral or "Mid" tone as one of them.) Favorite examples of the contrasts are /ko´ra/ 'leper', /ko`ra/ 'horse', and ("Mid" or unmarked tone) /ko. ra/ ‘whip’.” Therefore, Masica (ibid) does not consider the mid Punjabi tone as one of the three tones and eliminate its status as a distinct tone.
Owing to the fact that there has not been much research on languages spoken in the areas of Pakistan, people interested in linguistic and especially phonetics research were not aware of the fact that this area was very rich in languages and literature. That is why Bhatia (1993: p. 343, as cited in Baart, 2004) comments: “Punjabi is the only modern Indo-Aryan language which has developed tonal contrasts.” And Yip (2002: 171, as cited in Baart, 2004: p. 5) states that: “even here we find the occasional tonal language, such as Punjabi.” Whereas, the fact is that Pakistan is located in an area which has got many tonal languages. Baart (2004: p. 5) finds and states: “In actual fact, Punjabi is not the only tone language in the region, and neither is it an ‘occasional’ tone language. Rather, it is part of a much larger area, covering north-western India, northern Pakistan, and possibly also bordering regions in Afghanistan, that is remarkably rich in tone languages. These include language varieties such as Hindko and Pahari-Pothwari, which are closely related to Punjabi, and also more distant ones such as many of the so-called ‘Dardic’ languages of the mountains of northern Pakistan, several languages belonging to the Rajasthani and Western Pahari subgroups of Indo-Aryan, and the non-Indo-Aryan language Burushaski.” Baart (2003) presents and discusses 18 tone languages only in the areas of northern Pakistan and divides them into three groups, namely Shina (with 2 tones), Punjabi (with 3 tones), and Kalami (with more than 3 tones). Baart (2003: p. 7) asserts that: “the most basic observation for all the tone languages of northern Pakistan is that the tone features are associated with the stressed syllable.”
Masica (1991: pp. 118-119) states that: “Punjabi tone is definitely prosodic (and thus resembles - in terms of its acoustic impression as well as structurally - Scandinavian rather than Chinese or – even less - African or Mesoamerican tone) in that its domain (described by Gill and Gleason in terms of an "onset" and a "tail") normally extends over two syllables although a monosyllable may also have tone.” As discussed earlier (See 2.9) that the TBU in Punjabi is a stressed syllable; and this study confirms it because all the stimuli in the study are mono-syllabic words. Therefore, it is pertinent to mention here that Punjabi tone does not extend over two syllables.

Karamat (2002) also investigates and finds that Punjabi has three tones, namely, High, Mid, and Low tones. She describes the three tones in the following way: High tone is of higher pitch than the other two tones with a shorter syllable. The pitch of mid tone is at mid level with a medium duration of syllable. The low tone is of low pitch with longer syllable duration than of the other two tones. So, Karamat (2002) describes the Punjabi tones in terms of their fundamental frequency and duration only.

Earlier, Bhatia (1993) also asserts that, in Punjabi, that there are three tones, namely, the low tone (low rising tone), the high tone (rising falling tone) and the mid tone is never represented. Bhatia (ibid: p. 343) further claims that: “Punjabi does not have contour tones as does Chinese”, and gives the following examples of Punjabi tonal contrasts:
Table 2.8. Punjabi tonal contrasts by Bhatia (1993 : p. 343)

<table>
<thead>
<tr>
<th>Low</th>
<th>Mid</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>koRaa</td>
<td>koRaa</td>
<td>koRaa</td>
</tr>
<tr>
<td>(horse)</td>
<td>(whip)</td>
<td>(leper)</td>
</tr>
<tr>
<td>malaa</td>
<td>malaa</td>
<td>malaa</td>
</tr>
<tr>
<td>(lady)</td>
<td>(mix)</td>
<td>(boat man)</td>
</tr>
<tr>
<td>kaR</td>
<td>kaR</td>
<td>kaR</td>
</tr>
<tr>
<td>(chisel)</td>
<td>(bottom)</td>
<td>(boil)</td>
</tr>
</tbody>
</table>

2.15.5. Development of Tone in Punjabi

The historical development of a tone language is known as tonogenesis. Hombert, Ohala and Ewan (1979: p. 38) propose that: “The development of contrastive tones on vowels because of the loss of a voicing distinction on obstruents in prevocalic position is probably the best documented type of tonogenesis. When such a development occurs, a relatively lower tone develops on vowels following a previously voiced series, and a relatively higher tone is found after a previously voiceless (or voiceless aspirated) series.” That is probably how Punjabi has undergone the process of tonogenesis with the passage of time, as it is claimed that once the voiced aspirates in the language lost their aspiration and voicing and the low tone came into the language.

Gruber (2011) discusses Maran’s (1973) five stages of tone development in a language. Probably Punjabi has also undergone the same process of tonogenesis. Maran 1973: p. 107, as cited in Gruber, 2011: p. 31) states that: “the manner in which a tonal system takes over is gradual… ”
Maran’s (1973) stages of tonogenesis are as under:

Stage 1: Atonal

Stage 2: “Attendant pitch characteristics” without functional load

Stage 3: Redundancy of pitch and conditioning environment – codas and pitch perturbation exist side-by-side

Stage 4: Tone is primary contrast. An “advanced depletion of finals” (i.e. coda distinctions) makes tone unpredictable, determined lexically.

Stage 5: Tonal

Clark, Yallop and Fletcher (2007: p. 345) discuss the process of tonogenesis and state that: “tone has arisen where pitch differences, originally conditioned by consonants, have become distinctive when the consonants have been changed or lost.” They support their viewpoint by referring to the studies by Homber, 1978; Hyman, 1978; and Ohala, 1978. Talking about the development of Punjabi as a tone language, Masica (1991: pp. 118-9, as cited in Baart 2003: p. 2) state that: “a relation was noted between the loss of voiced aspirates ([bh], [dh], etc.) and the emergence of tone in Punjabi”. Therefore, over a period of hundreds of years, Punjabi has evolved and developed tone substituting voiced aspirates. In this regard, the /h/ phoneme is also considered to play an important part in explaining the phenomenon of tone in the language which is discussed subsequently.
Masica (1991: p. 119) gives a comprehensive historic account and states as under:

“As Shackle (1972) points out, words without one of the distinctive tones (or, in other terms, with the neutral "tone") are far more common than words with them… this is because Punjabi tone has clearly evolved from certain kinds of aspiration, and is therefore found only in words whose equivalents in other N I A languages have voiced aspirates, aspirate nasals or liquids, or /h/ itself. (For example, the Hindi equivalents of the words above are /korha/- with a different suffix, /ghora/, and /kora/.) Bahl (1969) observes further that tone (that is, tone onset) is found only on stem vowels and those of certain (stem forming) derivational suffixes, never on inflectional endings… According to Bahl, Punjabi tone was first noticed by Bailey in 1913, and not fully described until B. D. Jain's 1934 accounts, which were restated by Bahl in phonemic terms in 1957. The late recognition of Punjabi tone by scholars is undoubtedly related to the way it is represented in writing.”

Ohalà (1978: p. 26) also states that: “In fact Punjabi has tones today, presumably due to the influence of an earlier consonant system similar to the one Hindi has.” Like in Hindi, Urdu has also got the voiced aspirates, which Punjabi and Pahari are reported to have lost and replaced them with tone. Hombert, Ohala and Ewan (1979: p. 47) also refer to some studies and state as: “In Punjabi, breathy voiced consonants became unaspirated, leaving a low tone on the following vowel (Gill & Gleason, 1969; Haudricourt 1972). Data presented by Glover (1970) on Tibeto-Burman languages indicate that breathy voiced consonants are stronger F0 depressors than (simple) voiced obstruents. In Ndebele, breathy voiced consonants pattern with voiced obstruents in lowering the pitch on following vowels (Ladefoged, 1971)”.
The Urdu language (also an Indo-Aryan language) is the national language of Pakistan. Discussing and comparing the Urdu language with the Pahari (spoken in Azad Jammu & Kashmir, Pakistan) and Punjabi (spoken in Punjab, Pakistan), Khan (2013: p. 9) suggests that: “the cognate words in Urdu that have voiced aspirated consonants at the word initial position are realized by low tone voiceless sounds in Pahari.” Khan (ibid) gives the following table which shows the correspondences of voiced aspirated consonants in Urdu as used in Pahari and Punjabi:

Table 2.9. Voiced aspirates in Urdu, Pahari, and Punjabi by Khan (2013: p. 9)

<table>
<thead>
<tr>
<th>Urdu</th>
<th>Pahari</th>
<th>Punjabi</th>
</tr>
</thead>
<tbody>
<tr>
<td>bʰul ‘forget’</td>
<td>pɦʊl [pʊ̀ l] ‘forget’</td>
<td>pɦʊl [pʊ̀ l] ‘forget’</td>
</tr>
<tr>
<td>ɡʰoɽa ‘horse’</td>
<td>kɦoːɽa: [kɔːɽa:] ‘horse’</td>
<td>kɦoɽa [kɔɽa] ‘horse’</td>
</tr>
<tr>
<td>dʰol ‘dust’</td>
<td>t̪ɦu:l [t̪ʊ:l] ‘dust’</td>
<td>t̪ɦu:l [t̪ʊ:l] ‘dust’</td>
</tr>
</tbody>
</table>

The glottal fricative [h] plays a significant role in the occurrence of tone in Punjabi. Khan (2013: p. 9) suggests that: “Urdu has voiceless fricative /h/ that does not exist in Pahari. Instead, Pahari has a tone producing voiced glottal consonant /ɦ/.” Nearly similar is the difference between Urdu and Punjabi. Karamat (2002) also finds that glottal fricative [h] is pronounced only word initially in the language and at other positions, i.e., in the middle and at the end of a word it is manifested as a H or L tone.

Hombert, Ohala and Ewan (1979: p. 45) discuss the production of /h/ sound and state that: “The distinctive character of the aspirates including /h/, as observed in the time
course of the subglottal air pressure, is not increased subglottal air pressure as proposed by Chomsky and Halle. Rather, the occurrence of reduced glottal resistance during a period when there is no accompanying oral constriction invariably causes a momentary lowering of the pressure. Those momentary increases in subglottal air pressure that do occasionally occur during the closure portion of stops, whether aspirated or not, can be explained without reference to any different behavior on the part of the respiratory system.” This comment gives a good description of the physiological process of the production of aspirates including /h/ sound.

Ohala and Ohala (1972: p. 39) discuss the presence of aspirates in Indo-Aryan languages and state that: “Hindi and some other Indo-Aryan languages (e.g., Marathi) are unique among the world’s languages in possessing contrasts between aspirated and non-aspirated stops in both the voiceless and the voiced series, i.e., /p/ vs. /ph/ and /b/ vs. /bh/.” Bailey (1904) also discusses and compares Urdu, Hindi and Punjabi and states that [h] is pronounced in Urdu and Hindi in the same way as it is in English. Anyhow, in Punjabi, when it, i.e., [h] appears either alone or in conjunction with b, g, j, d, d, w, n, l it has a deep guttural sound not wholly unlike Arabic ‘ain’. Tisdall (1887) also suggests that the aspirates in the language, e.g. bh, gh, are not pronounced exactly as Urdu, but with a peculiar sound. Tisdall (ibid: p. 7) further states that: “h is very lightly sounded and is often entirely inaudible. At other times it serves to lengthen the sound of the preceding vowel.”
There is much evidence as to support this point that /h/ sound lowers fundamental frequency in some contexts. Hombert, Ohala and Ewan, 1979: p. 51) investigate the given Arabic data and suggest that in Arabic language: “an [h] produces a drop in F0 (varying from 25 to 50 Hz) on the preceding vowel, while [?] produces a rise in F0 (from 9 to 48 Hz).” In the case of Punjabi this lowering in F0 may be seen in the words replacing Urdu voiced aspirates in the word initial positions.

Karamat (2002: p. 182) discusses the voice quality of Punjabi language and states that: “Absence of the voiced aspirates is compensated by the presence of tone. Voiced aspirates exist in written script, but in speech, word initially they are replaced by corresponding voiceless stop and presence of high tone; whereas, in the middle and end of words the voicing feature remains and a tone is added”. Bhatia (1993: p. 331) is also of the view that: “Punjabi lacks voiced aspirates. Only unaspirates occur with following voiceless aspirate”. Khan (1997: as cited in Karamat, 2002: p. 180) conducts a study on Punjabi and finds that: “It was observed that orthographically voiced aspirated stops are converted into corresponding voiceless stop with high tone on the syllable”.

2.15.6. Stress Placement in Punjabi

Stress placement in the language should not be confused with its tonal system. Anyhow, Bhatia (1993) suggests that Punjabi shows interaction of tone placement with accent / stress and presents the Punjabi low tone which must be on the same
syllable as the accent. That is how the role of stress in the language becomes important to be discussed because it is believed that the low tone in the language is placed on a stressed syllable. Bhatia (ibid: p. 344) gives the following examples (underlining indicates the placement of accent / stress):

<table>
<thead>
<tr>
<th>Word</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>tarak</td>
<td>(throb)</td>
</tr>
<tr>
<td>pandaar</td>
<td>(storage)</td>
</tr>
<tr>
<td>paRaa</td>
<td>(cause to study)</td>
</tr>
</tbody>
</table>

Bhatia (1993: p. 343) suggests that the existence and phonemic status of stress cannot be denied in Punjabi and is used in “disyllabic syllables to distinguish between grammatical categories. In nouns, stress accent falls on the initial syllable and in the verb category (particularly imperative and causative) stress accent falls on the final syllable.” Referring to another important phenomenon of geminates in the language, Lata and Arora (2008: p. 1) also suggest that an important feature of Punjabi is “the occurrence of double consonants, i.e., geminates, which results in phonemic stress that can occur on either initial or final syllable”. Whereas this stress due to geminates should not be confused with tone because unlike tone it does not create any lexical contrasts in Punjabi. On the other hand, this kind of stress in the language seems very similar to the stress in the English language. Bhatia (1993: p. 343) gives the following examples from the Punjabi language to prove his point:
### Nouns

*galaa (throat)  ga*Iaa (cause to melt)
*talaa (sole)    ta*Iaa (cause to fry)
*balaa (evil spirit)  ba*Iaa (call)

Bhatia (1993) gives the following phonetic rules for stress placement in Punjabi:

- “Stress falls on the final syllable in cases where the initial syllable has a syllable peak with centralized vowels (ɪ, ə, ʊ) and the final syllable has a consonant cluster with centralized vowel peaks, e.g., a*nand (joy), pa*khanD (hypocrisy);
- When the first syllable is long or heavy and the second is a close one, the stress falls on the first syllable, e.g., *tobaN (washerwoman), *gaajar (carrot);
- In the disyllabic words, the initial syllable has a stress if the final syllable is open, e.g., *adaa (half), *maalii (gardener), *kallaa (alone);
- In the trisyllabic words the stress falls on the second syllable if it is long, otherwise it falls on the first syllable, e.g., ka*saaii (butcher), cam*kiilaa (shining) but *pinjaraa (cage).” (pp. 343)

Bhatia (1993: p. 343) further asserts that “the vowel quality and the length remains unaffected by any difference in stress placement”. Lastly, Bhatia (ibid) invites further investigation and research on the Punjabi stress.
SUMMARY OF CHAPTER 2

This chapter presents a critical review of the related literature highlighting the current status of the related discoveries in the related fields. It starts with further explaining the terms tone and tone languages by presenting some facts regarding the tone languages in the world. Then Pike’s (1948) typology of tone languages is discussed which divides the tone languages into two groups, i.e., register tone languages (with no pitch variations over a TBU) and contour tone languages (with pitch variations over a TBU). Then the phenomena of accentual languages and tone sandhi are discussed. Then tone levels are discussed as a tone language can have many levels based on tonal contrasts. For example, Cantonese can have six different pitches with six different meanings and Punu, a Miao Yao language, can have eight distinctive tones. How to transcribe tone in different ways is also discussed. Chao’s (1930) system of tone transcription is of key importance in this regard due to its simplicity. Then possible tone bearing units in tone languages are also discussed including word, syllable, and mora.

The second key phenomenon explored in the study is phonation which is discussed at length in different dimensions. It is discussed that the most common phonation configurations in world’s languages include breathy phonation, modal phonation, and creaky phonation. It is discussed, as Keating and Esposito (2006) suggest that there are degrees of creakiness and of breathiness in a language because the opening and closing of vocal cords takes place in the form of a continuum due to which a breathy
voice in one language can be taken as a modal in another language. Therefore, it is concluded that there are no absolute values to determine breathiness or creakiness in a language, rather they are relative. The role of vocal cords is also discussed with particular focus on the development of tone and phonation. A brief account of the physiology of vocal cords is also discussed in this regard.

The interaction of tone and phonation is also discussed with examples. There is enough evidence presented in the chapter to support that tone and phonation may exist in a language without any interaction, i.e., independent of each other. At the same time, there is evidence available in literature to support the point in favor of their interaction and inter-dependence. Then acoustic correlates of tone and phonation including fundamental frequency, duration, intensity, final velocity, H1, H2, H1-H2, H1*-H2*, CPP, H1-A1, H1-A2, H1-A3, and H2-H4 are discussed along with their definitions (wherever required) by means of which tone and phonation systems in a language may be described. In this regard, as discussed earlier, Heinz (2011) describes the phonation related measure H1-H2 and suggests that H1 would be higher than H2 for a breathy phonation type, H1 would be nearly equal to H2 for a modal phonation type, and H1 would be lower than H2 for the creaky phonation type. The following studies have been reviewed and discussed where the tone and phonation types have been explored with the help of above mentioned acoustic correlates. The studies include: Pickett (1999), Khan (2012), Wayland and Jongman (2003), Huffman (1987), Esposito (2006), Esposito (2010), Esposito (2012), Garellek and Keating (2011),

Furthermore, some facts have been reported regarding the Punjabi language that it is an Indo-Aryan language spoken majorly in Pakistan and India with some other parts around the globe. According to McWhorter (2004) Punjabi is the 12th most spoken language in the world. In Pakistan, Punjabi is under the influence of Arabic and Persian languages. Then phonological system of Punjabi is discussed in this chapter. It shows that the canonical syllable template of this language is (C) (C) V (C) (C) and that Punjabi can have syllable structure with complex onsets and complex codas. For example, a Punjabi word /d̪ɾəx̱t̪/ means ‘tree’. There are thirty two consonant sounds in the language and there are ten vowel sounds. There are three tones in the language. It is also discussed that Punjabi has developed tone in place of voiced aspirates which are no more there in the language.
3.0. INTRODUCTION

The second chapter, literature review, suggests that many of the tonal languages in the world show co-occurrence of tone and phonation. This study investigates as to what extent these two phenomena, i.e., tone and phonation, co-exist in Punjabi as it is spoken in Lahore. The study is conducted by measuring the acoustic correlates of tone and phonation, i.e., fundamental frequency (F0), duration, intensity, and final velocity specifically for tone, and the phonation measures H1-H2, H1*-H2*, and CPP are also used to see the role of phonation in tonal contrasts in the language. This chapter explains as to what the stimuli were, how the stimuli were chosen, who the participants were and how they were selected; how and where the data were collected; and how the experiment was conducted to investigate tone and phonation in the language.

3.1. PARTICIPANTS

In this study, ten Punjabi speakers were selected conveniently from Lahore, the capital of Punjab province of Pakistan. There were 5 male speakers with their name initials as (Fn, Im, Tr, Tq, and Um) and 5 female speakers with their name initials as (As, No, Nr, Uz, and Zr). The author of this dissertation (Tr) was one of the speakers. All the participants have been living in Lahore since birth and acquired Punjabi (Majhi
dialect as spoken in Lahore) as their mother tongue. Special care was taken in choosing the participants who used mostly Punjabi in their routine life. Urdu is also spoken in Lahore which was understood by all the speakers but all of them would use Punjabi as a mode of communication in their routine. The age of the participants ranged from 28 to 45 years with an average age of 34 years. None of the participants except the author knew about the nature of the experiment. It was also ensured that the participants do not have any physiological problem which could affect their speech. None of participants reported any hearing or listening impairment in their line as well. The education of the participants varied from matriculation to a post-graduate degree.

3.2. STIMULI

In this study, the stimuli were chosen carefully. As some published research is available on the tone contrasts mainly in the bi-syllabic words of Punjabi (e.g. Bhatia, 1993; Baart, 2003; Karamat, 2002; and Rafi, 2010), but, probably (at least to the author’s knowledge), there has not been much research on the tonal contrasts in the mono-syllabic words of Punjabi. Furthermore, as Punjabi has been reported to have contour tones it was better to see their occurrence at the minimal possible level so that the contour tones are analyzed in a better way. That was why the mono-syllabic words were selected by the author who is a native speaker of Punjabi. Special care was taken in choosing the words having the tonal contrasts. It was also taken care of that the words were familiar and used frequently in routine life. In this regard no data were
available as to show which words were familiar and used frequently, so being native speaker of Punjabi the author decided and chose words according to his knowledge.

All the words in the study were mono-syllabic, having a voiceless onset consonant. Only the words with voiceless consonants were taken so that the voicing of the voiced consonants do not cause any difficulty in measuring tonal and phonation contrasts in the language. All the words were selected having the syllable template as ‘CV’, i.e., a voiceless consonant followed by a vowel because it is noted that: “onset consonant effects on F0 are well attested in the literature” (Hombert et al 1979, Xu 2001; as cited in Sarmah, 2009: p. 52). Therefore the onset consonants were given special care in selection so that the words under investigation have the same context. Following the voiceless consonant part, all the words contained /a/ vowel so that all the tones and phonation configurations were investigated in a controlled manner and in the same environment. Another reason for choosing words having /a/ vowel was this finding: “The majority of studies on linguistically relevant voice qualities (e.g. Bickley, 1982; Ladefoged, 1983; Huffman, 1987; Ladefoged et al., 1988; Kirk et al., 1993; Silverman et al., 1995; Blankenship, 1997) have not made use of corrected or normalized measures, but instead focused on /a/, because the high first formant minimizes the effects on the first and second harmonics.” (Esposito, 2010: p. 185)

A list of Punjabi words was prepared with the above mentioned specifications. The words were written on flash cards in Urdu script along with their meaning. So, there
were three flash cards in total with each card for a set of stimuli containing three words with tonal contrasts written in a row (see Appendix A). Based on the tonal contrast, the words made three sets of stimuli with three words in each set representing three tones in the language. These words in three sets having the tonal contrast were recorded, which made a total corpus of 450 tokens in the following way:

10 speakers x 3 sets x 3 words x 5 repetitions = 450 tokens

The three sets of words were composed of monosyllabic words as follows:

Table 3.1. Data set of Punjabi words with tonal contrast

<table>
<thead>
<tr>
<th>Low Tone</th>
<th>Mid Tone</th>
<th>High Tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>[pa] (price)</td>
<td>[pa] (quarter)</td>
<td>[pa] (track)</td>
</tr>
<tr>
<td>[ka] (grass)</td>
<td>[ka] (possession)</td>
<td>[ka] (a handful pile of reaped crop)</td>
</tr>
<tr>
<td>[ʧa] (peep through)</td>
<td>[ʧa] (desire, affection)</td>
<td>[ʧa] (tea)</td>
</tr>
</tbody>
</table>

In the above table, the words in the first column having low tone are produced as [pa] with low tone, [ka] with low tone, and [ʧa] with low tone, respectively. Similarly, the second column in the table comprises of words with level tone; whereas, the third column in the table shows words with high tone.
3.3. DATA COLLECTION

The procedure was explained to the participants and they were given practice of reading the words from the flash cards so that they could read the words easily during actual recordings. All the instructions were given in Punjabi and Urdu. The participants were asked to read the words from the cards. They were asked to shuffle the words and say every word for five times. The words were shuffled in such a way that first repetition started from first word in the row and then the next two words were recorded; second repetition started from second word in the row followed by third word and then first word; third repetition started from third word followed by first and then second word; and so on. In the same way a total of five repetitions were recorded for each set of words. They were allowed to follow their own speed of reading the words. They were asked to say the words with reasonable loudness which should not be too loud or too soft. The recording was done in silent rooms of homes and colleges. The speakers Tq and Um were recorded while the author visited their college. The speakers Fn, Im, Nr, and Zr were recorded while the author visited their residence. Whereas, the speakers As, Tr, No, Uz were recorded at the author’s residence. A good quality voice recorder (WAV file recorder) was used for recording the data with a sampling rate of 44100 Hz and 16 bit amplitude resolution/quantization rate. The participants were asked to keep a fixed distance (varied from 4 inches to 6 inches) from the microphone during recordings. The microphone was placed in front of them in such a way as to avoid noise bursts during speech. PRAAT (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014) software were used for analyzing the data.
3.4. SEGMENTATION OF DATA

The data were divided into segments using Praat (Boersma and Weenink, 2014) software. Each recorded word made a different segment; which made a total corpus of 450 segments, i.e., 450 tokens for analysis. All the tokens were named referring to the specific speakers with their name initials along with the specific tonal contrast. For the purpose of tone identification, the words in the first column of the table above (Low Tone) were labeled as letter ‘L’, the words in the second column (Mid Tone) were labeled as letter ‘M’, and the words in the third column (High Tone) were labeled as letter ‘H’. For example, First token for /pa/ word with low tone by speaker ‘Fn’ was named as ‘FnL_P1’ and second as ‘FnL_P2’ etc.

3.5. ANALYSIS OF DATA FOR PUNJABI TONES

The traditional acoustic correlates of tone, i.e., F0, duration and intensity, along with a new correlate of final velocity (Xu, 2013) were measured for analyzing Punjabi tone in this study. The direction of tones can easily be seen with the help of the acoustic measure of final velocity. All the tokens were first labeled for [a] vowel using ProsodyPro (Xu, 2014). Then the software was put to run for processing all the sounds. Finally, their ensemble values were obtained for 150 repetitions for each tone by using ProsodyPro (Xu, 2014).
3.6. ANALYSIS OF DATA FOR THE ROLE OF PHONATION IN PUNJABI TONES

The acoustic correlates of phonation, i.e., H1-H2, H1*-H2*, and CPP were also measured to see their values for the Punjabi tonal contrasts so that their contribution in Punjabi tones may be explored. First, all the words were labeled for [a] vowel using ProsodyPro (Xu, 2014). Then the software was put to run for processing all the sounds. Finally, their ensemble values were obtained for 150 repetitions for each tone type by using ProsodyPro (Xu, 2014).

3.7. PROSODYPRO

In order to measure the prosodic features of a language, this software is used which can read values generated by another software, namely, Praat (a software for speech analysis). ProsodyPro is developed by Xu. Xu (2013: p. 7) describes it as: “A software tool for facilitating large scale analysis of speech prosody, especially for experimental data.” Xu (ibid: p. 8) further states that: “To facilitate both graphical and numerical analysis, ProsodyPro has a function to pool the outputs of all individual sounds in a folder together into a large set of ensemble files”. This software minimizes human labor as Xu (ibid: p. 10) himself explains as: “It also minimizes labor by automating tasks that do not require human judgment, and facilitates human intervention of processes that are prone to error, thus delivering high accuracy and reliability in prosody analysis.” Therefore, due to its accuracy, reliability and speedy analysis, this software helps in understanding prosodic features of a language in a much better way.
Xu (2013: p. 8) proposes that: “the following measurements are automatically generated by ProsodyPro for each non-blank interval in the TextGrid and saved in the file X.means, where X stands for the name of the sound file being analyzed:

1. Max f0 — maximum F0 in Hz
2. Min f0 — minimum F0 in Hz
3. Excursion size — difference between maximum F0 and minimum F0 in semitones
4. mean f0 — average F0 in Hz
5. max velocity — maximum F0 velocity in semitones/s
6. final f0 — F0 near the interval offset in Hz
7. final velocity — F0 velocity near the interval offset in semitones/s
8. duration — interval duration in ms
9. mean intensity — mean intensity in dB”
SUMMARY OF CHAPTER 3

The methodology part of this study is discussed in this chapter. Ten Punjabi speakers were selected from Lahore with five male and five female speakers having age from 28 to 45 years with an average of 34 years. The stimuli were finalized carefully which consisted of three Punjabi words with each word with its three versions based on the tonal contrasts. Overall there were nine words. All the words were mono-syllabic. All the words belonged to the Punjabi syllable template as ‘CV’, i.e., a voiceless consonant followed by a vowel /a/. All the words were written on three flash cards in such a way that each card was written for a set of stimuli containing three words with tonal contrasts. The Punjabi word [pa] with three different tones, i.e., low, mid, and high means ‘price’, ‘quarter’, and ‘track’ respectively. The Punjabi word [ka] with three different tones, i.e., low, mid, and high means ‘grass’, ‘possession’, and ‘a handful pile of reaped crop’ respectively. The Punjabi word [ʧa] with three different tones, i.e., low, mid, and high means ‘peep through’, ‘desire’, and ‘tea’ respectively. All these words were recorded for five times with the help of a good quality WAV file recorder with a sampling rate of 44100 Hz and 16 bit amplitude resolution by all the ten speakers making the corpus of 450 tokens in the following way:

10 speakers x 3 sets x 3 words x 5 repetitions = 450 tokens

The data were then divided into segments with the help of Praat (Boersma and Weenink, 2014). All the tokens were analyzed for Punjabi tones by means of the
acoustic correlates of tone, i.e., F0, duration, intensity, and final velocity (Xu, 2013) using the software Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The role of phonation in Punjabi tonal contrasts was explored with the help of some phonation related acoustic correlates including H1-H2, H1*-H2*, and CPP using the software Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). Lastly, there is a brief introduction to a software ProsodyPro developed by Xu (2013). This software can read Praat files automatically with speed, accuracy, and reliability.
RESULTS

4.0. INTRODUCTION

This chapter presents the findings and results of the experiment conducted in this study. First of all, the visual impressions (wave forms) of the three Punjabi tones which were obtained with the help of Praat (Boersma and Weenink, 2014) are presented in the form of images. In the second part of the chapter, the results and findings of the acoustic analyses, with the help of software Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014), and statistical analyses, with the help of SPSS, conducted in the study are presented. Afterwards, male female contrast in also presented by focusing on their average values on all the acoustic measures in the study in order explore gender based differences (if there are any) in producing Punjabi tones because some studies reported, mentioned in the literature review, that higher and lower F0 values show a good effect on the phonation types in a language which result in slightly different phonation types by male and female speakers. Last part of the chapter presents data based on the values obtained by the individual speakers in order to explore individual differences among the speakers so as to find out if there is any speaker whose values may affect the average values by all the other speakers.
4.1. **PRAAT IMAGES OF THE PUNJABI TONES**

In order to have a visual inspection of the Punjabi tones, the Praat images were taken. The visual impression of the mean values (mean wave forms) of the tones with the help of Praat could not be obtained in the study. Therefore, the images were taken of only the middle of the five repetitions of recordings of only one of the speakers (Fr) just to have a visual impression of the tones. For a better description of the results of the study, the mean values of all the recordings across all the speakers and the statistical analyses with the help of SPSS are conducted and presented later in the chapter.

4.1.1. **Praat Images of the Punjabi Low Tone**

The images of the low tone for the three Punjabi words as obtained with the help of Praat (Boersma and Weenink, 2014) are as under:

![Spectrograms of Punjabi words](image)

The above images show spectrograms of the words /ʧa/, /ka/, and /pa/ all with low tone. The consonant part in all the recordings was not included in the measurement.
The highlighted part in the images (in light grey shade) was labeled for /a/ vowel which was measured for the tone with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The alphabets with a number on the bottom left side of the images within parenthesis (like FrL_C3) show a particular token of recording where Fr shows speaker, L shows low tone, C shows /ʧa/ word, and number 3 shows third repetition. Third repetition was taken in order to avoid any boundary effects. It can be viewed in the images that the dotted line towards the bottom of the images first shows a slight downward movement and then there is a clear rising trend while it moves towards the end. The dotted line which shows pitch is better displayed in the next images as shown below:

4.1.2. Praat Images of the Punjabi Mid Tone

The images of the mid tone for the three Punjabi words as obtained with the help of Praat (Boersma and Weenink, 2014) are as under:
The above images show spectrograms of the words /ʧə/, /kə/, and /pə/ all with mid tone. For the mid tone also, the consonant part in all the recordings was not included in the measurement. The light grey highlighted part in the images was labeled for /a/ vowel which was measured for the tone with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). It can be viewed in the images that the dotted line show slight upward trend in all the three images, i.e, it shows less upward movement than it is seen in the case low tone. The dotted line which shows pitch is better displayed in the images as shown below:
4.1.3. **Praat Images of the Punjabi High Tone**

The images of the high tone for the three Punjabi words as obtained with the help of Praat (Boersma and Weenink, 2014) are as under:

![Image of /ʧa/ with high tone](FrH_C3)

![Image of /ka/ with high tone](FrH_K3)

![Image of /pa/ with high tone](FrH_P3)

The above images of the three Punjabi words /ʧa/, /ka/, and /pa/ show high tone. The consonant part in the high tone, like in other tone groups, was not included in the measurement. The highlighted (in light grey shade) part in the images was labeled for /a/ vowel which was measured for the tone with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). It can be viewed in the images that the dotted line shows a clear downward movement while moving towards the end. The dotted line which shows pitch is better displayed in the images as shown below:
4.2. STATISTICAL ANALYSES OF THE PUNJABI TONES

In this study, the descriptive statistical analyses of different correlates of tone which include fundamental frequency (F0), duration, intensity, and final velocity are conducted. Separate statistical analyses are done for each of the factors considered to be involved in the production of tone in the language. As there are three groups based on three tone categories in the Punjabi language, namely, Low Tone, Mid Tone and High Tone, which are to be compared with one another with respect to the above mentioned correlates, so one way ANOVA test is applied. Each of the measures of fundamental frequency (F0), duration, intensity, and final velocity is taken as a dependent variable and the tone types as independent variables. The one way ANOVA test was followed by post hoc Bonferroni test also in each case. The results of the statistical analyses are considered significant for \( p \leq .05 \) in all the tests.

4.2.1. Statistical Analysis of Fundamental Frequency (F0) of Punjabi Tones

In the current study, SPSS was used and one way ANOVA test was conducted in order to see whether or not there was a statistically significant difference in the three tones of Punjabi based on their fundamental frequency. F0 was taken as a dependent variable and the three tone types in the language were taken as independent variables in the test. The post hoc Bonferroni test was also conducted in order to see which tone categories show better contrast and greater difference from one another. The results of the tests are as under:
Table 4.1. Difference in means of the F0s of the Punjabi tones

<table>
<thead>
<tr>
<th>Descriptives</th>
<th>95% Confidence Interval for Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Low Tone</td>
<td>118.9106</td>
</tr>
<tr>
<td>Mid Tone</td>
<td>122.4714</td>
</tr>
<tr>
<td>High Tone</td>
<td>130.2312</td>
</tr>
</tbody>
</table>

The second column of the table shows that there were ten participants (N = 5 male + 5 female) whose recordings were made for all the words having tonal contrasts. The third column (Mean) shows mean values of F0s of the three tone groups. The low tone shows a mean F0 of 149 Hz with a minimum value of F0 as 96 Hz to a maximum value of 203 Hz. The mid tone shows a mean F0 of 151 Hz with a minimum value of F0 as 100 Hz to a maximum value of 206 Hz. Whereas the high tone shows a mean F0 of 161 Hz with a minimum value of F0 as 105 Hz to a maximum value of 232 Hz.
Figure 4.1. Graphical representation of the three Punjabi tones with respect to their mean F0s

The graph also represents the three tone groups in the language. It shows that there is only a slight difference between the low tone and mid tone groups on the basis of their F0s.

Table 4.2. One way ANOVA for the F0s of Punjabi tones

<table>
<thead>
<tr>
<th>ANOVA</th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>903.539</td>
<td>2</td>
<td>451.769</td>
<td>.257</td>
<td>.775</td>
</tr>
<tr>
<td>Within Groups</td>
<td>47463.138</td>
<td>27</td>
<td>1757.894</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>48366.677</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

p > 0.05
The one way ANOVA test shows significance value of \( p = 0.775 \) with \( [F (2, 27) = 0.257, p > 0.05] \) which clearly means that the three tone types in the language are not statistically significantly different from one another in terms of their fundamental frequency. So, the major difference among the three tonal contrasts could be due to some other factors involved like duration, final velocity etc. The following post hoc Bonferroni test further shows if any two of the three tone groups differed significantly from one another with some better margin with respect to their F0s.

Table 4.3. Post hoc Bonferroni test for the F0s of Punjabi tones

<table>
<thead>
<tr>
<th>F0 Bonferroni</th>
<th>Multiple Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I) Tone Types</td>
<td>(J) Tone Types</td>
</tr>
<tr>
<td>Low Tone</td>
<td>Mid Tone</td>
</tr>
<tr>
<td></td>
<td>High Tone</td>
</tr>
<tr>
<td>Mid Tone</td>
<td>Low Tone</td>
</tr>
<tr>
<td></td>
<td>High Tone</td>
</tr>
<tr>
<td>High Tone</td>
<td>Low Tone</td>
</tr>
<tr>
<td></td>
<td>Mid Tone</td>
</tr>
</tbody>
</table>

\( p > 0.05 \)

The above table shows significance value of 1 for all the comparisons in the test. Therefore, the post hoc Bonferroni test confirms the point that there is no statistically significant difference between any two of the three tone groups. So, the primary cue for tone identification, i.e., fundamental frequency, does not prove to be a statistically significant measure in distinguishing the three tones in the language. However, there
could be some other factors majorly responsible for the tonal contrasts in the language which are explored and discussed subsequently.

4.2.1.1. Male - Female contrast on the measure of F0

Although finding the gender based differences is not the key objective of the study, the average values of fundamental frequency for male and female speakers are presented in order to see how both the groups differ with respect to the measure of F0 in producing tone. Do they produce the tone differently or in the same way? The average values of F0 for male and female speakers are obtained with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The following values are obtained:

<table>
<thead>
<tr>
<th></th>
<th>F0</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Tone</td>
<td>123.6412</td>
<td>199.3874</td>
<td></td>
</tr>
<tr>
<td>Mid Tone</td>
<td>114.7927</td>
<td>187.266</td>
<td></td>
</tr>
<tr>
<td>Low Tone</td>
<td>110.696</td>
<td>187.2765</td>
<td></td>
</tr>
</tbody>
</table>

The average values of F0 for five male and five female speakers in this study suggest that this measure makes a clear contrast between the two groups, i.e., between male and female speakers for each of the three Punjabi tones. Due to their higher pitch range, female speakers produced all the Punjabi tonal words with higher values of F0 than the male speakers. For the within group differences, there are only slight variations of F0 for the three tones. Especially the mid tone and the low tone in the
language do not show any difference as produced by the female speakers. The values are better described in the form of a chart as follows:

Figure 4.2. Chart for the male female contrast on the measure of F0

![Male Female Contrast on F0 measure](image)

4.2.2. Statistical Analysis of Duration of the TBUs

Duration is also considered as a very important acoustic correlate of tone. The TBU in Punjabi is a stressed syllable and the most important acoustic cue for stress is duration. Therefore, it is one of the main acoustic correlates of tone in this study. Kuang (2013) suggests that the duration is increased as the tone is lowered. So, in order to see the correlation of tone and duration in this study, duration of the tone bearing units was measured with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). Then the data were analyzed with the help of SPSS. A one way ANOVA test was conducted in order to see whether or not there was a
statistically significant difference in the three tone groups of Punjabi based on their duration. Duration was taken as a dependent variable and the three tones were taken as independent variables in the test. The post hoc Bonferroni test was also conducted in order to see which tone groups show greater difference from one another. The findings of the tests are as under:

Table 4.5. Difference in means of the duration of Punjabi tones

<table>
<thead>
<tr>
<th>Descriptives</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duration</strong></td>
<td>N</td>
<td>Mean</td>
<td>Std. Deviation</td>
<td>Std. Error</td>
<td>95% Confidence Interval for Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>10</td>
<td>333.1916</td>
<td>49.98246</td>
<td>15.80584</td>
<td>297.4363</td>
<td>368.9469</td>
<td>258.69</td>
<td>429.11</td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>10</td>
<td>274.7322</td>
<td>56.46726</td>
<td>17.85652</td>
<td>234.3379</td>
<td>315.1264</td>
<td>197.61</td>
<td>367.88</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>10</td>
<td>182.6946</td>
<td>41.24156</td>
<td>13.04172</td>
<td>153.1922</td>
<td>212.1970</td>
<td>104.56</td>
<td>229.45</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>263.5395</td>
<td>79.13648</td>
<td>14.44828</td>
<td>233.9894</td>
<td>293.0895</td>
<td>104.56</td>
<td>429.11</td>
<td></td>
</tr>
</tbody>
</table>

The second column of the table (N) shows that there were ten participants (N = 5 male + 5 female) who were recorded for all the Punjabi words having tonal contrasts. The third column (Mean) shows the mean values of duration of the three tone groups. The low tone shows a mean duration of 333 ms with a minimum value of duration as 259 ms to a maximum value of 429 ms. The mid tone shows a mean duration of 275 ms with a minimum value of duration as 198 ms to a maximum value of 368 ms. Whereas the high tone shows a mean duration of 183 ms with a minimum value of duration as 104 ms to a maximum value of 229 ms. The mean values of duration of the low, mid,
and high tones and their minimum and maximum values clearly suggest that there are three tonal categories in the language.

Figure 4.3. Graphical representation of the three Punjabi tones with respect to their mean duration

The above graph shows nearly a straight line suggesting that the three tone groups in the language have clearly different values with respect to their duration. Low tone has the longest duration. The duration of the mid tone lies in the middle. Whereas, the high tone has the shortest duration among the three tones.
Table 4.6. One way ANOVA for the duration of Punjabi tones

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>115125.901</td>
<td>2</td>
<td>57562.950</td>
<td>23.375</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>66488.976</td>
<td>27</td>
<td>2462.555</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>181614.877</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

p < 0.05

The one way ANOVA test shows significance value of $p = 0.000$ with $[F (2, 27) = 23.37, p < 0.05]$ which clearly means that the three tone types in the language are statistically significantly different from one another in terms of their duration. Therefore, the difference among the three tonal contrasts is much dependent upon the duration of TBUs in the language along with some other factors discussed subsequently. To see which tone groups show greater difference from one another with respect to their duration, the following post hoc Bonferroni test was also conducted:
Table 4.7. Post hoc Bonferroni test for the duration of Punjabi tones

<table>
<thead>
<tr>
<th>(I) tone type</th>
<th>(J) tone type</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Mid</td>
<td>58.45942*</td>
<td>22.19259</td>
<td>.041</td>
<td>1.8138</td>
<td>115.1051</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>150.49701*</td>
<td>22.19259</td>
<td>.000</td>
<td>93.8513</td>
<td>207.1427</td>
</tr>
<tr>
<td>Mid</td>
<td>Low</td>
<td>-58.45942*</td>
<td>22.19259</td>
<td>.041</td>
<td>-115.1051</td>
<td>-1.8138</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>92.03759*</td>
<td>22.19259</td>
<td>.001</td>
<td>35.3919</td>
<td>148.6833</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>-150.49701*</td>
<td>22.19259</td>
<td>.000</td>
<td>-207.1427</td>
<td>-93.8513</td>
</tr>
<tr>
<td></td>
<td>Mid</td>
<td>-92.03759*</td>
<td>22.19259</td>
<td>.001</td>
<td>-148.6833</td>
<td>-35.3919</td>
</tr>
</tbody>
</table>

p < 0.05

The above table shows significance value of p = 0.041 for the comparison between low tone group and mid tone group where p < 0.05, which shows that these two groups are statistically significantly different from each other. Similarly, the table shows significance value of p = 0.000 for the comparison between low tone group and high tone group where p < 0.05, which also shows that these two groups are statistically significantly different from each other with even greater margin. In the same way, the table shows significance value of p = 0.001 for the comparison between mid tone group and high tone group where p < 0.05, which also shows that these two groups are statistically significantly different from each other. Therefore, the post hoc Bonferroni test confirms the point that there is a clear statistically significant difference between any two of the three tone groups in the language. So, in this study, one of the acoustic correlates of tone, i.e., duration does prove to be a statistically significant measure in distinguishing the three tone types in the language.
4.2.2.1. Male - Female contrast on the measure of duration

The average values of the measure of duration for male and female speakers are obtained in order to explore the gender based differences in the study. The average values on the measure of duration for the male and female speakers are obtained with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The following values are obtained:

Table 4.8. Duration values for male and female speakers

<table>
<thead>
<tr>
<th>Duration</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Tone</td>
<td>198.0626</td>
<td>167.3266</td>
</tr>
<tr>
<td>Mid Tone</td>
<td>283.0535</td>
<td>266.4108</td>
</tr>
<tr>
<td>Low Tone</td>
<td>325.9342</td>
<td>340.449</td>
</tr>
</tbody>
</table>

The average values of duration for five male and five female speakers in this study suggest that this measure also makes some contrast between the two groups, i.e., between male and female speakers for any of the Punjabi tones. The values produced by the male speakers on the measure of duration for the high Punjabi tone and mid Punjabi tone are higher than the values produced by the female speakers. Anyhow the female speakers produced the low Punjabi tone with a higher average value of duration. Furthermore, there are clear differences among the three Punjabi tones with respect to their duration within each group suggesting that this measure is responsible for creating tonal contrast in the language. The values on the measure of duration are better described in the form of a chart as follows:
4.2.3. **Statistical Analysis of Intensity of Punjabi Tones**

In this study, in order to investigate the role of intensity in Punjabi tone and phonation contrasts, intensity was measured with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). Then the data were analyzed with the help of SPSS. A one way ANOVA test was performed in order to see whether or not there was a statistically significant difference in the three tone groups of Punjabi based on their intensity. Intensity was taken as a dependent variable and the three tones were taken as independent variables in the test. Later, the post hoc Bonferroni test was also conducted in order to see which tone groups show better contrast from one another with respect to their intensity.
Table 4.9. Difference in means of the intensity of Punjabi tones

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Minim-</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>10</td>
<td>69.1118</td>
<td>4.80473</td>
<td>1.51939</td>
<td>65.6747</td>
<td>72.5489</td>
<td>61.88</td>
<td>76.45</td>
</tr>
<tr>
<td>Mid</td>
<td>10</td>
<td>68.7683</td>
<td>5.01284</td>
<td>1.58520</td>
<td>65.1823</td>
<td>72.3542</td>
<td>58.83</td>
<td>75.84</td>
</tr>
<tr>
<td>High</td>
<td>10</td>
<td>71.3156</td>
<td>4.53494</td>
<td>1.43407</td>
<td>68.0715</td>
<td>74.5597</td>
<td>63.70</td>
<td>76.78</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>69.7319</td>
<td>4.76057</td>
<td>.86916</td>
<td>67.9542</td>
<td>71.5095</td>
<td>58.83</td>
<td>76.78</td>
</tr>
</tbody>
</table>

The second column of the table for intensity shows that there were ten participants (N = 5 male + 5 female) whose voice was recorded for all the selected words of Punjabi having tonal contrasts. The third column shows the mean values of intensity of the three tone groups. The low tone group shows a mean intensity of 69 dB with a minimum value of intensity as 62 dB to a maximum value of 76 dB. The mid tone group also shows a mean intensity of 69 dB with a minimum value of intensity as 59 dB to a maximum value of 76 dB. Whereas the high tone group shows a mean intensity of 71 dB with a minimum value of intensity as 64 dB to a maximum value of 77 dB.
The graph also shows a slight fall in the values of intensity while we move from low tone group to mid tone group and then there is a clear rise in the values when we move from mid tone group to high tone group in the language. So there is only a slight difference between the intensity of low tone and mid tone. Whereas, high tone is clearly on the higher side on the intensity measure than the other two tone groups. Anyhow, the statistics below reveal the true nature of this measure of the tone:

Table 4.10. One way ANOVA for the intensity of Punjabi tones

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>38.211</td>
<td>2</td>
<td>19.106</td>
<td>.833</td>
<td>.445</td>
</tr>
<tr>
<td>Within Groups</td>
<td>619.017</td>
<td>27</td>
<td>22.927</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>657.228</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

p > 0.05
The one way ANOVA test for the measure of intensity shows significance value of $p = 0.445$ with $[F(2, 27) = 0.833, p > 0.05]$ which means that the three tone groups in the language are not statistically significantly different from one another in terms of their intensity. Low tone group is not much different from mid tone group on intensity measure in the study. Similar is the case with the high tone group which does not show a clear contrast with the other two tone groups. Therefore, the difference among the three tonal contrasts could be mainly dependent upon some other factors which are responsible for the three tonal contrasts in the language like duration and final velocity discussed in the previous sections. To see if any two of the three comparisons in the groups of tone types show greater difference with respect to their intensity, the following post hoc Bonferroni test was also conducted. Result of which are as under:

Table 4.11. Post hoc Bonferroni test for the intensity of Punjabi tones

<table>
<thead>
<tr>
<th>(I) tone type</th>
<th>(J) tone type</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Low</td>
<td>Mid</td>
<td>.34352</td>
<td>2.14133</td>
<td>1.000</td>
<td>-5.1221</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-2.20377</td>
<td>2.14133</td>
<td>.938</td>
<td>-7.6694</td>
</tr>
<tr>
<td>Mid</td>
<td>Low</td>
<td>-.34352</td>
<td>2.14133</td>
<td>1.000</td>
<td>-5.8092</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-2.54730</td>
<td>2.14133</td>
<td>.734</td>
<td>-8.0130</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>2.20377</td>
<td>2.14133</td>
<td>.938</td>
<td>-3.2619</td>
</tr>
<tr>
<td></td>
<td>Mid</td>
<td>2.54730</td>
<td>2.14133</td>
<td>.734</td>
<td>-2.9184</td>
</tr>
</tbody>
</table>

$p > 0.05$ (for all the three comparisons)
The table shows significance value of $p = 1.00$ for the comparison between low tone group and mid tone group where $p > 0.05$, which shows that these two groups are not statistically significantly different from each other. The table shows significance value of $p = 0.938$ for the comparison between low tone group and high tone group where $p > 0.05$, which also shows that these two groups are not statistically significantly different from each other. Similarly, the table shows significance value of $p = 0.734$ for the comparison between mid tone group and high tone group where $p > 0.05$, which also shows that these two groups are not statistically significantly different from each other. So, none of the three comparisons in the post hoc Bonferroni test shows any statistically significant difference which indicate that the measure of intensity is not responsible for any tonal contrast in the language.

4.2.3.1. Male - Female contrast on the measure of intensity

The average values for the measure of intensity for male and female speakers are obtained in order to explore the gender based differences for the three tones in the language. The average values of intensity are taken with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The following values are obtained:

Table 4.12. Intensity values for male and female speakers

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Tone</td>
<td>73.10865</td>
<td>69.52247</td>
</tr>
<tr>
<td>Mid Tone</td>
<td>70.72482</td>
<td>66.81172</td>
</tr>
<tr>
<td>Low Tone</td>
<td>70.95772</td>
<td>67.26585</td>
</tr>
</tbody>
</table>
The average values of intensity for five male and five female speakers in this study suggest that this measure also shows some contrast between the two groups, i.e., between male and female speakers for any of the Punjabi tones. The values produced by the male speakers on the measure of intensity for all the three Punjabi tones are higher than the values produced by the female speakers. Anyhow this measure does not show any significant contrast within each group for the three tones due to which it is found to be not responsible for the tonal contrasts in the language. The obtained values on the measure of intensity are better described in the form of a chart as follows:

Figure 4.6. Chart for the male female contrast on the measure of intensity
4.2.4. **Statistical Analysis of Final Velocity of Punjabi Tones**

In this study, final velocity was also measured with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). Then the data were analyzed with the help of SPSS. A one way ANOVA test was conducted in order to see whether or not there was a statistically significant difference in the three tone groups of Punjabi based on their final velocity. Final velocity was taken as a dependent variable and the three tones were taken as independent variables in the test. The post hoc Bonferroni test was also conducted in order to see which tone groups show greater difference from one another. The findings of the tests are as follows:

Table 4.13. Difference in means of the final velocity of Punjabi tones

<table>
<thead>
<tr>
<th>Final Velocity</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Minimu-m</th>
<th>Maximu-m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>10</td>
<td>22.0181</td>
<td>14.98594</td>
<td>4.73897</td>
<td>11.2978 - 32.7384</td>
<td>3.70</td>
<td>47.03</td>
</tr>
<tr>
<td>Mid</td>
<td>10</td>
<td>15.0608</td>
<td>12.25890</td>
<td>3.87661</td>
<td>6.2913 - 23.8303</td>
<td>-1.51</td>
<td>32.70</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>7.3534</td>
<td>20.06552</td>
<td>3.66345</td>
<td>-0.1392 - 14.8459</td>
<td>-27.75</td>
<td>47.03</td>
</tr>
</tbody>
</table>

The second column of the table above for final velocity shows that there were ten participants (N = 5 male + 5 female) whose recordings were made for all the Punjabi words having tonal contrasts. The third column shows the mean values of final velocity of the three tone groups. The low tone group shows a mean final velocity of 22 semitones with a minimum value of final velocity as 4 semitones to
a maximum value of 47 semitones. The mid tone group shows a mean final velocity of 15 semitones with a minimum value of final velocity as -1.5 semitones to a maximum value of 33 semitones. Whereas the high tone group shows a mean final velocity of -15 semitones with a minimum value of final velocity as -28 semitones to a maximum value of -4 semitones.

Figure 4.7. Graphical representation of the three Punjabi tones with respect to their final velocity

![Graphical representation of the three Punjabi tones with respect to their final velocity](image)

The above graph shows gradual lowering of the values of mean final velocity as we move from low tone to high tone. Low tone has the highest value of final velocity, mid tone lies slightly downwards and high tone has the lowest value of final velocity. The
values suggest that the direction of low tone is upwards, i.e., rising, the value of mid tone is slightly lower but it is positive so it is also moving upwards, whereas, the value of high tone much lower and negative also, so it is moving downwards, i.e., the high tone shows falling trend.

Table 4.14. One way ANOVA for the final velocity of Punjabi tones

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>7749.736</td>
<td>2</td>
<td>3874.868</td>
<td>26.646</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>3926.392</td>
<td>27</td>
<td>145.422</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11676.128</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

p < 0.05

The one way ANOVA test shows significance value of p = 0.000 with [F (2, 27) = 26.65, p < 0.05] which clearly means that the three tone types in the language are statistically significantly different from one another in terms of their final velocity. Hence, it is proved that the tones in the language are statistically different from one another with respect to the shape of their contours. Therefore, the difference among the three tonal contrasts is much dependent upon the final velocity of TBUs in the language along with some other factors discussed in the study. To see which tone groups show greater difference from one another with respect to their final velocity, the following post hoc Bonferroni test was also conducted:
Table 4.15. Post hoc Bonferroni test for the final velocity of Punjabi tones

<table>
<thead>
<tr>
<th></th>
<th>Final Velocity</th>
<th>Multiple Comparisons</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bonferroni</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(I) tone type</td>
<td>(J) tone type</td>
<td>Mean Difference (I-J)</td>
<td>Std. Error</td>
<td>Sig.</td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td>95% Confidence Interval</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Mid</td>
<td>6.95733</td>
<td>5.39299</td>
<td>.624</td>
<td>-6.8081</td>
<td>20.7227</td>
<td>-6.8081 - 20.7227</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>37.03693*</td>
<td>5.39299</td>
<td>.000</td>
<td>23.2715</td>
<td>50.8023</td>
<td>23.2715 - 50.8023</td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>Low</td>
<td>-6.95733</td>
<td>5.39299</td>
<td>.624</td>
<td>-20.7227</td>
<td>6.8081</td>
<td>-20.7227 - 6.8081</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>30.07960*</td>
<td>5.39299</td>
<td>.000</td>
<td>16.3142</td>
<td>43.8450</td>
<td>16.3142 - 43.8450</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>-37.03693*</td>
<td>5.39299</td>
<td>.000</td>
<td>-50.8023</td>
<td>-23.2715</td>
<td>-50.8023 - -23.2715</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mid</td>
<td>-30.07960*</td>
<td>5.39299</td>
<td>.000</td>
<td>-43.8450</td>
<td>-16.3142</td>
<td>-43.8450 - -16.3142</td>
<td></td>
</tr>
</tbody>
</table>

p > 0.05 (For low tone vs. mid tone)
p < 0.05 (For low tone vs. high tone, and mid tone vs. high tone)

The table shows significance value of $p = 0.624$ for the comparison between low tone group and mid tone group where $p > 0.05$, which shows that these two groups are not statistically significantly different from each other. Anyhow, the direction of both of the tones, i.e., low tone and mid tone is different from each other which show a contrastive trend in both the groups. However, the table shows significance value of $p = 0.000$ for the comparison between low tone group and high tone group where $p < 0.05$, which clearly shows that these two tone groups are statistically significantly different from each other. Similarly, the table shows significance value of $p = 0.000$ for the difference between mid tone group and high tone group where $p < 0.05$, which also shows that these two groups are statistically significantly different from each other. Therefore, the post hoc Bonferroni test confirms the point that two of the three comparisons, i.e., low tone group vs. high tone group, and mid tone group vs. high tone group show statistically significant difference. Whereas, one comparison, i.e.,
low tone group vs. mid tone group does not show a statistically significant difference. So, overall, in this study, the acoustic correlate of tone, i.e., final velocity does prove to be a statistically significant measure in distinguishing at least two of the three tone types in the language.

4.2.4.1. Male - Female contrast on the measure of final velocity

The average values for the measure of final velocity for male and female speakers are obtained in order to see if there are any gender based differences for the three tones in the language. The average values for the measure of final velocity are obtained with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The following values are obtained:

Table 4.16. The values of final velocity for male and female speakers

<table>
<thead>
<tr>
<th>Final Velocity</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Tone</td>
<td>-17.8586</td>
<td>-12.1791</td>
</tr>
<tr>
<td>Mid Tone</td>
<td>12.14186</td>
<td>17.97971</td>
</tr>
<tr>
<td>Low Tone</td>
<td>16.8471</td>
<td>27.18912</td>
</tr>
</tbody>
</table>

The average values of final velocity for five male and five female speakers in this study suggest that this measure also shows a clear contrast between the two groups, i.e., between male and female speakers for all the three Punjabi tones. The values produced by the female speakers on the measure of final velocity for all the three Punjabi tones are higher than the values produced by the male speakers. Furthermore, this measure shows a significant contrast within each group for the three tones due to
which it is found to be clearly responsible for the tonal contrasts in the language. The values on the measure of final velocity are described in the form of a chart as follows:

Figure 4.8. Chart for the male female contrast on the measure of final velocity

<table>
<thead>
<tr>
<th>Tones</th>
<th>Mean Final Velocity Male</th>
<th>Mean Final Velocity Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>-10</td>
<td>-15</td>
</tr>
<tr>
<td>Mid</td>
<td>0</td>
<td>-5</td>
</tr>
<tr>
<td>Low</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>

4.3. STATISTICAL ANALYSES FOR PUNJABI TONES ON PHONATION RELATED ACOUSTIC MEASURES

In this study, the descriptive statistical analyses of Punjabi tones on some of the acoustic correlates of phonation types which include H1-H2, H1*-H2*, and CPP are also conducted in order to explore the role of phonation in Punjabi tonal contrasts. These measures have been proved to be the most important measures in distinguishing among the phonation types in a language including breathy, modal and creaky phonations as the most common ones. Breathy phonation is supposed to be accompanied by low tone in the language and modal phonation is supposed to be
accompanied by mid tone. Mainly, there are three groups based on three tone categories in the Punjabi language, namely, Low Tone, Mid Tone and High Tone, which are to be compared with one another with respect to the above mentioned acoustic correlates of phonation. SPSS was used and one way ANOVA test was applied. Each of the measures of H1-H2, H1*-H2*, and CPP is taken as a dependent variable and the tone types as independent variables. A one way ANOVA test was then followed by post hoc Bonferroni test in each case.

4.3.1. **Statistical Analysis of H1-H2 of Punjabi Tones**

In this study, H1-H2 was also measured with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). Then the data were analyzed with the help of SPSS. A one way ANOVA test was conducted in order to see whether or not there was a statistically significant difference in the three tone groups of Punjabi based on the measure of H1-H2. H1-H2 was taken as a dependent variable and the three tones were taken as independent variables in the test. Later, the post hoc Bonferroni test was also conducted in order to see which tone groups show greater difference from one another with respect to their H1-H2 values.
Table 4.17. Difference in means of the phonation measure H1-H2 for Punjabi tones

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>10</td>
<td>2.3488</td>
<td>2.12903</td>
<td>.67326</td>
<td>.8258</td>
<td>3.8718</td>
<td>-.17</td>
<td>6.11</td>
</tr>
<tr>
<td>Mid</td>
<td>10</td>
<td>1.9899</td>
<td>3.28881</td>
<td>1.04001</td>
<td>-.3628</td>
<td>4.3425</td>
<td>-5.76</td>
<td>6.82</td>
</tr>
<tr>
<td>High</td>
<td>10</td>
<td>.9245</td>
<td>2.71984</td>
<td>.86009</td>
<td>-1.0212</td>
<td>2.8702</td>
<td>-3.98</td>
<td>4.48</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>1.7544</td>
<td>2.72722</td>
<td>.49792</td>
<td>.7360</td>
<td>2.7727</td>
<td>-5.76</td>
<td>6.82</td>
</tr>
</tbody>
</table>

Like in the other measures, the second column of the above table for H1-H2 shows that there were ten participants (N = 5 male + 5 female) whose recordings were made for all the selected words having tonal contrasts. The third column shows the mean values of H1-H2 of the three tone groups. The low tone group (breathy phonation) shows a mean value of H1-H2 of 2.34 dB with a minimum value of H1-H2 as -.17 dB to a maximum value of 6.11 dB. The mid tone group shows a mean value of H1-H2 as 1.99 dB with a minimum value of H1-H2 as -5.76 dB to a maximum value of 6.82 dB. Whereas, the high tone group shows a mean value of H1-H2 as 0.92 dB with a minimum value of H1-H2 as -3.98 dB to a maximum value of 4.48 dB.
Figure 4.9. Graphical representation of the three Punjabi tones with respect to the phonation measure H1-H2

The graph shows gradual decline in values of H1-H2 while we move from low tone group to high tone group. Mid tone group lies in the middle slightly downwards from low tone group. So, a contrastive trend is visible in the figure where low tone shows the highest H1-H2 value, mid tone shows intermediate value on H1-H2, and high tone shows lowest H1-H2 value. Therefore, the role of phonation in creating tonal contrasts in Punjabi language cannot be ignored.

Table 4.18. One way ANOVA for the measure H1-H2 of Punjabi tones

<table>
<thead>
<tr>
<th>h1-h2</th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>10.975</td>
<td>2</td>
<td>5.487</td>
<td>.724</td>
<td>.494</td>
</tr>
<tr>
<td>Within Groups</td>
<td>204.719</td>
<td>27</td>
<td>7.582</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>215.694</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

p > 0.05
The one way ANOVA test for the phonation measure H1-H2 shows significance value of \( p = 0.494 \) with \( F(2, 27) = 0.724, p > 0.05 \) which means that the three tone groups in the language are not statistically significantly different from one another in terms of the phonation measure H1-H2. Therefore, the difference among the three tonal contrasts could be majorly dependent upon some other factors which are responsible for the three tonal contrasts in the language like duration, final velocity and phonation measure CPP discussed in the study. However, a simple contrastive trend in the three tone groups on the basis of H1-H2 cannot be ignored. In order to see if any two of the three comparisons in the groups of tone types show a significant difference with respect to their H1-H2 values, the following post hoc Bonferroni test was also conducted:

Table 4.19. Post hoc Bonferroni test for the phonation measure H1-H2 for Punjabi tones

<table>
<thead>
<tr>
<th>(I) tone types</th>
<th>(J) tone types</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Mid</td>
<td>.35893</td>
<td>1.23144</td>
<td>1.000</td>
<td>-2.7843 - 3.5021</td>
</tr>
<tr>
<td>High</td>
<td>Mid</td>
<td>1.42430</td>
<td>1.23144</td>
<td>.773</td>
<td>-1.7189 - 4.5675</td>
</tr>
<tr>
<td>Mid</td>
<td>Low</td>
<td>-.35893</td>
<td>1.23144</td>
<td>1.000</td>
<td>-3.5021 - 2.7843</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>1.06537</td>
<td>1.23144</td>
<td>1.000</td>
<td>-2.0778 - 4.2086</td>
</tr>
<tr>
<td>High</td>
<td>Mid</td>
<td>-1.42430</td>
<td>1.23144</td>
<td>.773</td>
<td>-4.5675 - 1.7189</td>
</tr>
</tbody>
</table>

\( p > 0.05 \) (for all the three comparisons)
The above table of post hoc Bonferroni test shows significance value of $p = 1.00$ for the difference between low tone group and mid tone group where $p > 0.05$, which shows that these two groups are not statistically significantly different from each other. The table shows significance value of $p = 0.773$ for the difference between low tone group and high tone group where $p > 0.05$, which also shows that these two groups are not statistically significantly different from each other. Furthermore, the table shows significance value of $p = 1.00$ for the difference between mid tone group and high tone group where $p > 0.05$, which also shows that these two groups are not statistically significantly different from each other. So, none of the three comparisons in the post hoc Bonferroni test shows even a slight statistically significant difference which indicate that the phonation measure of H1-H2 is not responsible for any tonal contrast in the language. However, low tone and high tone groups show some contrast between them.

4.3.1.1. Male - Female contrast on the measure of H1-H2

Some studies propose that the measure of H1-H2 shows different values for male and female speakers. In this regard, Wayland and Jongman (2003: p. 196) suggest that: “for female speakers, amplitude of H1 is always greater than that of H2 and the difference between H1 and H2 amplitude is greater (suggesting a higher degree of open quotient) in breathy vowels than in clear vowels. For male speakers, on the other hand, H2 amplitude is greater than H1 amplitude and the difference between H1 and H2 amplitude is greater for clear vowels than for breathy vowels.” That is
why, although gender based differences are beyond the scope of this study, the average values of H1-H2 for male and female speakers are separated. The average values of H1-H2 for male and female speakers are obtained with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The following values are obtained:

Table 4.20. H1-H2 values for male and female speakers

<table>
<thead>
<tr>
<th>H1-H2</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Tone</td>
<td>0.858892</td>
<td>0.990099</td>
</tr>
<tr>
<td>Mid Tone</td>
<td>1.150418</td>
<td>2.829308</td>
</tr>
<tr>
<td>Low Tone</td>
<td>2.207657</td>
<td>2.489935</td>
</tr>
</tbody>
</table>

The average values of H1-H2 for five male and five female speakers in this study suggest that overall this measure makes some contrast between the two groups, i.e., between male and female speakers. The female speakers in the study produced all the three tones in the language with higher values on the measure of H1-H2 than the male speakers. The values of H1-H2 for the mid tone show a contrastive trend between male and female speakers which suggest that the female speakers produce the Punjabi mid tone when their vocal cords are more in abducted position than the male speakers, i.e., for the Punjabi mid tone female speakers have higher OQ values than male speakers. Anyhow, for the within group variation, there is a slight variation within each group among the three tones with respect to this measure. Especially for the high tone and low tone, male and female speakers show nearly the same H1-H2 values. The values are better described in the form of a chart as follows:
4.3.2. Statistical Analysis of H1*-H2* of Punjabi Tones

In this study, H1*-H2* was also measured with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). Then the data were analyzed with the help of SPSS. A one way ANOVA test was conducted in order to see whether or not there was a statistically significant difference in the three tone groups of Punjabi based on the measure of H1*-H2*. H1*-H2* was taken as a dependent variable and the three tone groups were taken as independent variables in the test. Later, the post hoc Bonferroni test was also conducted in order to see which tone groups show greater difference from one another with respect to their H1*-H2* values. The results of the tests are as under:
Table 4.21. Difference in means of the phonation measure $H_1^*-H_2^*$ for the Punjabi tones

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Low</td>
<td>10</td>
<td>-3.47</td>
<td>6.83</td>
<td>2.16</td>
<td>-8.35</td>
</tr>
<tr>
<td>Mid</td>
<td>10</td>
<td>3.37</td>
<td>9.28</td>
<td>2.94</td>
<td>-3.50</td>
</tr>
<tr>
<td>High</td>
<td>10</td>
<td>5.37</td>
<td>15.23</td>
<td>4.82</td>
<td>-5.52</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>1.68</td>
<td>11.30</td>
<td>2.06</td>
<td>-2.54</td>
</tr>
</tbody>
</table>

The second column of the table for $H_1^*-H_2^*$ shows that there were ten participants ($N = 5$ male + 5 female) who were recorded for all the selected Punjabi words having tonal contrasts. The third column shows the mean values of $H_1^*-H_2^*$ of the three tone groups. The low tone group (breathy phonation) shows a mean value of $H_1^*-H_2^*$ of -3.47 dB with a minimum value of $H_1^*-H_2^*$ as -16.57 dB to a maximum value of 3.40 dB. The mid tone group shows a mean value of $H_1^*-H_2^*$ as 3.14 dB with a minimum value of $H_1^*-H_2^*$ as -8.41 dB to a maximum value of 21 dB. Whereas, the high tone group shows a mean value of $H_1^*-H_2^*$ as 5.37 dB with a minimum value of $H_1^*-H_2^*$ as -15.78 dB to a maximum value of 37.18 dB. The p value in the next table will tell us about the statistical significance of the three groups.
Figure 4.11. Graphical Representation of the three Punjabi tones with respect to the phonation measure $H_{1*}-H_{2*}$

The graph shows gradual increase in the values of $H_{1*}-H_{2*}$ when we move from the low tone group to the high tone group. Low tone is on the negative side whereas mid tone and high tone groups are on the positive side.

Table 4.22. One way ANOVA for the measure $H_{1*}-H_{2*}$ for Punjabi tones

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>422.447</td>
<td>2</td>
<td>211.224</td>
<td>1.738</td>
<td>.195</td>
</tr>
<tr>
<td>Within Groups</td>
<td>3282.218</td>
<td>27</td>
<td>121.564</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3704.665</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

p > 0.05
The one way ANOVA test for the phonation measure of H1*-H2* shows significance value of p = 0.195 with [F (2, 27) = 1.738, p > 0.05] which means that the three tone groups in the language are not statistically significantly different from one another in terms of the phonation measure H1*-H2*. Therefore, the difference among the three tonal contrasts could be mainly dependent upon some other factors which for responsible for the three tonal contrasts in the language like duration, final velocity and the phonation measure CPP as discussed in the study. In order to see if any two of the three comparisons among the groups of tone types show a significant difference with respect to their H1*-H2* values, the following post hoc Bonferroni test was also conducted:

Table 4.23. Post hoc Bonferroni test for the phonation measure H1*-H2* of Punjabi Tones

<table>
<thead>
<tr>
<th>(I) tone types</th>
<th>(J) tone types</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Mid</td>
<td>-6.60495</td>
<td>4.93079</td>
<td>.575</td>
<td>-19.1906</td>
<td>5.9807</td>
<td></td>
</tr>
<tr>
<td>Mid</td>
<td>Low</td>
<td>6.60495</td>
<td>4.93079</td>
<td>.575</td>
<td>-5.9807</td>
<td>19.1906</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-2.23359</td>
<td>4.93079</td>
<td>1.000</td>
<td>-14.8192</td>
<td>10.3521</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>8.83854</td>
<td>4.93079</td>
<td>.253</td>
<td>-3.7471</td>
<td>21.4242</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mid</td>
<td>2.23359</td>
<td>4.93079</td>
<td>1.000</td>
<td>-10.3521</td>
<td>14.8192</td>
<td></td>
</tr>
</tbody>
</table>

p > 0.05 (for all the three comparisons)

The above table of post hoc Bonferroni test shows significance value of p = .575 for the comparison between low tone group and mid tone group where p > 0.05, which
shows that these two groups are not statistically significantly different from each other. The table shows significance value of \( p = 0.253 \) for the comparison between low tone group and high tone group where \( p > 0.05 \), which also shows that these two groups are also not statistically significantly different from each other. Similarly, the table shows significance value of \( p = 1.00 \) for the comparison between mid tone group and high tone group where \( p > 0.05 \), which also shows that these two groups are not statistically significantly different from each other. So, none of the three comparisons in the post hoc Bonferroni test shows even a slight statistically significant difference which indicate that the phonation measure of \( H1^{*} - H2^{*} \) is not responsible for any tonal contrast in the language.

### 4.3.2.1. Male - Female contrast on the measure of \( H1^{*} - H2^{*} \)

Some studies propose that the measure of \( H1^{*} - H2^{*} \) shows different values for male and female speakers. In this regard, Wayland and Jongman (2003: p. 191) suggest that: “among female speakers, \( H1^{*} - H2^{*} \) amplitudes are greater for breathy vowels than for clear vowels. However, the negative values in the male speakers’ data indicate that the amplitude of the \( H2 \) is consistently greater than that of \( H1 \), and that the degree of \( H2 \) prominence is greater among clear vowels than breathy vowels.” That is why, although gender based differences are beyond the scope of this study, the average values of \( H1^{*} - H2^{*} \) for male and female speakers are also separated. The average values of \( H1^{*} - H2^{*} \) for male and female speakers are obtained with the help of
Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The following $H_1^* - H_2^*$ values are obtained:

Table 4.24. $H_1^* - H_2^*$ values for male and female speakers

<table>
<thead>
<tr>
<th>$H_1^* - H_2^*$</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Tone</td>
<td>5.727295</td>
<td>5.013903</td>
</tr>
<tr>
<td>Mid Tone</td>
<td>3.400255</td>
<td>2.873761</td>
</tr>
<tr>
<td>Low Tone</td>
<td>-2.44622</td>
<td>-4.48967</td>
</tr>
</tbody>
</table>

The average values of $H_1^* - H_2^*$ for five male and five female speakers in this study suggest that overall this measure shows a bit of contrast between the two groups, i.e., between male and female speakers. The average values on the measure of $H_1^* - H_2^*$ for all the three Punjabi tones are higher by the male speakers than the female speakers. The values of $H_1^* - H_2^*$ for the comparison between the mid tone group and low tone group show a better contrastive trend between the male and female speakers; whereas, high tone group shows a slight contrast between the male and female speakers. Furthermore, the study shows a slight contrast for the three tones within each group. Low tone group lies on the negative side for both the groups. The $H_1^* - H_2^*$ values for male and female speakers are better described in the form of a chart as follows:
4.3.3. **Statistical Analysis of CPP of the Punjabi Tones**

In this study, CPP was also measured with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). Then the data were analyzed with the help of SPSS. A one way ANOVA test was conducted in order to see whether or not there was a statistically significant difference in the three tone groups of Punjabi based on this phonation measure of CPP. For that purpose, CPP was taken as a dependent variable and the three tones were taken as independent variables in the test. Later, the post hoc Bonferroni test was also conducted in order to see which tone groups show better contrast from one another with respect to their CPP values. The findings of the tests are as under:
Table 4.25. Difference in means of the phonation measure CPP of the Punjabi tones

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>10</td>
<td>69.43</td>
<td>1.56356</td>
<td>.49444</td>
<td>68.3128</td>
<td>70.5498</td>
<td>67.28</td>
<td>72.41</td>
</tr>
<tr>
<td>Mid</td>
<td>10</td>
<td>71.13</td>
<td>1.94858</td>
<td>.61620</td>
<td>69.7364</td>
<td>72.5243</td>
<td>68.84</td>
<td>75.90</td>
</tr>
<tr>
<td>High</td>
<td>10</td>
<td>72.64</td>
<td>2.76576</td>
<td>.87461</td>
<td>70.6619</td>
<td>74.6189</td>
<td>69.15</td>
<td>76.88</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>71.07</td>
<td>2.46752</td>
<td>.45051</td>
<td>70.1460</td>
<td>71.9887</td>
<td>67.28</td>
<td>76.88</td>
</tr>
</tbody>
</table>

The second column of the table for CPP shows that there were ten participants (N = 5 male + 5 female) whose recordings were made for all the selected Punjabi words having tonal contrast. The third column in the table shows the mean values of CPP of the three tone groups. The low tone group (breathy phonation) shows a mean value of CPP as 69.43 with a minimum value of CPP as 67.28 to a maximum value of 72.41. The mid tone group shows a mean value of CPP as 71.13 with a minimum value of CPP as 68.84 to a maximum value of 75.90. Whereas, the high tone group shows a mean value of CPP as 72.64 with a minimum value of CPP as 69.15 to a maximum value of 76.88. The p value in the next table will tell us about the statistical significance of CPP measure:
Figure 4.13. Graphical representation of the three Punjabi Tones with respect to the phonation measure CPP

The above graph clearly shows that the values on the measure of CPP increase while we move from low tone group to the high tone group. Mid tone group lies in the middle. Straight line in the graph shows that the contrast among the tone groups should be statistically significant also which is confirmed in the following section.

Table 4.26. One way ANOVA for the phonation measure CPP for the Punjabi tones

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>51.551</td>
<td>2</td>
<td>25.775</td>
<td>5.567</td>
<td>.009</td>
</tr>
<tr>
<td>Within Groups</td>
<td>125.020</td>
<td>27</td>
<td>4.630</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>176.571</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

p < 0.05
The one way ANOVA test for the phonation measure of CPP shows significance value of \( p = 0.009 \) with \( [F (2, 27) = 5.567, p < 0.05] \) which means that the three tone groups in the language are statistically significantly different from one another in terms of the phonation measure CPP. Therefore, the difference among the three tonal contrasts is dependent upon the phonation measure of CPP along with some other factors like duration and final as explored in the study. In order to see if any two of the three comparisons among the groups of tone types show a more significant difference with respect to their CPP values, the following post hoc Bonferroni test was also conducted:

Table 4.27. Post hoc Bonferroni test for the phonation measure CPP of the Punjabi tones

<table>
<thead>
<tr>
<th>(I) tone type</th>
<th>(J) tone type</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Mid</td>
<td>-1.69909</td>
<td>.96233</td>
<td>.266</td>
<td>-4.1554 - .7572</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-3.20908*</td>
<td>.96233</td>
<td>.007</td>
<td>-5.6654 - -.7528</td>
</tr>
<tr>
<td>Mid</td>
<td>Low</td>
<td>1.69909</td>
<td>.96233</td>
<td>.266</td>
<td>-.7572 - 4.1554</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>-1.50999</td>
<td>.96233</td>
<td>.385</td>
<td>-3.9663 - .9463</td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
<td>3.20908*</td>
<td>.96233</td>
<td>.007</td>
<td>-.9463 - 3.9663</td>
</tr>
<tr>
<td></td>
<td>Mid</td>
<td>1.50999</td>
<td>.96233</td>
<td>.385</td>
<td>-.7528 - 5.6654</td>
</tr>
</tbody>
</table>

\( p > 0.05 \) (for low tone vs. mid tone; and mid tone vs. high tone)
\( p < 0.05 \) (for low tone vs. high tone)

The table of post hoc Bonferroni test for the measure CPP shows significance value of \( p = .266 \) for the comparison between low tone group and mid tone group where \( p >
0.05, which shows that these two groups are not statistically significantly different from each other. Similarly, the table shows significance value of $p = 0.385$ for the comparison between mid tone group and high tone group where $p > 0.05$, which also shows that these two groups are not statistically significantly different from each other. Whereas, the table shows significance value of $p = 0.007$ for the comparison between low tone group and high tone group where $p < 0.05$, which clearly suggests that these two groups are statistically significantly different from each other. So, one of the three comparisons in the post hoc Bonferroni test shows a statistically significant difference, i.e., between low tone group and high tone group which indicate that the phonation measure of CPP is responsible for tonal contrast in these two tones in the language.

4.3.3.1. Male - Female contrast on the measure of CPP

As mentioned earlier, although finding the gender based differences do not make the main objective of this study, the average values of the measure of CPP for the male and female speakers are obtained. The average values of CPP for all the Punjabi tones for the male and female speakers are obtained with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The following $H_{1^*}-H_{2^*}$ values are obtained:
Table 4.28. CPP values for male and female speakers

<table>
<thead>
<tr>
<th>CPP</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Tone</td>
<td>71.15093</td>
<td>74.12979</td>
</tr>
<tr>
<td>Mid Tone</td>
<td>70.25715</td>
<td>72.00359</td>
</tr>
<tr>
<td>Low Tone</td>
<td>68.26771</td>
<td>70.59484</td>
</tr>
</tbody>
</table>

The average values of CPP for the five male and five female speakers in this study suggest that overall this measure shows a clear contrast between the two groups, i.e., between male and female speakers. The average values on the measure of CPP for all the three Punjabi tones are higher by the female speakers than the male speakers. Furthermore, the study shows a clear contrast among the three tones within each group as the value of CPP gradually increases while moving from the low Punjabi tone to the high Punjabi tone. The mid Punjabi tone lies in the middle in both the groups. The values on the measure CPP for male and female speakers are better described in the form of a chart as follows:
4.4. DIFFERENCE AMONG THE INDIVIDUAL SPEAKERS

The overall results of the study have been presented and described up to this point in this chapter. Now, in order to see individual differences among the speakers, the data of the individual speakers is also presented for the three Punjabi tones with respect to the seven measures explored in the study including fundamental frequency (F0), duration, intensity, final velocity, H1-H2, H1*-H2*, and CPP. The values by the individual speakers are presented in order to explore if there is any speakers whose values are affecting the average values by all the other speakers in the study.

4.4.1. Individual Speakers on the Acoustic Measure F0

In this study, the values by the individual speakers on the measure fundamental frequency (F0) for the three tones of Punjabi are as under:
Table 4.29. Median pitch of the individual speakers

<table>
<thead>
<tr>
<th>Speakers</th>
<th>High tone</th>
<th>Mid tone</th>
<th>Low tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>190.9649</td>
<td>176.8716</td>
<td>179.7128</td>
</tr>
<tr>
<td>Fn</td>
<td>148.6206</td>
<td>123.7887</td>
<td>124.931</td>
</tr>
<tr>
<td>Im</td>
<td>112.4084</td>
<td>105.7586</td>
<td>106.4757</td>
</tr>
<tr>
<td>No</td>
<td>199.471</td>
<td>188.0931</td>
<td>187.2976</td>
</tr>
<tr>
<td>Nr</td>
<td>190.662</td>
<td>180.9562</td>
<td>185.7342</td>
</tr>
<tr>
<td>Tq</td>
<td>138.7296</td>
<td>132.9183</td>
<td>128.2399</td>
</tr>
<tr>
<td>Tr</td>
<td>105.2309</td>
<td>99.96584</td>
<td>97.40799</td>
</tr>
<tr>
<td>Um</td>
<td>113.2165</td>
<td>111.532</td>
<td>96.42552</td>
</tr>
<tr>
<td>Uz</td>
<td>183.9452</td>
<td>184.806</td>
<td>180.9167</td>
</tr>
<tr>
<td>Zr</td>
<td>231.8941</td>
<td>205.6029</td>
<td>202.721</td>
</tr>
</tbody>
</table>

There were five male speakers in the study with their name initials as: Fn, Im, Tq, Tr, and Um. There were five female speakers in the study with their name initials as: As, No, Nr, Uz, and Zr. The values are better described and compared in the form of a chart as follows:

Figure 4.15. Chart for individual speakers on the acoustic measure F0
It is clear from the above chart that the values of F0 of the male speakers in the study nearly range from 100 Hz to 150 Hz. Whereas the values of the female speakers nearly range from 150 Hz to 200 Hz. Overall, rather in most of the speakers, there is no much difference among the three tone types which is already discussed in the previous section in the statistical analysis.

Only five of the speakers including ‘No’, ‘Tq’, ‘Tr’, ‘Um’, and ‘Zr’ produced the high tone with highest F0, the mid tone with intermediate F0, and the low tone with the lowest F0. The remaining five speakers produced the three tones by not keeping the them at their respective positions, i.e., they did not produce high tone with the highest F0, mid tone with the intermediate F0, and low tone with the lowest F0. All the speakers except ‘Uz’ produced the Punjabi high tone with the highest F0 value, whereas, she produced the high tone and the mid tone with nearly the same F0 values, although the mid tone F0 is slightly on the higher side. Four of the speakers including ‘As’, ‘Fn’, ‘Im’ and ‘Nr’ produced the mid tone with the lowest F0 value. Therefore, the results of the data based on the individual speakers also suggest that the acoustic measure of F0 could not distinguish the three Punjabi tones.

4.4.2. **Individual Speakers on the Acoustic Measure Duration**

In this study, the values by the individual speakers on the measure of duration for the three tones of Punjabi are as under:
Table 4.30. Duration of the individual speakers

<table>
<thead>
<tr>
<th>Speakers</th>
<th>High tone</th>
<th>Mid tone</th>
<th>Low tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>198.8281</td>
<td>266.8308</td>
<td>349.0853</td>
</tr>
<tr>
<td>Fn</td>
<td>181.3521</td>
<td>367.8806</td>
<td>429.1145</td>
</tr>
<tr>
<td>Im</td>
<td>218.9534</td>
<td>268.9926</td>
<td>299.9969</td>
</tr>
<tr>
<td>No</td>
<td>228.75</td>
<td>320.7326</td>
<td>400.8135</td>
</tr>
<tr>
<td>Nr</td>
<td>145.543</td>
<td>332.6341</td>
<td>334.7006</td>
</tr>
<tr>
<td>Tq</td>
<td>206.3823</td>
<td>291.0311</td>
<td>311.5907</td>
</tr>
<tr>
<td>Tr</td>
<td>154.1708</td>
<td>280.1232</td>
<td>330.2801</td>
</tr>
<tr>
<td>Um</td>
<td>229.4544</td>
<td>207.2403</td>
<td>258.689</td>
</tr>
<tr>
<td>Uz</td>
<td>158.9494</td>
<td>197.6077</td>
<td>300.4525</td>
</tr>
<tr>
<td>Zr</td>
<td>104.5624</td>
<td>214.2489</td>
<td>317.1929</td>
</tr>
</tbody>
</table>

The values are better described and compared among the groups in the form of a chart as follows:

Figure 4.16. Chart for individual speakers on the acoustic measure duration

The above chart shows a clear difference among all the three tone types with respect to duration in all the speakers except one speakers ‘Um’ who is different from all the
other nine speakers. Nine of the ten speakers show shortest duration for the high tone, intermediate duration for the mid tone and the longest duration for the low tone. The speaker ‘Um’ showed longest duration for the low tone, intermediate duration for the high tone, and shortest duration for the mid tone. Therefore, the results of the data based on the individual speakers also suggest that the acoustic measure of duration well distinguished the three Punjabi tones.

4.4.3. Individual Speakers on the Acoustic Measure Intensity

In this study, the values by the individual speakers on the measure intensity for the three tones of Punjabi are as under:

Table 4.31. Intensity of the individual speakers

<table>
<thead>
<tr>
<th>Speakers</th>
<th>High tone</th>
<th>Mid tone</th>
<th>Low tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>70.70701</td>
<td>67.14242</td>
<td>66.61548</td>
</tr>
<tr>
<td>Fn</td>
<td>74.77018</td>
<td>68.76676</td>
<td>71.02547</td>
</tr>
<tr>
<td>Im</td>
<td>76.78015</td>
<td>75.84363</td>
<td>76.4484</td>
</tr>
<tr>
<td>No</td>
<td>64.95081</td>
<td>63.46668</td>
<td>63.55503</td>
</tr>
<tr>
<td>Nr</td>
<td>63.70154</td>
<td>58.82937</td>
<td>61.88357</td>
</tr>
<tr>
<td>Tq</td>
<td>71.87173</td>
<td>69.76126</td>
<td>70.70877</td>
</tr>
<tr>
<td>Tr</td>
<td>74.79475</td>
<td>72.64378</td>
<td>72.52506</td>
</tr>
<tr>
<td>Um</td>
<td>67.32645</td>
<td>66.60865</td>
<td>64.08091</td>
</tr>
<tr>
<td>Uz</td>
<td>73.73195</td>
<td>72.94498</td>
<td>73.38325</td>
</tr>
<tr>
<td>Zr</td>
<td>74.52104</td>
<td>71.67512</td>
<td>70.89193</td>
</tr>
</tbody>
</table>

The values are better described and compared among the groups in the form of a chart as follows:
It is clear from the above chart that nearly in all the speakers, there is no much difference among the three tone types which is already discussed in the previous section with the help of statistical analysis. All the speakers produced the high tone with the highest value of intensity. Anyhow there was some variation among the speakers for their intensity values on low tone and mid tone. Six of the speakers including ‘Fn’, ‘Im’, ‘No’, ‘Nr’, ‘Tq’, and ‘Uz’ produced the low tone with the intermediate intensity and mid tone with the lowest intensity, whereas, the remaining speakers produced the mid tone with the intermediate intensity and the low tone with the lowest intensity. Overall, it was found in the study that the measure of intensity was not responsible for creating tonal contrast in the language.
4.4.4. Individual Speakers on the Acoustic Measure Final Velocity

In this study, the values by the individual speakers on the measure of final velocity for the three tones of Punjabi are given in the table as under:

Table 4.32. Final velocity of the individual speakers

<table>
<thead>
<tr>
<th>Speakers</th>
<th>High tone</th>
<th>Mid tone</th>
<th>Low tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>-4.28363</td>
<td>16.6164</td>
<td>34.75757</td>
</tr>
<tr>
<td>Fn</td>
<td>-13.2879</td>
<td>30.75078</td>
<td>36.42837</td>
</tr>
<tr>
<td>Im</td>
<td>-13.7712</td>
<td>-1.50931</td>
<td>3.696637</td>
</tr>
<tr>
<td>No</td>
<td>-7.04118</td>
<td>1.886911</td>
<td>5.64056</td>
</tr>
<tr>
<td>Nr</td>
<td>-26.9784</td>
<td>32.69746</td>
<td>47.02799</td>
</tr>
<tr>
<td>Tq</td>
<td>-13.7054</td>
<td>5.361277</td>
<td>8.620584</td>
</tr>
<tr>
<td>Tr</td>
<td>-27.7533</td>
<td>16.3248</td>
<td>20.25716</td>
</tr>
<tr>
<td>Um</td>
<td>-20.775</td>
<td>9.781741</td>
<td>15.23273</td>
</tr>
<tr>
<td>Uz</td>
<td>-12.147</td>
<td>9.745836</td>
<td>14.68963</td>
</tr>
<tr>
<td>Zr</td>
<td>-10.4451</td>
<td>28.95193</td>
<td>33.82986</td>
</tr>
</tbody>
</table>

The values are better described and compared among the groups in the form of a chart as follows:

Figure 4.18. Chart for individual speakers on the acoustic measure final velocity
The above chart clearly shows that all the speakers got positive values for the low tone group. Nine of the ten speakers produced the mid tone with a positive value except one speaker ‘Im’ who produced it with a negative value. All the speakers produced high tone with a negative value. The chart shows that the measure of final velocity for the low tone has the highest value by all the speakers, for the mid tone has the intermediate value and for the high tone has the lowest value by all the speakers. The results clearly indicate different trend of direction for each tone, i.e., the high tone is falling while moving towards its offset; the mid tone is slightly rising while moving towards its offset; and the low tone is maximally rising while moving towards its offset in comparison with one other.

4.4.5. Individual Speakers on the Acoustic Measure H1-H2

The values by the individual speakers in the study on the measure H1-H2 for the three tones of Punjabi are as under:

Table 4.33. H1-H2 of the individual speakers

<table>
<thead>
<tr>
<th>Speakers</th>
<th>High tone</th>
<th>Mid tone</th>
<th>Low tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>-1.3989</td>
<td>3.00554</td>
<td>0.994968</td>
</tr>
<tr>
<td>Fn</td>
<td>1.663599</td>
<td>4.066133</td>
<td>1.698231</td>
</tr>
<tr>
<td>Im</td>
<td>2.015709</td>
<td>0.462348</td>
<td>1.058011</td>
</tr>
<tr>
<td>No</td>
<td>2.604093</td>
<td>1.070314</td>
<td>4.184072</td>
</tr>
<tr>
<td>Nr</td>
<td>4.475894</td>
<td>6.815319</td>
<td>5.350651</td>
</tr>
<tr>
<td>Tq</td>
<td>3.475039</td>
<td>3.884778</td>
<td>6.111271</td>
</tr>
<tr>
<td>Tr</td>
<td>-3.9823</td>
<td>-5.76329</td>
<td>0.473653</td>
</tr>
<tr>
<td>Um</td>
<td>1.122411</td>
<td>3.102126</td>
<td>1.697121</td>
</tr>
<tr>
<td>Uz</td>
<td>1.877562</td>
<td>1.216259</td>
<td>2.086683</td>
</tr>
<tr>
<td>Zr</td>
<td>-2.60815</td>
<td>2.039106</td>
<td>-0.1667</td>
</tr>
</tbody>
</table>
The values are better described and compared among the tone groups in the form of a chart as follows:

Figure 4.19. Chart for individual speakers on the acoustic measure H1-H2

The above chart clearly shows that all the speakers produced the Punjabi tonal words in their unique way with respect to the measure H1-H2. Five of the speakers (As, Fn, Nr, Um, and Zr) produced the mid tone with the highest value of H1-H2. Four of the speakers (No, Tq, Tr, and Uz) produced the Punjabi low tone with the highest value of the measure H1-H2. Whereas the remaining one of the speakers (Im) produced the high tone with the highest H1-H2 value. There are no uniform results among the speakers for any of the tones. Therefore, the results of the data based on the individual speakers suggest that the acoustic measure of H1-H2 could not distinguish the three Punjabi tones. Earlier in this chapter, it is already proved with the help of statistical
analyses that this measure does not contribute in making tonal contrasts in the language.

4.4.6. Individual Speakers on the Acoustic Measure H1*-H2*

The values by the individual speakers in the study on the measure H1*-H2* for the three tones of Punjabi are as under:

Table 4.34. H1*-H2* values by the individual speakers

<table>
<thead>
<tr>
<th>Speakers</th>
<th>High tone</th>
<th>Mid tone</th>
<th>Low tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>5.712989</td>
<td>4.276882</td>
<td>-16.5668</td>
</tr>
<tr>
<td>Fn</td>
<td>2.264623</td>
<td>-4.214</td>
<td>-12.8087</td>
</tr>
<tr>
<td>Im</td>
<td>-2.51321</td>
<td>21.00386</td>
<td>3.395889</td>
</tr>
<tr>
<td>No</td>
<td>-15.7789</td>
<td>12.37367</td>
<td>0.62285</td>
</tr>
<tr>
<td>Nr</td>
<td>6.812074</td>
<td>-1.75071</td>
<td>0.060326</td>
</tr>
<tr>
<td>Tq</td>
<td>3.58342</td>
<td>-8.40649</td>
<td>1.29016</td>
</tr>
<tr>
<td>Tr</td>
<td>1.63826</td>
<td>1.986249</td>
<td>-2.58842</td>
</tr>
<tr>
<td>Um</td>
<td>23.66338</td>
<td>6.631659</td>
<td>-1.52002</td>
</tr>
<tr>
<td>Uz</td>
<td>37.18084</td>
<td>-8.07221</td>
<td>-8.61337</td>
</tr>
<tr>
<td>Zr</td>
<td>-8.85749</td>
<td>7.541187</td>
<td>2.048592</td>
</tr>
</tbody>
</table>

The values are better described and compared for all the speakers among the three tone groups in the form of a chart as follows:
Having the reverse values, with reference to the previously described un-corrected measure H1-H2, by most of the speakers, the above chart also shows that all the speakers produced the Punjabi tonal words in their unique way with respect to the corrected measure H1*-H2*. Six of the ten speakers in the study (As, Fn, Nr, Tq, Um, and Uz) produced the high Punjabi tone with the highest H1*-H2* value. Four of the speakers (Im, No, Tr, and Zr) produced the mid tone with the highest value on the measure H1*-H2*. No speaker produced the low tone in the language with the highest value of H1*-H2*. So, there are no uniform results among the speakers for any of the tone types in the language. Therefore, the results of the data based on the individual speakers suggest that the acoustic measure of H1*-H2* did not distinguish the three tones in the language. With the help of statistical analyses, it is already explored
earlier in this chapter that this measure also does not contribute in making tonal contrasts in the language.

4.4.7. Individual Speakers on the Acoustic Measure CPP

The values by the individual speakers in the study on the phonation measure CPP for the three tones of Punjabi are given in the table as under:

Table 4.35. CPP values by the individual speakers

<table>
<thead>
<tr>
<th>Speakers</th>
<th>High tone</th>
<th>Mid tone</th>
<th>Low tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>75.0472</td>
<td>71.45536</td>
<td>70.10526</td>
</tr>
<tr>
<td>Fn</td>
<td>72.6828</td>
<td>70.47896</td>
<td>69.30925</td>
</tr>
<tr>
<td>Im</td>
<td>71.25163</td>
<td>70.70064</td>
<td>67.28498</td>
</tr>
<tr>
<td>No</td>
<td>76.88356</td>
<td>75.9004</td>
<td>72.40826</td>
</tr>
<tr>
<td>Nr</td>
<td>69.14902</td>
<td>69.40696</td>
<td>69.7015</td>
</tr>
<tr>
<td>Tq</td>
<td>72.48531</td>
<td>71.40654</td>
<td>69.12581</td>
</tr>
<tr>
<td>Tr</td>
<td>69.92101</td>
<td>69.86313</td>
<td>67.70688</td>
</tr>
<tr>
<td>Um</td>
<td>69.41389</td>
<td>68.83649</td>
<td>67.91166</td>
</tr>
<tr>
<td>Uz</td>
<td>73.38761</td>
<td>71.24273</td>
<td>71.01855</td>
</tr>
<tr>
<td>Zr</td>
<td>76.18156</td>
<td>72.01249</td>
<td>69.74065</td>
</tr>
</tbody>
</table>

The values are better described and compared for all the speakers among the three tone types in the language in the form of a chart as follows:
The order of the bars in the above chart is given as high, mid, and low tones. It shows a clear trend in the values of CPP by all the speakers in the study. All the speakers except one (Nr) produced high tone with the highest CPP value. The values of CPP for the mid tone lie in the middle by all the speakers. Whereas the low tone was produced with the least CPP values by nine out of ten speakers. The speaker ‘Nr’ produced the high tone with the least CPP value, whereas, she produced the low Punjabi tone with the highest CPP value, suggesting that she might have replaced the two tones while making recordings. Therefore, overall the results of the data based on the individual speakers clearly suggest that the acoustic measure of CPP well distinguished the three Punjabi tones. Earlier in this chapter, it is already proved with the help of statistical
analyses that this measure distinguished the three tone types in the language with statistical significance.
SUMMARY OF CHAPTER 4

This chapter presents the findings of the experiment conducted in the study. Seven acoustic measures including F0, duration, intensity, final velocity, H1-H2, H1*-H2*, and CPP were measured with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014) for the three tone types in the language as well as for exploring the role of phonation in the tonal contrasts. First of all, Praat images (wave forms) of the three tone types are shown. Praat images for the low tone (section 4.1.1.) show that the dotted line which shows tone first shows a slight downward movement and then there is a clear rising trend while it moves towards the end. Praat images for the mid Punjabi tone (section 4.1.2.) show that the blue dotted line is nearly straight, i.e, it neither shows any downward movement nor any upward movement. Praat images for the high Punjabi tone (section 4.1.3.) show that the blue dotted line shows slight rise and then there is a clear downward movement while moving towards the end.

Then, with the help of SPSS, the descriptive statistical analyses of different correlates of tone and phonation which include fundamental frequency (F0), duration, intensity, final velocity, H1-H2, H1*-H2*, and CPP are conducted. The one way ANOVA test was applied followed by post hoc Bonferroni test in each case. The results of the statistical analyses are considered significant for p ≤ .05 in all the tests. Each of the above mentioned acoustic correlates was taken as a dependent variable and the three
tone types were taken as independent variables in the tests. The results show that the low Punjabi tone shows a mean F0 of 149 Hz, the mid tone in the language shows a mean F0 of 151 Hz, and the high Punjabi tone shows a mean F0 of 161 Hz. The one way ANOVA test shows significance value of $p = 0.775$ with $[F (2, 27) = 0.257, p > 0.05]$ which indicates that the three Punjabi tone types are not statistically significantly different from one another in terms of their F0. The post hoc Bonferroni test also shows that there is no statistically significant difference between any two of the three tone groups based on their F0s. Male female contrast in the study shows that the female speakers produced all the Punjabi tonal words with higher values of F0 than the male speakers.

For the measure of duration, the Punjabi low tone shows a mean duration of 333 ms, the mid tone in the language shows a mean duration of 275 ms, and the high Punjabi tone shows a mean duration of 183 ms. The one way ANOVA test shows significance value of $p = 0.000$ with $[F (2, 27) = 23.37, p < 0.05]$ which clearly indicates that the three Punjabi tone types are statistically significantly different from one another. The subsequent post hoc Bonferroni test also shows that there is a clear statistically significant difference between any two of the three tone types in the language. The male female contrast in the study shows that the male speakers produced higher values than the female speakers on the measure of duration for the high and mid Punjabi tones; whereas, the female speakers produced the low Punjabi tone with a higher average value of duration than the male speakers.
For the measure of intensity, the low tone in the language shows a mean intensity of 69 dB, the Punjabi mid tone shows a mean intensity of 69 dB, and the high tone in the language shows a mean intensity of 71 dB. The one way ANOVA test for the measure of intensity shows significance value of $p = 0.445$ with $[F (2, 27) = 0.833, p > 0.05]$ which indicates that the three tone types in the language are not statistically significantly different from one another in terms of their intensity. The post hoc Bonferroni test also shows that the three Punjabi tones are not statistically significantly different from one another with respect the measure of intensity. The male female contrast shows that the male speakers produced higher values on the measure of intensity for all the three Punjabi tones than the female speakers.

For the measure of final velocity, the low Punjabi tone shows a mean final velocity of 22 semitones, the mid tone in Punjabi shows a mean final velocity of 15 semitones, and the high Punjabi tone shows a mean final velocity of -15 semitones. The one way ANOVA test shows significance value of $p = 0.000$ with $[F (2, 27) = 26.65, p < 0.05]$ which clearly indicates that the three tone types in the language are statistically significantly different from one another in terms of their final velocity. The post hoc Bonferroni test shows that two of the three comparisons, i.e., low tone group vs. high tone group, and mid tone group vs. high tone group show statistically significant difference; whereas, one comparison, i.e., low tone group vs. mid tone group does not show a statistically significant difference. The male female contrast on the measure of
final velocity shows that the female speakers produced higher values for all the three Punjabi tones than the male speakers.

For the measure of H1-H2, the low tone in Punjabi shows a mean value of H1-H2 of 2.34 dB, the mid tone in the language shows a mean value of H1-H2 as 1.99 dB, and the high tone in the language shows a mean value of H1-H2 as 0.92 dB. The one way ANOVA test for the measure H1-H2 shows significance value of p = 0.494 with [F (2, 27) = 0.724, p > 0.05] which indicates that the three tone groups in the language are not statistically significantly different from one another in terms of H1-H2. The post hoc Bonferroni test also shows that the three tone types in the language are not statistically significantly different from one another in terms of the measure H1-H2. The male female contrast on the measure H1-H2 shows that the female speakers produced all the three tones in the language with higher values than the male speakers.

For the measure of H1*-H2*, the low Punjabi tone shows a mean value of H1*-H2* of -3.47 dB, the mid tone in Punjabi shows a mean value of H1*-H2* as 3.14 dB, and the high tone in the language shows a mean value of H1*-H2* as 5.37 dB. The one way ANOVA test for the measure of H1*-H2* shows significance value of p = 0.195 with [F (2, 27) = 1.738, p > 0.05] which indicates that the three tone types in the language are not statistically significantly different from one another in terms of the measure H1*-H2*. The post hoc Bonferroni test also shows that the three Punjabi tone types are not statistically significantly different from one another in terms of the measure
H1*-H2*. The male female contrast for the measure H1*-H2* shows that the male speakers produced higher values than the female speakers for all the three Punjabi tones.

For the measure of CPP, the low tone in Punjabi shows a mean value of CPP as 69.43, the mid Punjabi tone shows a mean value of CPP as 71.13, and the high tone in the language shows a mean value of CPP as 72.64. The one way ANOVA test for the measure of CPP shows significance value of p = 0.009 with \([F (2, 27) = 5.567, p < 0.05]\) which clearly indicates that the three tone types in the language are statistically significantly different from one another in terms of the measure CPP. The post hoc Bonferroni test shows that one of the three comparisons, i.e., between low tone group and high tone group shows a statistically significant difference. Whereas, the other two comparisons do not show statistically significant difference. The male female contrast on the measure CPP shows that the female speakers produced higher values than the male speakers for all the three tone types in the language.

In the study, individual differences in the speakers have also been explored for the three tone types in Punjabi with respect to the seven measures including fundamental frequency (F0), duration, intensity, final velocity, H1-H2, H1*-H2*, and CPP. Only a few times it happened that a speaker differed from the average values by all the other speakers. Overall, the actual findings of the study remained the same even by considering individual difference for all the acoustic measures.
Chapter 5

DISCUSSION

5.0. INTRODUCTION

The experiment conducted in the study, as described in the previous chapter four ‘results’ of this dissertation, proved that Punjabi has three acoustically distinct tones namely, rising, falling and mid tone. Seven acoustic measures namely, F0, duration, intensity, final velocity, H1-H2, H1*-H2*, and CPP were tested for each of the three Punjabi tones. Three out of seven measures, i.e., duration, final velocity and CPP distinguished the three tone types in Punjabi with statistical significance. The remaining four measures including F0, intensity, H1-H2, and H1*-H2* showed very small differences in the three Punjabi tones which were not statistically significant. Also, the measure H1*-H2* showed the values which were the reverse of its non-normalized measure, i.e., H1-H2. This chapter discusses the findings of this study. Firstly, this chapter discusses how the Punjabi tone is represented orthographically. Keeping in view the findings of this study and the previous studies presented in the literature review, it is also discussed and suggested in this chapter that the tone bearing unit in the language is a stressed syllable (in mono-syllabic and bi-syllabic words). Then it highlights the role of different acoustic correlates of tone as explored in this research. Lastly, it further highlights the importance of some phonation related
acoustic correlates to uncover the role of phonation in making tonal contrasts in the language.

5.1. ORTHOGRAPHIC REPRESENTATION OF PUNJABI TONE

As discussed in the chapter ‘literature review’ of this dissertation and as the findings of this study suggest, Punjabi tone is placed on a word starting from a voiced aspirated consonant which is orthographically represented by “كسر” (for aspiration) following a voiced consonant. Orthographically, in Punjabi dictionaries there is no indication of tone, rather voiced aspirates are there written exactly in the same way as they are written in Urdu (another Indo Aryan language which is the national language of Pakistan) dictionaries. However, in Punjabi, they are to be produced in spoken form by replacing them with their neighboring voiceless consonant in IPA along with a tone. Therefore, although orthographically the voiced aspirates are written in the same way in both the languages, in spoken form Urdu word /ɡʰoɽa/ becomes /kоɽa/ in Punjabi, and the Urdu word /bha/ becomes /pa/ in Punjabi. It is discussed earlier in Table 2.9 in detail that the Urdu words /bʰul/ ‘forget’, /ɡʰoɽa/ ‘horse’, and /dʰul/ ‘dust’ are spoken with low tone as [pʊ̀l] ‘forget’, [kʊɽa] ‘horse’, and [t̪ʊːl] ‘dust’ in Punjabi respectively. The mid tone in Punjabi is not represented orthographically. Whereas the high tone in the language is sometimes represented orthographically by a word final /ə/ symbol like it is present in Punjabi word /kah/ not in /ʧa/. As mentioned earlier in the dissertation, Karamat (2002) also suggests that glottal fricative [h] is pronounced only word initially in the language and at other positions,
i.e., in the middle and at the end of a word it is manifested as a H or L tone. Anyhow, the word /ʧa/ with high tone does not have a [h] sound at the end.

5.2. TONE BEARING UNIT (TBU) IN PUNJABI

The stimuli in this research consisted of mono-syllabic words of Punjabi. The study suggests that the tone in the language is placed on the stressed syllable of mono-syllabic words with a long vowel [a]. For example, as explored in the study along with two more examples (see Table 3.1.), the Punjabi word /ʧa/ with low tone means ‘peep through’, /ʧa/ with high tone means ‘tea’ and /ʧa/ with mid tone means ‘desire’. Whereas, it is also discussed with evidence in the literature review part of this dissertation that the stressed syllable in bi-syllabic words in Punjabi also carry tone. A much quoted example is the Punjabi word /koɽa/ with low tone means ‘horse’, /koɽa/ with high tone means ‘leper’ and /koɽa/ with mid tone means ‘whip’ (see Table 2.8. for more examples). The first syllable in these words is stressed which carry tone. As tone is placed on the stressed syllable in both type of words in Punjabi, i.e., mono-syllabic and bi-syllables words, therefore, there seems to be no other tone bearing unit in Punjabi other than a stressed syllable. Baart (2003: pp. 7-8) also suggests that “the most basic observation for all the tone languages of northern Pakistan is that the tone features are associated with the stressed syllable. The pitch patterns that are characteristic of one tone or another occur on or near the stressed syllable.”
Orthographically a voiced aspirated consonant in a word (mono-syllabic or bi-syllabic) initial position is of key importance for the low tone in Punjabi in this regard. This rule seems to be applicable to the words with low tone in the language, whereas no rule can be stated for the high tone in the language because sometimes orthographically a word with high tone ends with “s” (h) letter like in /kah/, and sometimes there is no “s” like in /ʧa/. Therefore, be it a low tone or a high tone, the tone bearing unit (TBU) in the language is a stressed syllable.

5.3. ROLE OF F0 IN PUNJABI TONE AND PHONATION TYPES

Pitch is the perceived correlate of fundamental frequency (F0) which is considered to distinguish among the tonal contrasts a language has got. That is why it is reported in the literature reviewed to be the most significant and major cue in the analysis of a tone language. Furthermore, as discussed in chapter two, literature review, low tone in Punjabi is expected to be produced with the breathy phonation type. In this regard, Wayland and Jongman (2003) also suggest that the fundamental frequency of a breathy phonation is expected to be lower than that of a modal phonation. In this study also, based on the values obtained by means of the acoustic analyses on the measures of H1-H2, H1*-H2* and CPP, the low tone in the language is found to co-exist with breathy phonation type. The breathiness of the mid Punjabi tone lies in the middle, whereas, the high tone in the language is least breathy of the three tones. The values on the above mentioned measures in the study suggest that the low tone in the language is produced when the vocal cords are in most abducted
position for the most time, the mid tone is produced with intermediate abduction of the cords for the intermediate time period, and the high tone in the language is produced when the vocal cords are abducted for the least time period.

Discussing the interaction of pitch and phonation types, Wayland and Jongman (2003) also suggest that the fundamental frequency of a breathy vowel is expected to be lower than that of a clear vowel. In this study also, low tone in the language is proved to be produced with breathy phonation configuration due to its values on different measures including H1-H2, H1*-H2*, and CPP. As the vocal cords are in abducted position and remain slack during the production of Punjabi low tone, so they take more time in their vibrations per unit amount of time due to which the value of F0 was low. During the mid tone production, the vocal cords are relatively less slack and less abducted causing them to vibrate more rapidly, so the mid tone F0 remained in the middle. Whereas, during the production of high tone, the vocal cords remain relatively more adducted and least slack, due to which they vibrate most rapidly among the three Punjabi tones. Therefore, in the study, the high tone F0 was the highest of the three.

Based on the findings in this study, it is presented earlier in chapter four of this dissertation that the measure of F0 could not distinguish the three Punjabi tones with statistical significance. The low Punjabi tone showed a mean F0 of 149 Hz, the mid Punjabi tone showed a mean F0 of 151 Hz, whereas, the high tone showed a mean F0 of 161 Hz. As, Sarmah (2009: p. 71) refers to the studies (Fok, 1974; Peng, 1997; and
Barry and Blamey, 2004) and states that: “it is not uncommon to have such small differences of fundamental frequency in the production of contrastive tones in tone languages.” In this study, same was the case with Punjabi tones which showed small differences of F0 (especially between the Punjabi low tone and mid tone) and did not distinguish the three tones with respect to their fundamental frequency with statistical significance.

As mentioned earlier also, Sarmah (2009: p. 71) proposes that: “Contour tones in tone languages demonstrate a plethora of variations in terms of the difference between the offset and onset of the pitch contour. Languages like Mandarin Chinese and Thai show large differences between the onset and offset of contour tones.” In order to explore as to how the three Punjabi tones behaved from their onset to offset, the recordings of one of the speakers (Fn) were measured manually with the help of Praat (Boersma and Weenink, 2014). The average values for the high or falling Punjabi tone showed a fall of 17 Hz (from 150 Hz to 133 Hz) from the tone onset to its offset. The average values for the low or rising Punjabi tone showed a rise of 86 Hz (from 129 Hz to 215 Hz) from the tone onset to its offset. The average values for the mid Punjabi tone showed a slight rise of 33 Hz (from 133 Hz to 166 Hz) from the tone onset to its offset.

The findings of this study with respect to the rise and fall of Punjabi tones can be compared to the findings of the other studies also so that a trend in other languages can be compared with Punjabi tones. Sarmah (2009: p. 72) refers to a study by
Chuang, Hiki, Sone and Nimura (1972) which finds that the rising tone in Mandarin Chinese can rise for 25 Hz (85 Hz to 110 Hz) from its onset to the offset and a falling tone can fall for 40 Hz (125 Hz to 85 Hz) from its onset to the offset. Sarmah (ibid: p. 72) refers to another study by Moore and Jongman (1997) which finds that rising tones in Mandarin Chinese can rise for 60 Hz (210 Hz to 270 Hz) from their onset to the offset and falling tones can fall for 90 Hz (270 Hz to 180 Hz) from their onset to their offset.

5.4. ROLE OF DURATION IN PUNJABI TONE AND PHONATION CONTRASTS

As explored and presented in the chapter four ‘results’ of this dissertation, the acoustic measure of duration proved to be a measure which distinguished the three Punjabi tones with statistical significance. The low tone in Punjabi showed a mean duration of 333 ms, the Punjabi mid tone showed a mean duration of 275 ms, and the high tone in the language showed a mean duration of 183 ms. As the vocal cords are slack and abducted during low tone production, so they take more time in completing a segment with low tone. Probably that is why the duration of low tone is longest of the three tones in the language. During the mid tone production, the vocal cords are less slack and less abducted, so they take lesser time in completing a segment with mid tone. Whereas, during the production of the segments containing the high tone, the vocal cords are least slack and least abducted so they take least time in completing the segment among the three Punjabi tone types. As mentioned earlier, Gill (1960)
also finds that there are three tones in the language where the duration of L tone is longer than H tone and M tone is longer than H tone.

For a better description of the role of phonation in the tonal contrasts in Punjabi, the study suggests that the low tone in the language is produced when the vocal cords are in abducted position and they take more time in producing a segment carrying tone. Therefore, the low tone in the language co-exists with the breathy phonation and takes longest time of the three tones. The mid tone in the language co-exists with the modal phonation type and takes intermediate time. Whereas, the high tone in the language is the tensest of the three tones which takes the shortest time of the three tones.

5.5. ROLE OF INTENSITY IN PUNJABI TONE AND PHONATION TYPES

Intensity as an acoustic correlate of tone and phonation is also considered an important measure in distinguishing different tonal and phonation contrasts in a language. Pickett (1999) mentions intensity as one of the three basic measures (along with F0 and duration) for analyzing acoustic patterns of the prosodic features in a language. Crystal (2008) suggests that greater intensity of a speech sound leads to a greater sensation of its loudness which results in greater amplitude. The role of intensity in making phonation contrasts is also very important. Gordon and Ladefoged (2001) propose that intensity is decreased in breathy and creaky phonation types. Whereas, Wayland and Jongman (2003) discuss two studies (Fischer-Jorgensen, 1967;
and Thongkum, 1988) which show that intensity is decreased in breathy voice, and one study (Wayland et al., 1994) which shows that intensity is increased in breathy vowels in Javanese. So mixed results are available in literature which highlight the effect of this measure in creating phonation types.

It is also explored and discussed in chapter four (results) of this dissertation that the measure of intensity did not distinguish the three Punjabi tones with statistical significance; anyhow this measure showed a small differences between Punjabi low tone and Punjabi high tone, and Punjabi mid tone and Punjabi high tone which are statistically insignificant. There is nearly no difference at all between Punjabi low tone and Punjabi mid tone. The low tone in the language showed a mean rounded off value of intensity as 69 dB, the mid tone in the language also showed a mean rounded off value of intensity as 69 dB, whereas the high tone in the language showed a mean rounded off value of intensity as 71 dB. Therefore, the Punjabi low tone and mid tone share the same level of loudness, whereas the high tone is louder than the other two tones. Again the reason behind this distinction could be, probably, the tension of the vocal cords which is less in the case of low and mid Punjabi tones, and high in the case of Punjabi high tone causing the high tone to be louder among the three tones.

In this study, the role of phonation in the Punjabi tonal contrasts is evident in the case of intensity also. The low tone and the mid tone in the language are produced with the least values of intensity suggesting that the low tone which co-exists with the breathy
phonation and the mid tone which co-exists with the modal phonation show the same level of loudness based on their intensity. Whereas, the high tone in the language which co-exists with the tense phonation configuration shows the highest value of intensity due to its highest loudness of the three tones.

5.6. ROLE OF FINAL VELOCITY IN PUNJABI TONES

Final velocity as an acoustic correlate of tone is also considered an important indicator in the analysis of a tone language, especially a contour tone language, because the direction of tones can easily be seen with the help of this measure. Xu (2013) suggests that the measure of final velocity gives the value of F0 velocity near the interval offset. The direction of contour tones has been judged with the help of some other measures also. For example, Sarmah (2009) investigates the contour tones of Dimasa and Rabha by means of acoustic analysis and the measures like F0d by using ANOVA and post hoc Bonferroni tests where F0d indicates the direction of the pitch contour. Sarmah (ibid) suggests that the value of F0d should be positive in case of a rising tone, negative for a falling tone and nearly zero for a register tone. Anyhow, for the same purpose, in this study, the acoustic correlate of final velocity was measured with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014).

In this study, the acoustic measure of final velocity distinguished the three Punjabi tones with statistical significance as explored and described in the chapter four.
‘results’ of this thesis. The measure of final velocity shows direction of the tones as they move from their onset to offset. This study found that the low tone in the language showed a mean final velocity of 22 semitones which is positive in its value, the Punjabi mid tone showed a mean final velocity of 15 semitones which is also positive in its value, whereas the high tone in the language showed a mean final velocity of -15 semitones which is negative in its value. The results clearly indicate that the three Punjabi tones have different directions while moving from their onset to their offset. The low Punjabi tone shows a rising trend with the highest value of final velocity, the mid Punjabi tone also shows a rising trend but relatively there is less rise as compared with the rise of the low tone with the intermediate value of final velocity, whereas the Punjabi high tone shows a falling trend while moving from its onset to its offset due to its lowest and negative value of final velocity.

With reference to the direction of the Punjabi tones, the acoustic and statistical analyses in this study found that the three Punjabi tones were rising, slightly rising (mid level), and falling. It was also found that the direction of the tones was more important in distinguishing the three Punjabi tones in a statistically significant way, whereas, the tones were not distinguished with statistical significance with respect to their fundamental frequency. The findings suggest that all the three Punjabi tones are contour tones and they are statistically different from one another with respect to their shape and direction of the contours.
5.7. IMPORTANCE OF THE MEASURE H1-H2 IN PUNJABI TONE AND PHONATION TYPES

In this study, the tones in Punjabi were measured for their values on some most important phonation measures also so as to explore the role of phonation in creating tonal contrasts in the language. Kuang (2013) proposes that non-modal phonations give very important cues in tonal contrasts by either enhancing pitch contrasts or by providing additional contrastive cues. Kuang (ibid: p. 115) gives a good account of different ranges of F0s which favor some phonation types and states as: “The best positive correlation between voice quality and pitch happens in the lower pitch range, 110 – 180 Hz for males, 170 – 200 Hz for females; and the best negative correlation happens in the higher pitch range, 180 – 250 Hz for males, 200 – 270 Hz for females. Finally, 110 Hz for males and 170 Hz for females are the threshold F0 values for the natural occurrence of creaky voice; and there is a clear voice break at 250 Hz for female speakers. These threshold F0 values for voice quality suggest that glottal configurations might require significant changes when passing through these pitch values.” The above mentioned different pitch ranges and their correlation for male and female speakers provides us with a new dimension to be explored in the case of Punjabi also. Anyhow the difference in these values may be taken as reference values for another language.

H1-H2 is considered to be the most effective measure in distinguishing among phonation types in a language. Fung (2014) proposes that H1-H2 is the most popular
measure for distinguishing phonation types in a language which is expected to be large and positive for breathy voices and small and / or negative for creaky voice. Finkeldey (2011: p. 27) mentions some studies like (Stevens, 1998) which discuss the usefulness of this measure and suggest that the values of H1-H2 around +5 dB indicate breathy phonation, values around -5 db indicate creakiness, and approximately equal values indicate modal voicing. However, higher harmonics in breathy vowels may be as much as 15 dB weaker than their modal counterparts (Stevens 2000: 89: as cited in Finkeldey, 2011: p. 27). So, these values may be taken as reference values to indicate phonation configurations in a language based on H1-H2, or in the least these values would show what kind of trend is there in a language.

H1-H2 was one of the measures which was explored and described in chapter four (results) of this dissertation. This measure is used to find out as to what extent the vocal cords are in abducted position while producing a speech segment. This measure also could not distinguish the three Punjabi tones with statistical significance. It showed only a small difference among the three tones. In the study, the low tone in Punjabi showed a mean value of H1-H2 as 2.34 dB, the mid tone in the language showed a mean value of H1-H2 as 1.99 dB, whereas, the high tone in the language showed a mean value of H1-H2 as 0.92 dB. It is also discussed in the literature that there are no absolute values for any of these measures. The phonation configurations take place in a language only relative to one another within that language. The findings in the study indicate that the value of H1 (first harmonic) is highest as
compared to H2 for the low tone, intermediate for the mid tone and least for the high Punjabi tone. It showed that the vocal cords are in most abducted position while producing the low tone, in intermediate abducted position for the mid tone, and in the least abducted position for the high tone. All the values are positive suggesting that there is no creakiness involved in any of the three Punjabi tones.

In the study, the results of the measure H1-H2, based on the acoustic and statistical analyses, also indicate that the low tone in Punjabi is the breathiest of the three tones, mid tone lies in the middle and the high tone is least breathy of the three tones. Therefore, the Punjabi low tone is found to co-exist with the breathy phonation, the mid tone is found to co-exist with the modal phonation, and the high tone in the language is found to co-exist with the tensest phonation type.

5.8. IMPORTANCE OF THE MEASURE H1*-H2* IN PUNJABI TONE AND PHONATION TYPES

Another very important acoustic measure of phonation is H1*-H2* which is also measured for Punjabi tones in this study. H1*-H2* is also considered an effective measure in distinguishing contrasts among the phonation configurations in a language. Keating et al. (2010: p. 188) investigate and compare contrastive phonation types of four languages, i.e., Gujarati (modal vs. breathy), Hmong (modal vs. breathy vs. creaky), Mazatec (modal vs. breathy vs. creaky), and Yi (tense vs. lax) on several acoustic measures, within and across languages and states that: “While several
acoustic measures distinguished phonation types within each language, only H1*- H2* did so in all four languages.” Keating et al. (ibid) find H1*-H2* to be the most important measure of phonation types across languages. Therefore, H1*-H2* has also been included in this study. Garellek (2010) suggests that the value of H1*H2* is higher in breathy phonation types and lower in creaky phonation types. As stated earlier, Fung (2014) suggests that asterisks in H1*-H2* indicate that the harmonic amplitude of the acoustic speech signals were corrected to recover the source spectrum of the vocal fold pulses by reducing the influence of formant resonances.

In this study, for H1*-H2* the harmonic amplitudes were corrected automatically with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The results of the experiment are described in the chapter four, namely results, of this dissertation. The findings in the study indicate that this measure also could not distinguish the three Punjabi tones with statistical significance. Anyhow it showed results which are reverse of what we got for the measure H1-H2. That means the highest value in H1-H2 became lowest in H1*-H2*. The low tone group in the language showed a mean value of H1*-H2* as -3.47 dB, the mid tone in the language showed a mean value of H1*-H2* as 3.14 dB, and the high tone in the language showed a mean value of H1*-H2* as 5.37 dB. Whereas, the un-corrected version of this measure, i.e., H1-H2 showed highest positive value for the low tone, slightly lower but positive value for the mid tone and the least of the three but still positive value for the Punjabi high tone. May be the automatic reduction of the influence of
formant resonances by means of software like Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014) could have produced such results. Regarding the role of such measures in tonal contrasts in a language, Kuang (2013: p. 40) suggests that: “F0 is the dominant phonetic correlate for tonal contrasts; the measures that are related to the degree of glottal opening, e.g. CQ and H1* related measures, make very little contribution to the tonal contrasts.” This study proves the point that the measures like H1-H2 and H1*-H2* make little contribution to the tonal contrasts in the language as they showed only a bit of a contrastive trend among the three Punjabi tones because of no their statistical significance. Anyhow in this study, F0 also could not distinguish the three Punjabi tones with statistical significance and instead the direction of the contours realized with the help of acoustic measure of final velocity distinguished the three tone types in the language with statistical significance.

5.9. IMPORTANCE OF THE MEASURE CPP IN PUNJABI TONE AND PHONATION TYPES

One more very important and effective phonation measure is CPP (cepstral peak prominence) which is used in acoustic analyses for distinguishing different types of phonation configurations in a language. Fung (2014) suggests that the difference in amplitude between the cepstral peak and the value of regression line at the cepstral peak which indicates the harmonics to noise ratio because the noise excitation is an important component of breathy voice. As discussed earlier, Keating et al. (2010) investigate phonation types of four languages, i.e., Gujarati (modal vs. breathy),
Hmong (modal vs. breathy vs. creaky), Mazatec (modal vs. breathy vs. creaky), and Yi (tense vs. lax) and find that CPP, the measure of noise and / or periodicity, distinguishes among the phonation types in the three out of four languages; it could not distinguish modal from breathy phonations in Gujarati only. Therefore this measure has also been included in the present study. Regarding its role in phonation types, Fung (2014) states that this measure is expected to be small for the breathy voices. Keating et al. (2010: p. 196) also state that: “In Mazatec, the only measure that differs with tone is CPP, with Mid tones having the highest CPP value, and Low tones having the lowest value.”

In this study, the acoustic measure for phonation CPP was also explored for all the three Punjabi tones and the results are described in the chapter four ‘results’ of this dissertation. This measure (which indicates the harmonic to noise ratio), just like in Mazatec (Keating et al. 2010), proved to be a measure which distinguished the three Punjabi tones with statistical significance. In the study, the low tone in Punjabi showed a mean value of CPP as 69.43, the mid tone in the language showed a mean value of CPP as 71.13, whereas, the high tone in the language showed a mean value of CPP as 72.64. The results indicate that the harmonic to noise ratio for the low Punjabi tone is lowest, for the mid Punjabi tone intermediate, and for the high Punjabi tone is highest. Hillenbrand et al. (1994) suggest that the measure of CPP gives lower values in breathy phonation due to the additional noise of increased airflow. Whereas, higher
value of CPP indicates that the speech signal is more periodic (Keating and Esposito, 2006).

In the study, the results of the acoustic and statistical analyses on the measure CPP also indicate that the low tone in Punjabi is the breathiest of the three tones, mid tone lies in the middle and the high tone is least breathy of the three tones. As discussed earlier, there are no absolute values for the phonation types in language, rather all the types exist in relation to one another. Therefore, the CPP values also suggest that the low tone in the language co-exists with the breathy phonation, the mid tone in the language co-exists with the modal phonation type, and the high tone in the language is produced when the vocal cords are most tense so the high tone co-exists with the tensest phonation configuration.

The purpose of the inclusion of male vs. female groups in the work is to see how these two groups produce tone in Punjabi. Do they produce it in the same way or differently? It is seen, although their pitch range is different, both the groups produce difference tone systems also. For example, with respect to F0, male speakers tend to have three tone types although with minor differences, whereas, female speakers show only two tone types. Furthermore, with respect of intensity, female speakers tend to show three tone types, whereas, male speakers show two tone types. The male vs. female contrast raises important questions for future research in the area.
CONCLUSION

This study explores the phenomena of tone and phonation in Punjabi, as it is spoken in Lahore, by means of acoustic and statistical analyses conducted with the help of software Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014) and concludes that there are three tone types in the language which are contour tones in nature. The study also concludes that tone and phonation co-exist in the language significantly. The detailed conclusion is given in the next paragraphs of this chapter. The key objectives of the study were to explore the tonal inventory of the Punjabi language, the nature of Punjabi tones, and the role of phonation in contributing to the tonal contrasts in the language. This chapter concludes the major findings of the study according to the set objectives in the study. This chapter is followed by the summary of the thesis which is followed by some suggestions for further research in this area.

The literature reviewed in the study as well as the evidence provided by the acoustic and statistical analyses conducted in the study conclude that the Punjabi low tone is represented orthographically at a word initial position by a “ʰ” symbol (used for aspiration) following a voiced consonant. (Whereas, in another Indo-Aryan non-tonal language, i.e., Urdu these type of words are produced as voiced aspirates. For example, as discussed in detail in the previous chapter also, an Urdu word /gʰorə/
which contains a voiced aspirate at its onset position is produced in Punjabi as /koɽa/
with low tone which contains a voiceless un-aspirated consonant at the onset position,
and another Urdu word /bha/ which also contains a voiced aspirate at the onset position
is produced in the language as /pa/ with low tone which contains a voiceless un-aspirated consonant at the onset position.) So, the orthographic voiced aspirates in
the language are produced in spoken form by replacing them with their neighboring
voiceless consonant in IPA accompanied by a low tone.

The literature reviewed and the findings of this research also conclude that the tone in
Punjabi is placed on the stressed syllables, i.e., the tone bearing unit in the language is
a stressed syllable in a mono-syllabic or a bi-syllabic word. For example, a mono-
syllabic Punjabi word /ʧa/ with the low tone means ‘peep through’, with the high tone
means ‘tea’ and with the mid tone means ‘desire’. In the same way, the first syllable in
the bi-syllabic Punjabi word like /koɽa/ is stressed which with the low tone means
‘horse’, with the high tone means ‘leper’ and with the mid tone means ‘whip’.

On the basis of evidence provided by the acoustic and statistical analyses conducted in
this study, it is also confirmed that there are three tone types (tonemes) in the
language, namely, low tone (rising), high tone (falling), and mid tone (mid level). The
study finds that the three Punjabi tones are distinguished from one another with
statistical significance with respect to their shape and direction of the contours,
whereas, the tones show small differences with respect to their average F0s. As quoted
earlier, Sarmah (2009: p. 71) refers to the studies (Fok, 1974; Peng, 1997; and Barry and Blamey, 2004) and states that: “it is not uncommon to have such small differences of fundamental frequency in the production of contrastive tones in tone languages.” So, the Punjabi as spoken in Lahore does not show tonal contrasts mainly on the basis of F0 values. The direction of the tones is more important which is realized and measured with the help of acoustic correlate of final velocity. The Punjabi speakers in Lahore seem to rely more on the direction of the contours than on the average F0 values for the tonal contrasts. Therefore, it can be stated that the Punjabi tones are contour tones in nature.

This study provides the evidence based on the acoustic and statistical analyses conducted on some other acoustic measures of tone including duration and intensity also. The study proves that the measure of duration distinguishes the three tones in Punjabi with statistical significance. The low tone in the language takes the longest time duration, the mid tone takes the intermediate time duration, whereas, the high tone in the language takes the shortest time duration. The study also proves that the measure of intensity does not distinguish the three tones with statistical significance. This measure shows minor differences among the speakers as all the speakers produced the high tone with the highest intensity; six out of ten speakers produced the low tone in the language with the intermediate intensity and the mid tone with the lowest intensity.
Also, in the study, with the help of acoustic and statistical analyses, the Punjabi tones were measured on certain very important phonation specific measures (including H1-H2, H1*-H2*, and CPP) so as to explore particularly the role of phonation in Punjabi tonal contrasts. The study concludes that the measures of H1-H2, and H1*-H2* could not distinguish the three tones in the language with statistical significance. These measures show small differences in the Punjabi tonal contrasts; whereas, the measure of CPP (measure of noise and periodicity) distinguishes the three Punjabi tones with statistical significance. As mentioned earlier, Kuang (2013: p. 40) states that: “the measures that are related to the degree of glottal opening, e.g. CQ and H1* related measures, make very little contribution to the tonal contrasts.” That is what is found in Punjabi spoken in Lahore also that the spectral measures do not distinguish the tone type with significance.

Therefore, on the basis of acoustic and statistical evidence, the study finds that the phenomena of tone and phonation co-exist in Punjabi in such a way that phonation plays an important role in contributing to the tonal contrasts in the language. The acoustic measures of H1-H2, and H1*-H2* with only minor differences and the acoustic measure of CPP prove with statistical significance in the study that the low tone in the language is the breathiest of the three tones. The mid tone in the language co-exists with the modal phonation type. Whereas, the high tone co-exists with the tensest vocal cords. The measure of H1-H2, H1*-H2*, and CPP also show a continuum which suggests that the Punjabi low tone which is the breathiest of the
three tones is produced with the abducted vocal cords for the most time period, the
mid Punjabi tone lies in the middle due to its intermediate time of abduction of the
cords, whereas, the high tone in the language which is least breathy of the three tones
due to the tensest vocal cords is produced with the abducted vocal cords for the least
time period. Therefore, the study concludes that the low tone in Punjabi co-exists with
the breathy phonation configuration, the mid tone in the language is produced with the
modal phonation configuration and the high tone in the language co-exists with the
tensest phonation type of the three tone types in the language.
SUMMARY OF THE THESIS

This study investigates the nature of Punjabi (an Indo-Aryan language) tone system along with the role of phonation types in creating the tonal contrasts in the language. In a tone language, tone is a phonemic unit in exactly the same way as the consonants and vowels are in a language. Tone is a variation in pitch which results in lexical contrasts in a language. The role of phonation is also important in the study. Phonation refers to how we set up our larynx in producing different sounds. An important point to remember is that, as both the phenomena, i.e., tone and phonation share the same power source for their production, there is expected to be high probability that they may affect each other. Therefore, in this study, the role of phonation in the Punjabi tonal contrasts is also explored for a better description of Punjabi tone system.

For a deeper understanding of both the phenomena of tone and phonation, extensive related literature is reviewed along with some latest published research. Pike (1948) has a good contribution to developing the foundation in the area of studying a tone system. According to Pike’s (ibid) typology of tone languages, tone language are divided into two groups, i.e., register tone languages (with no pitch variations over a TBU) and contour tone languages (with pitch variations over a TBU). It is discussed that Goldsmith’s (1990) theory of auto-segmentalism is very important in describing supra-segmental phenomenon like tone because in this framework tone has got a
separate tier due to which tone gets full attention. Tone levels in a tone language are also discussed based on tonal contrasts. Cantonese with six different pitches and Punu, a Miao Yao language, with eight distinctive tones are good examples with maximum tone levels. The transcription of tone is also discussed and in this regard it is discussed that Chao’s (1930) system is famous for its simplicity. Tone bearing units (TBUs) in a tone language are also discussed.

For the role of phonation in tonal contrasts, the common phonation types including breathy phonation, modal phonation, and creaky phonation are discussed. In this regard, Keating and Esposito’s (2006) description is very appealing when they state that there are degrees of creakiness and of breathiness in a language because the opening and closing of vocal cords takes place in the form of a continuum due to which a breathy voice in one language can be taken as a modal in another language. The role of vocal cords is also discussed because their role is of key importance in producing tone and phonation types in a language. Due to the same power source for tone and phonation, i.e., larynx, the interaction of tone and phonation becomes important which is also discussed with examples in the study. The study describes that in some language tone and phonation interact; whereas, in some other language they do not interact.

Acoustically we need some correlates by means of which we can analyze and describe tone and phonation systems in a language. For that, the acoustic correlates of tone and
phonation including fundamental frequency, duration, intensity, final velocity, H1, H2, H1-H2, H1*-H2*, CPP, H1-A1, H1-A2, H1-A3, and H2-H4 along with some studies where some of these have been used.

The Punjabi language has also been introduced in the study along with a brief description of its phonological system. The syllable system, the consonants, the vowels in the language, and the tone system in the language are discussed.

For conducting the experiment in the study, in order to analyze Punjabi tone system and to uncover the contribution of phonation in tonal contrasts in the language, ten Punjabi native speakers (five male and five female) were selected from Lahore having age from 28 to 45 years with an average of 34 years. The stimuli consisted of three Punjabi mono-syllabic words with each word along with its three versions based on the tonal contrasts making a total of nine Punjabi words following the same syllable template as ‘CV’, i.e., a voiceless consonant followed by a vowel /a/. All the words were written on three flash cards with three Punjabi tonal words on each card. The stimuli consisted of the following words: The Punjabi word [pa] with three different tones, i.e., low, mid, and high means ‘price’, ‘quarter’, and ‘put’ respectively. The Punjabi word [ka] with three different tones, i.e., low, mid, and high means ‘grass’, ‘possession’, and ‘a handful pile of reaped crop’ respectively. The Punjabi word [ʧa] with three different tones, i.e., low, mid, and high means ‘peep through’, ‘desire’, and ‘tea’ respectively. All the words were recorded for five times with the help of a good
quality WAV file recorder with a sampling rate of 44100 Hz and 16 bit amplitude resolution by all the speakers making a total corpus of 450 tokens. The data were analyzed with the help of software Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014).

Seven acoustic measures for tone and role of phonation in tone including F0, duration, intensity, final velocity, H1-H2, H1*-H2*, and CPP were measured for the three Punjabi tones. SPSS was used for the descriptive statistical analyses. A one way ANOVA test was applied followed by post hoc Bonferroni test in each case. The results of the statistical analyses were considered significant for p ≤ .05. Each of the above mentioned acoustic correlates was taken as a dependent variable and the three tones were taken as independent variables in the tests. The results of one way ANOVA and post hoc Bonferroni tests indicated that the three Punjabi tone types were not statistically significantly different from one another in terms of their F0, intensity, H1-H2, and H1*-H2*. Whereas, the results of one way ANOVA and post hoc Bonferroni tests clearly indicated that the three Punjabi tone types were statistically significantly different from one another in terms of their duration, final velocity, and CPP.

The literature reviewed in the study and the results of the study suggest that there are three tones in the language, namely low tone, mid tone, and high tone. The study further concludes that the three tones in the language are contour tones. The study also suggests that the Punjabi low tone has replaced the voiced aspirates which are still
present in other Indo-Aryan language, like in Urdu. The study concludes that the low tone in the language is the breathiest of the three tones and the mid tone is of modal phonation type, and the high tone in the language co-exists with the most tense phonation configuration of the three tone types. Therefore, the study concludes that the phonation types do have a role in contributing to the tonal contrasts in the language. The study also suggests that the tone bearing unit in the language is a stressed syllable in mono-syllabic and bi-syllabic words.

Summary of the Findings

This study explores the phenomena of tone and phonation in Punjabi, as it is spoken in Lahore, by means of acoustic and statistical analyses conducted with the help of software Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). The first research question dealt with in this research is: What is the nature of the tone types in Punjabi? On the basis of acoustic and statistical analyses, the study concludes that there are three tone types in the language, namely, low, mid, and high tones. These tones are contour in nature. The tone bearing unit in the language is a stressed syllable as duration as an acoustic correlate of tone shows statistical significance. The second research question dealt with in this research is: How many phonation configurations interact with tone in the language? The study concludes that tone and phonation co-exist in the language with statistical significance. The study finds that the low tone in the language is the breathiest of the three tones. The mid tone in the language co-exists with the modal phonation type. Whereas, the high tone in the
language co-exists with the tensest vocal cords. The third research question dealt with in this research is: Which acoustic correlates specific to phonation along with the acoustic correlates of tone can be used in investigating the tonal contrasts in Punjabi? In the study, the tones in the language are measured on certain phonation specific measures including H1-H2, H1*-H2*, and CPP. The study concludes that the measures of H1-H2, and H1*-H2* did not distinguish the three tones in the language with statistical significance, whereas, the measure of CPP (measure of noise and periodicity) distinguishes the three Punjabi tones with statistical significance.

**Some suggestions for future research**

In the end, there are some suggestions for future research to further unfold the phenomena of tone and phonation and their relation to each other in Punjabi. The suggestions are as under:

1. This study made use of the acoustic measures including F0, duration, intensity, final velocity, H1-H2, H1*-H2*, and CPP to investigate the nature of tone in Punjabi and to explore the role of phonation in tonal contrasts. Some other spectral measures like H1, H2, H1-A1, H1-A2, H1-A3, and H2-H4 etc may also be included in the list of acoustic correlates to further uncover and describe the phenomena of tone and phonation, and to explore the role of phonation in tonal contrasts in a language in a better way.

2. The phenomena of tone can be investigated by means of production as well as perception experiments. This study was based on the acoustic analyses of
production experiments. The findings of this study can be further supported by developing and including some perception experiments for investigating tonal and phonation contrasts in the language.
REFERENCES


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Appendix A

(The three cards with the three Punjabi tonal words on each card along with their meaning in Urdu in parenthesis)