Tone and its Acoustic Correlates in Punjabi

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Abstract

This study explores the phenomenon of tone and its acoustic correlates in Punjabi by means of acoustic and statistical investigation. Tone is considered to be a phonemic unit along with vowels and consonants in a tone language. The study is conducted in Lahore, the capital city of province Punjab of Pakistan. Ten speakers, including five male and five females, whose mother tongue is Punjabi were selected conveniently. The data comprised of three monosyllabic words of Punjabi with two tonal counterparts for each word; which means a total of nine Punjabi words were investigated. The words were written on flash cards along with their meaning and the speakers were asked to say each word for five times. The audio recordings of the words were made with the help of a good quality (WAV file) audio recorder. The recordings were made in a silent room. The data were analyzed with the help of Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014). SPSS was also used and one-way ANOVA test was applied. The three traditional acoustic correlates of tone including fundamental frequency (F0), duration, and intensity, along with another acoustic correlate named "final velocity" were measured in the study. The results of the study suggest that there are three tones in Punjabi, namely High, Mid, and Low tones with respect to the acoustic correlates duration and final velocity. Whereas, the acoustic correlates F0 and intensity do not distinguish the three tones in Punjabi with statistical significance.

1. Introduction

Pike (1948: p. 3) refers to a tone language as: "a language having lexically significant, contrastive, but relative pitch on each syllable". This relatively high or low value of pitch on different syllables of a word produces lexical contrast. In the same way as the minimal contrastive units of sound are referred to as phonemes, the minimal contrastive units in tonal analysis are called tonemes (Pike, 1948). That means in addition to having vowels and consonants tone languages have another phonemic unit which is called tone. A difference in pitch only makes semantic changes in identical words with respect to their vowels and consonants in these languages. Ladefoged (2001) emphasizes that these languages use pitch to signal difference in meaning between words. Clark, Yallop and Fletcher (2007: p. 331) refers to pitch as: "the perceived correlate of fundamental frequency". Some major East Asian languages such as Chinese, Vietnamese, Burmese and Thai along with a good number of languages of Africa, the Americas and the Papua Guinea are tonal languages (Clark, Yallop and Fletcher, 2007). English is not considered a tonal language because it does not differentiate words on the basis of tonal contrast. Baart (2003) presents Punjabi as a classic example of tone language which is mainly spoken in Pakistan and India. This study investigates the phenomenon of tone in Punjabi by means of its acoustic correlates including fundamental frequency (F0), duration, intensity and final velocity with the help of software including Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014).

1.1 Objectives

This study aims to:

1. Explore the nature of tone in Punjabi; and
2. Determine which acoustic correlates distinguish the three tones in Punjabi.

1.3 Research Questions

The study finds answers to the following questions:

3. What is the nature of Punjabi tones?
4. Which acoustic measures significantly distinguish the three tones in Punjabi?

1.3 Statement of the problem

Some research is found on the phenomenon of tone in Punjabi language but that is highly insufficient and lack systematic and acoustic analyses. So, this study helps in documenting a very important phonological feature of Punjabi, i.e., tone, by means of acoustic and statistical investigation with the help of some latest software including Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014).

2. Literature Review

2.1 Typology of Tone Languages

Pike (1948) divides tone languages into two categories: 'register tone languages' and 'contour tone languages. Pike (ibid: p. 8) defines a 'contour tone language' as: "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." That means in contour tone languages, as Pike (ibid) suggests, the pitch in the course of a tone bearing unit rises or falls, or there can be some combination of rise and fall, such as rise-fall or fall-rise. Punjabi and Mandarin (spoken in China) are considered as good examples of contour tone languages in which the tones, in the course of tone bearing unit, show pitch variation in the form of rise, fall, rise-fall, or fall-rise.

The second category, according to Pike (1948), is referred to as 'register tone languages' wherein the pitch in the course of a tone bearing unit does not get changed. The tones remain either high or low in these languages. Yoruba is considered a good example of register tone language. There are many other languages in West Africa also reported as register tone languages. In this category, the term 'register' is very important which is defined by Pike (ibid: p. 5) as: "when a language has a small, restricted, number of pitch contrasts between level tonemes, these contrastive levels are conveniently called registers." That means the pitch of a register toneme does not rise or fall in the course of a tone bearing unit in these languages.

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 2.1. Comparison between Contour and Register Tone Systems based on Pike (1948: p. 8)

	Contour tone system	Register tone system
Basic phonemic unit	Gliding	Level
Morphemes boundaries	Cannot be interrupted	Interrupted (non-phonemic compounded types)
Beginning and end points	Cannot be equated with level tonemes in the same system	All glides are to be interpreted phonemically in terms of their end points.
In the printed materials examined	Only one toneme per syllable	May have two or more tonemes per syllable (e.g., Mazateco)

Clark, Yallop and Fletcher (2007: p. 344) 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."

2.2 Tone Bearing Unit (TBU)

Tone bearing unit is a unit of tone languages which carries tone. Clark, Yallop and Fletcher (2007) suggest that this tone bearing unit is a syllable in contour tone languages and a word in register tone languages. Whereas, in autosegmental phonology a segment on the segmental tier which is linked with a tone is called tone bearing unit (TBU). One TBU is associated with one tone in register tone languages; whereas, in contour tone languages, one TBU is associated with more than one tone. Discussing the TBU in contour tone languages, Dutcher and Paster (2008: p. 123) state: "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."

2.3 Acoustic Correlates of Tone

Pickett (1999) suggests that the acoustic patterns of the prosodic features are found in the fundamental frequency (F0), duration, and intensity. Fundamental frequency (F0) is the rate of vibration of the vocal cords during speech. It is measured in Hertz (Hz). Duration is measured in millisecond (ms) and intensity is measured in dB. 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 (Gandour & Harshman, 1978). For example, Mandarin has four contrastive tones on the basis of difference in F0 (Howie, 1976):

Tone1	ma [High]	'mother'
Tone2	ma [Rising]	'hemp'
Tone3	ma [Low]	'horse'
Tone4	ma [Falling]	'scold'

"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).

In the same way as the change in pitch at the level of lexemes produces tone, a change in pitch at the level of sentences produces intonation. Fundamental frequency (F0) also gives information regarding intonation at the utterance level in a tone language (Yuan, 2004); whereas, in a non-tone language F0 gives information regarding intonation only (Lehiste, 1970).

2.4 Analysis of Tone

Analysis of tone is complicated because there are many factors involved which can affect pitch of a particular toneme. Pike (1948) highlights two features: "(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." (p. 164)

One of the key factors that affect pitch is considered to be 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. 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."

2.5 The Punjabi Language

Punjabi belongs to the Indo-Aryan family of languages. It is "spoken by about 130 million mainly in West Punjab in Pakistan and in East Punjab in India. There are also significant numbers of Punjabi speakers in the UK, Candada, the UAE, the USA, Saudi Arabia, and Australia" (Punjabi, 2014). In Pakistan, it 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. It is spoken in many dialects. Some of the major dialects include: Majhi, Pothohari, Lehandi, Multani, Doabi, Malwai and Puwadhi. Majhi dialect, which is investigated in this study, is spoken in Lahore and its adjacent cities.

Phonetically and phonologically, all the speech sounds in Punjabi are produced with the help of pulmonic egressive airstream mechanism (Bhatia, 1993). Bhatia (ibid) further discusses the sound system of Punjabi language and comments on the syllable template in Punjabi as: "The canonical syllable type is (C) (C) V (V) (C) (C), where V is one of the vowels, /a/, /e/ and /o/." (p. 342)

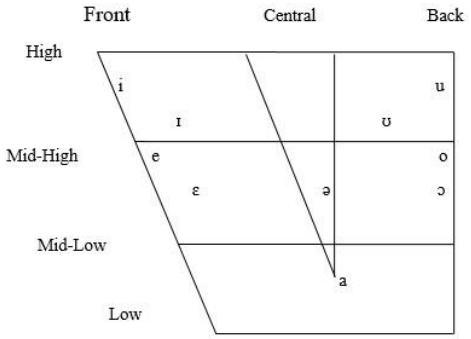
There are 32 consonants in Punjabi (spoken in Lahore) as Karamat (2002) finds in her study exploring the phonemic inventory of Punjabi. There are five voiceless plosives (four stops and an affricate), i.e., /p, t̪, t, ʧ, k/. There are five aspirated versions of voiceless plosives, i.e., /pʰ, t̪ʰ, tʰ,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

Table 2.2.Consonants of Punjabi based on Karamat (2002 : p. 182)

	Bilabial	**Labiodental**	**Dental**	**Alveolar**	**Retroflex**	**Palatal**	**Velar**	**Glottal**
Plosive	p		t̪		t	ʧ	k	
	pʰ		t̪ʰ		tʰ	ʧʰ	kʰ	
	b		d̪		d	ʤ	g	
Nasal	m			n	ɳ		ŋ	
Fricative		f		s		ʃ	x	h
		v		z			ɣ	
Trill				r				
Flap					ɾ			
Approximant				l	ɭ	j		

There are ten vowels in Punjabi (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 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, ə, 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) and all the oral vowels in Punjabi have their nasal counterparts as well (Gill and Gleason, 1969 as cited in Zahid, 2012: p. 32) The Punjabi vowel quadrilateral is as under:

Figure 2.1 Vowels of Punjabi based on Karamat (2002: p. 182)



2.6 Punjabi Tone

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 (ibid) gives the following example of Punjabi as a tone language:

‘horse’ (rising)	‘leper’ (falling)	‘whip’ (level)
koo:ɽa:	kooɽa:	koo:ɽa:
L H	H L	H

“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’” (Bailey 1915: ix, as cited in Baart, 2003: p. 2).

Karamat (2002) also finds that Punjabi has three tones namely High tone, Mid tone, and Low tone. 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. Bhatia (1993) claims that Punjabi is the only Indo-Aryan language which has developed tone, and 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 asserts that “Punjabi does not have contour tones as does Chinese”, and gives the following examples of Punjabi tonal contrast:

Table 2.3. Punjabi Tonal Contrast based on Bhatia (1993: p. 343)

Low		Mid		High	
koRaa	(horse)	koRaa	(whip)	koRaa	(leper)
malaa	(lady)	malaa	(mix)	malaa	(boat man)
kaR	(chisel)	kaR	(bottom)	kaR	(boil)

The historical development of a tone language is known as tonogenesis. Hombert, Ohala and Ewan (1979) propose that the "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" (p. 38). Probably, that is how Punjabi has undergone the process of tonogenesis with the passage of time. Discussing and comparing Urdu language with Pahari (spoken in Azad Jammu & Kashmir, Pakistan) and Punjabi, 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." Similar is the case with Punjabi, i.e., voiced aspirates in Urdu are realized as tonal words in Punjabi. Khan (ibid) gives the following table which shows the correspondences of voiced aspirated consonants in Urdu as used in Pahari and Punjabi:

Table 2.4. Voiced aspirates in Urdu, Pahari, and Punjabi based on Khan (2013: p. 9)

Urdu	Pahari	Punjabi
bʰul 'forget'	pɦʊl [pʊ̀l] 'forget'	pɦʊl [pʊ̀l] 'forget'
gʰoɽa 'horse'	kɦo:ɽa: [kʊ̀:ɽa:] 'horse'	kɦoɽa [kʊ̀ɽa] 'horse'
dʰol 'dust'	ʧɦu:l [ʧʊ̀:l] 'dust'	ʧɦu:l [ʧʊ̀:l] 'dust'

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) finds that glottal fricative [h] is pronounced only word-initially in Punjabi and at other positions, i.e., in middle and end of the word it is manifested as a H or L tone. Clark, Yallop and Fletcher (2007: p. 345) state that "tone has arisen where pitch differences, originally conditioned by consonants, have become distinctive when the consonants have been changed or lost." Talking about the development of Punjabi as a tone language, it is said that "a relation was noted between the loss of voiced aspirates ([bh], [dh], etc.) and the emergence of tone in Punjabi" (Masica 1991: pp. 118-9, as cited in Baart 2003: p. 2). The /h/ phoneme is considered to play an important part in describing the phenomenon of tone in Punjabi.

3. Methods and Materials

3.1 Participants

In this study, ten Punjabi speakers were selected randomly from Lahore, the capital of province Punjab of Pakistan. There were 5 male and 5 female speakers of age-range 27 to 36 years. 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 would use mainly Punjabi in their routine life.

3.2 Stimuli

In the study, the stimuli were chosen carefully. There has been some research on the tone contrasts mainly on the bi-syllabic words of Punjabi (e.g. Bhatia, 1993; Baart, 2003; Karamat, 2002; and Rafi, 2010), but not much research is found in literature on the tonal contrasts on the mono-syllabic words of Punjabi. Therefore, special care was taken in choosing the words with tonal contrasts.

All the words in the study were mono-syllabic and voiceless. Only the voiceless words were taken so that the voicing of the voiced words do not cause any difficulty in measuring the related acoustic measures of tone. All the words were selected having the syllable template as 'CV', i.e., a voiceless consonant followed by a vowel. Following the voiceless consonant part, all the words contained /a/ vowel so that all the tones were investigated in the same context.

A list of Punjabi words was prepared with the above-mentioned specifications. The words were written on flash cards in Urdu alphabets. The three words having tonal contrast were written on the same card. So, three cards were made with three contrastive words on each card. Based on the tonal contrast, the words made three sets with three words in each set representing three tones in Punjabi. 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

Low Tone	Mid Tone	High Tone
[pa] (price)	[pa] (quarter)	[pa] (path)
[ka] (grass)	[ka] (possession)	[ka] (a handful pile of reaped crop)
[ʧa] (peep through)	[ʧa] (desire, affection)	[ʧa] (tea)

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. The participants were asked to read the words from the cards. They were asked to shuffle the words and say every word five times. They were allowed to follow their own speed of reading the words. The recording was done in a silent room. A good quality voice recorder was used for recording the data with a sampling rate of 44100 Hz and 16-bit accuracy. Praat (Boersma and Weenink, 2014) and ProsodyPro (Xu, 2014) software were used for analyzing the 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 (tokens for analysis). All the tokens were named referring to the specific speakers with their name initials and the specific tonal contrast. The words in the first column of the table (3.1.) above were

labeled as number 1, the words in the second column (Mid Tone) were labeled as number 2, and the words in the third column (High Tone) were labeled as number 3.

3.4 Analysis of Data

The traditional acoustic correlates of tone, i.e., F0, duration and intensity, along with another acoustic correlate, i.e., final velocity (Xu, 2013) were measured. 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).

4. Results and Discussion

4.1 Statistical Analysis of Fundamental Frequency (F0)

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:

Table 4.1. Difference in means of the F0s of the Punjabi tones

Descriptives

F0

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimu-m	Maximu-m
					Lower Bound	Upper Bound		
Low Tone	10	148.9863	42.04288	13.29513	118.9106	179.0619	96.43	202.72
Mid Tone	10	151.0293	39.92119	12.62419	122.4714	179.5872	99.97	205.60
High Tone	10	161.5143	43.73072	13.82887	130.2312	192.7974	105.23	231.89
Total	30	153.8433	40.83891	7.45613	138.5938	169.0928	96.43	231.89

Figure 4.1. Graphical representation of the three Punjabi tones with respect to their mean F0s

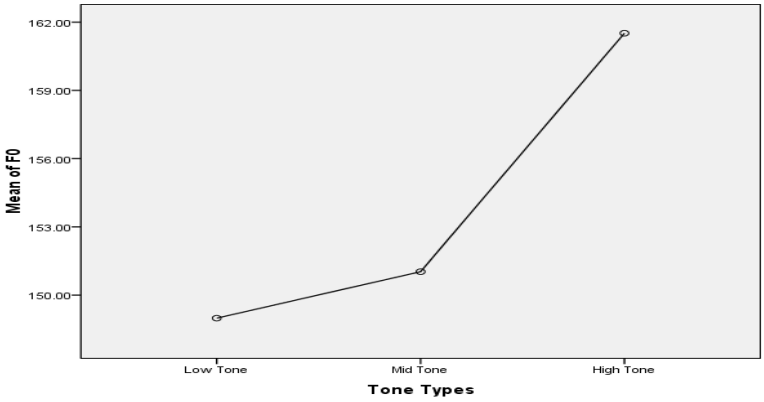


Table 4.2. One-way ANOVA for the F0s of Punjabi tones

ANOVA

F0

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	903.539	2	451.769	.257	.775
Within Groups	47463.138	27	1757.894		
Total	48366.677	29			

$p > 0.05$

The one-way ANOVA test shows significance value of $p = 0.775$ with [$F (2, 27) = 0.257$, $p > 0.05$] which means that the three tone types in the language are not statistically significantly different from one another in terms of their fundamental frequency.

4.2 Statistical Analysis of Duration

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. 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. The findings of the tests are as under:

Table 4.3. Difference in means of the duration of Punjabi tones

Descriptives

Duration

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

Figure 4.2. Graphical representation of the three Punjabi tones with respect to their mean duration

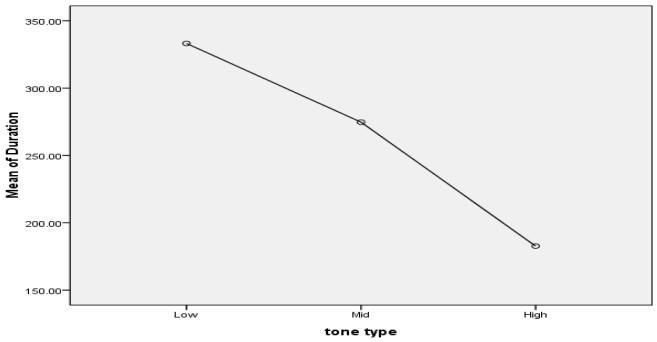


Table 4.4. One-way ANOVA for the duration of Punjabi tones

ANOVA

Duration

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	115125.901	2	57562.950	23.375	.000
Within Groups	66488.976	27	2462.555		
Total	181614.877	29			

$p < 0.05$

The one-way ANOVA test shows significance value of $p = 0.000$ with [$F(2, 27) = 23.37$, $p < 0.05$] which means that the three tone types in the language are statistically significantly different from one another in terms of their duration.

4.3 Statistical Analysis of Intensity

In the study, in order to investigate the role of intensity in Punjabi tonal contrasts, intensity 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. 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.

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

Descriptives

Intensity

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Low	10	69.1118	4.80473	1.51939	65.6747	72.5489	61.88	76.45
Mid	10	68.7683	5.01284	1.58520	65.1823	72.3542	58.83	75.84
High	10	71.3156	4.53494	1.43407	68.0715	74.5597	63.70	76.78
Total	30	69.7319	4.76057	.86916	67.9542	71.5095	58.83	76.78

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

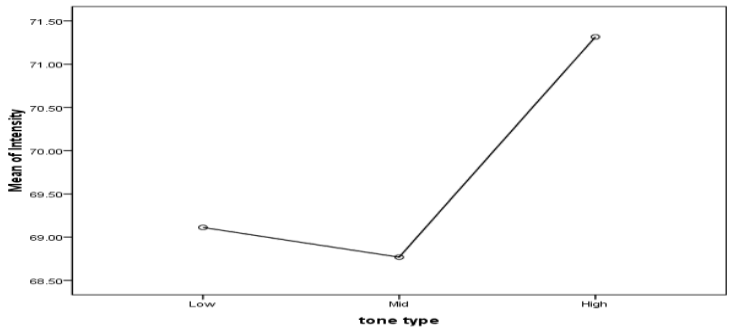


Table 4.6. One-way ANOVA for the intensity of Punjabi tones

ANOVA

Intensity

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	38.211	2	19.106	.833	.445
Within Groups	619.017	27	22.927		
Total	657.228	29			

$p > 0.05$

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.

4.4 Statistical Analysis of Final Velocity

In the 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. 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.

Table 4.7. Difference in means of the final velocity of Punjabi tones

Descriptives

Final Velocity

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Low	10	22.0181	14.98594	4.73897	11.2978	32.7384	3.70	47.03
Mid	10	15.0608	12.25890	3.87661	6.2913	23.8303	-1.51	32.70
High	10	-15.0188	7.83625	2.47804	-20.6245	-9.4131	-27.75	-4.28
Total	30	7.3534	20.06552	3.66345	-.1392	14.8459	-27.75	47.03

Figure 4.4. Graphical representation of the three Punjabi tones with respect to their final velocity

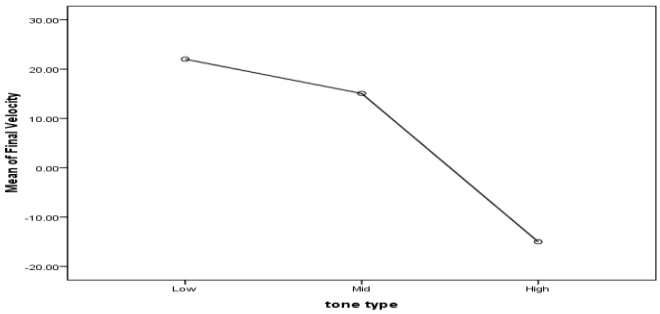


Table 4.8. One-way ANOVA for the final velocity of Punjabi tones

ANOVA

Final Velocity

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7749.736	2	3874.868	26.646	.000
Within Groups	3926.392	27	145.422		
Total	11676.128	29			

$p < 0.05$

The one-way ANOVA test shows significance value of $p = 0.000$ with [$F(2, 27) = 26.65$, $p < 0.05$] which means that the three tone types in the language are statistically significantly different from one another in terms of their final velocity.

5. Conclusion

The acoustic and statistical investigation in the study suggest that there are three contrastive tones in Punjabi, namely, High, Mid and Low tones. Furthermore, it highlights that the tones in the language are contour in nature, i.e., they are falling or rising, not level. Four acoustic correlates including F0, duration, intensity, and final velocity were measured in order to explore the phenomenon of tone in the language. The measure F0 did not distinguish the three Punjabi tones with statistical significance. Anyhow, the measure of final velocity distinguished the three tones in the language with statistical significance. 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 measure of duration also distinguished the three tones in Punjabi with statistical significance, i.e., the low tone in the language takes the longest time duration, the mid tone takes the intermediate time duration, and the high tone in the language takes the shortest time duration. Anyhow, the measure of intensity did not distinguish the three tones with statistical significance.

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