`

PRONUNCIATION LEXICON SPECIFICATION FOR PUNJABI LANGUAGE WITHIN W3C FRAMEWORK

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ਮੈਂ ਚਾਹੁੰਦਾ ਹਾਂ ਮੇਰੀ ਆਵਾਜ਼

ਹਵਾ ਬਣ ਕੇ ਹਰ ਥਾਂ ਘੁੰਮੇ

ਵਣਾਂ ਚੋਂ ਸਰਸਰਾਦੀ ਲੰਘੇ

ਜਾਂ ਪਾਣੀ ਬਣਕੇ

ਵਹਿੰਦੀ ਨਦੀ ਦਾ ਰੂਪ ਧਾਰਨ ਕਰੇ

ਇਹ ਪਹਾੜਾਂ ਤੇ ਚੜ੍ਹ ਕੇ

ਆਪਣੇ ਆਪ ਨੂੰ ਆਵਾਜ਼ ਦੇਵੇ । ... ਹੰਸ ਰਾਹੀ

Dedicated to my Parents

Sh. Hans Rahi & Smt. Raj Rani

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Contents

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CHAPTER 6: CORRELATION OF MORPHO-SYNTACTIC FEATURES WITH LEXICAL REPRESENTATION AND ITS CO-ARTICULATION **197-208**

CHAPTER 7: PROSODIC LEXICAL XML DATABASE-PLS FRAMEWORK, RULES AND SAMPLE DATA **209-252**

`

`

`

LIST OF FIGURES

`

Fig 3/7: Female Sample (ਝੱਗ /tʃə̀g/) - HL

Fig 3/8: Male Sample (ਢੱਕਣ /ʈə̀kkəɳ/) - HL

Fig 3/9: Female Sample (ਢੱਕਣ /ʈə̀kkəɳ/) - HL

Fig 3/10: Male Sample (ਗੰਧਲਾ /gə̃də́la/) - LH

Fig 3/11: Female Sample (ਗੰਧਲਾ /gə̃də́la/) - LH

Fig 3/12: Male Sample (ਸਧਾਰਨ /sədàrən/) - HL

Fig 3/13: Female Sample (ਸਧਾਰਨ /sədàrən/) - HL

Fig 3/14: Male Sample (ਨਾਭੀ /nábi/) - LH

Fig 3/15: Female Sample (ਨਾਭੀ /nábi/) - LH

Fig 3/16: Male Sample (ਗੰਭੀਰ /gə̃bìr/) - HL

Fig 3/17: Female Sample (ਗੰਭੀਰ /gə̃bìr/) - HL

Fig 3/18: Male Sample (ਝੁਨਝਨਾ /tʃʊ̀ntʃə̀na/) - HL

Fig 3/19: Female Sample (ਝੁਨਝਨਾ /tʃʊ̀ntʃə̀na/) - HL

Fig 3/20: Male Sample (ਚਾਹ /tʃâ/) - LHL

Fig 3/21: Female Sample (ਚਾਹ /tʃá/) - LH

Fig 3/22: Male Sample (ਢਾਹ /ʈǎ/) - HLH

Fig 3/23: Female Sample (ਢਾਹ /ʈǎ/) - HLH

Fig 3/24: Male Sample (ਵਿਦਰੋਹ /vɪdərô/) - LHL

Fig 3/25: Female Sample (ਵਿਦਰੋਹ /vɪdəró/) - LH

Fig 3/26: Male Sample (ਖਮੁਣੀ /kʰəmə́ɳi/) - LH

Fig 3/27: Female Sample (ਖਮੁਣੀ /kʰəmə́ɳi/) - LH

`

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LIST OF TABLES

`

`

`

`

ABBREVIATIONS

ASR – Automatic Speech Recognition

B- Broken Tone

BE - Burst Energy

C – Consonant

CC – Consonant Cluster

CI - Confidence Interval

Co - Coda

D – Duration

F_0 - Fundamental Frequency

F - Formants

H- High / Heavy

HL- Falling Tone

HLH – Falling-Rising Tone

I - Intensity

L- Low / Light

LH- Rising Tone

LHL – Rising – Falling Tone

M – Mid

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N – Nucleus

NT – Non-tonal

O - Onset

P – Pitch

P_r - Probability

PLS – Pronunciation Lexicon Specification

POS - Parts of Speech

R – Rhyme / Rime

SH – Super Heavy

S/s – Syllable

s_t - Empirical Stress Function

$\overline{s}_t$ – Mean of Intra-syllabic Stress

SOV – Subject Object Verb

TBU - Tone Bearing Unit (vowel)

V - Vowels (Monothongs)

V_1 - Short Vowels

V_2 - Long Vowels

V_d - Vowels (Dipthongs)

μ – Mean of Data

σ - Standard Deviation

Φ - Cumulative Distribution Function

ABSTRACT

Punjabi is a modern Indo-Aryan (Indic) language spoken primarily in the Punjab states of both India and Pakistan. Punjabi uses either Gurmukhi script (written from left to right), a Brahmi-derived script or Shahmukhi script (written from right to left), a Perso-Arabic script. The phonology discussed herein relates to Gurmukhi script as it is used by speakers in Punjab and also majority speakers across the globe. The characters in the script are normally aligned below the line of grapheme. Punjabi has concatenative morphology i.e. many words can be created using a root word and adding various morphemes. Punjabi and Dogri are the prominent tonal languages in this family. Lexical tone in Punjabi is utilized to distinguish words. The vowel is the tone bearing unit in Punjabi. A word has a single tone, which may co-occur with stress on the syllable.

The lexicon is the bridge between a language and the knowledge expressed in that language. The lexicon in any system plays an important, dynamic and necessary part in the syntactic and semantic fields. Monolingual (Punjabi) and bilingual (English & Punjabi) dictionaries are available in printed as well as e-form containing information such as meaning, pronunciation etc. A Pronunciation Lexicon for machine learning is required for development of speech systems. W3C (World Wide Web Consortium) has defined Pronunciation Lexicon Specification (PLS) - version 1.0 (2008) which covers the multiple Pronunciation and multiple orthography in the XML structure at the lexicon level thus providing the flexibility of creating language specific PLS documents. The current version of PLS 1.0 is a broad based base line specification which covers the requirements of Latin script based languages and can be used for all global languages. The specification document also cites few examples for Japanese and Chinese. The requirements of many other global languages such as Indian languages haven't been discussed in this document.

The grammatical information is relatively encoded in its morphology than syntax in Indian languages unlike English where the grammatical information is an integral part of the syntax. Hence there is a need to augment PLS structure to broadly cater to Indo-Aryan languages.

The main objective of the thesis is to evolve a Pronunciation Lexicon Specification for Punjabi Language within W3C Framework. This Framework is expected to capture the phonological features of the Punjabi language and provide phonetic evidence for them through the experimental study of recorded speech signals of the Malwai dialect of the language. The phonetic experiments involve collection of data, recording, data segregation, annotation and analysis. The data have been sourced from published Punjabi Dictionaries. The phonetically rich and frequently occurring words of Punjabi were collected for phonological analysis covering all phonemes, tonemes, consonant /h/ and conjuncts of /ɦ/ and schwa vowel of Punjabi. Monosyllabic/ disyllabic/ trisyllabic/ polysyllabic words containing various combinations of light, heavy & super heavy syllables were selected for study of lexical stress. Ten informants (4 male and 6 female) between 25-40 age group belonging to the rural, town and city background were identified. Total of 4000 words were recorded for 10 speakers and 50 sentences across 8 speakers for prosodic study. Data was recorded in the laboratory through good quality audio recording devices in standard speech and noise free environment having SNR>=45db as per standardized procedure for speech corpora development based on the ITU recommendations. The speech tools such as Praat, Gold Wave etc have been used for speech analysis. Other parameters such as frequency formants, duration and intensity of syllables in a word were also recorded for prosody analysis.

The discussion on tone has been covered under two categories of tone i.e. Independent Tone and Tone arising from Supra-laryngeal Consonants. For this words with each of five tonemes in initial, medial and final syllable of the word have been compiled ensuring the phonetic coverage in terms of various vowels, dipthongs, nasalization, gemination and other co-articulation parameters such as occurrence of Toneme as onset/ coda in above contexts across monosyllabic, disyllabic, trisyllabic and polysyllabic words.

For Independent tones, the words containing consonant /h/ in initial, medial and final syllable of the word were considered to examine these characteristics. Half /h/ does not occur in the initial syllable hence words containing conjuncts of /ɦ / in medial and final syllable were considered. The spectrographic analysis using PRAAT of all the male & female samples was carried out. The duration, fundamental frequency (F_0), quarter wise slope of the vowel associated with the Tone Bearing Vowel (TBU) have been recorded. The tabulation of data has been done for three categories of words i.e. tonemes, consonant /h/ & conjuncts of /ɦ/ capturing the variety of acoustic environments. The objective of experimental work carried out was to corroborate the tone rules of Punjabi as collated through the literature survey. These rules have been experimentally verified and are applicable by and large. The detailed analysis has been presented in the thesis based on experimental observations which lead to discovery of allotones and findings on tone variations due to various co-articulatory factors.

Stress is not a prominent feature of Punjabi, as in other Indic languages, however it is utilized in di-syllabic words to distinguish between grammatical categories. The text-to-speech technology uses concatenative approach which results in artificial production of speech and lacks prosody. The research on intra-syllabic stress at the lexical level can help bridge this gap. The empirical study has been used for this purpose. To start with, non-tonal words were taken as basis for determining the inter-relationship between syllables in a word to report the heaviest syllable which is the carrier of stress and can be utilized by TTS system for natural production of speech. The acoustic parameter of syllabic weight has been modeled using Linear Regression for relational analysis. The duration, Pitch and Intensity of both the syllable in a word averaged across 10 speakers for 95 words was tabulated in a spreadsheet and was plotted using Curve Expert Professional. This is a cross-platform solution for curve fitting and data analysis. The linear equations of all the three acoustic parameters i.e. Intensity (I), Pitch (P), Duration (D) which influence the lexical stress were obtained using Piece-wise curve fitting technique. The normal distribution curves for all the three acoustic parameters were plotted using Standard Deviation and mean of the data averaged over two syllables.

Analyzing the above functions driven from the stress patterns of the recorded samples, the corresponding weightage factors of the acoustic parameters viz I, P & D have been calculated. The different categories of data i.e. Di / Tri / Poly-syllabic non-tonal words, Di / Tri / Poly-syllabic tonal words were analyzed to find out the probability of occurrence of a score by standardizing the scores, known as z scores. Using this value of z-score, a value will be obtained from Z table, which gives the probability of the score. The lexical stress pattern for the given range of the data is obtained using 80-20 rule. The stress rules have been evolved based on minimum 80% probability of occurrence of that rule in the given data being analyzed using above defined heuristic approach. Based on this experimental study, the rules have been proposed for marking lexical stress in PLS for different categories of words.

Schwa is an important part of the vowel space but is considered as a weak vowel as compared to other vowels. The Schwa has been the subject of much research by phonologists yet substantially less consideration has been dedicated to the study of the phonetic attributes of Schwa vowel. In Punjabi, Schwa is a short neutral vowel, which sounds like every single other vowel, however its exact quality changes depending upon the adjacent consonants. The words containing Schwa in different positions and occurrence of these words in sentences has been considered in various phonetic contexts i.e. Word-initial Schwa or inherent Schwa in a Consonant Cluster (CC) and also Schwa as a tone bearing unit, Schwa with Nasalization, Schwa associated with geminated consonant as onset, Schwa as Release Vowel. The work has also been carried out for observing quality of Release Vowel in a sentence viz-a-viz isolated word in same acoustic context. The different parameters i.e. Fundamental frequency (F_0), Formants F1, F2, acoustic space in terms of F1 and F2, Intensity, Duration, Slope of F_0 contour over TBU and Burst Energy (BE) have been used to study the variations in the quality of schwa in these contexts. These variations have been discussed in terms of Vowel height and Vowel front-ness / back-ness. POS is an available source for feature extraction for building NLP & speech systems as Punjabi are a highly inflectional language. There is a need to develop prosodic PLS based on morphological and overriding phonological features such as stress, tone, germination, nasalization etc.

The complete phonological coverage of PLS data needs to be ensured by incorporating words that contain maximum inflection under each POS category. This can be a useful resource for training of speech systems. The thesis discusses the prosodic features of Punjabi with the help of examples along with IPA transcription and POS information. The various POS inflections in Punjabi such as prefix/Suffixes with change in grammatical categories have been presented. The distinctive features of morphology-phonology interface of Punjabi language will be discussed in this thesis such as Tone, Nasalization, Gemination, Word variants in Homonyms, Homographs, Homophones, borrowed words, Abbreviations etc.

The Framework for Pronunciation Lexicon Specification for Punjabi Language (PLS 2.0) with addition of new element tags and attributes has been proposed. The thesis represents the sample PLS data in XML conformance with PLS 2.0 framework of different POS categories such as Noun, Pronoun, Adjective, Adverb, Demonstrative words, Verb, Postposition, Conjunction, Homographs and Multi-Word Expressions such as echo words, duplicates etc.

The phonological research findings of the present study can be leveraged to implement a computational Phonology model for Punjabi language. This can also be utilized to build large word level speech corpus containing prosodic information, syntax and semantics that can be used for development of Punjabi Text-to-speech (TTS) Systems, Language Identification Systems, and Speech Recognition Systems. The foundational work done for Punjabi prosody in this thesis can provide a strong basis for future research in areas such as co-articulation modelling of Punjabi, prosodic features based modelling techniques for language recognition and the extension of work to other Indo-Aryan languages.

Chapter 1

Introduction

1.1 Research Problem

The Pronunciation Lexicon Specification (PLS 1.0) has been designed by World Wide Web Consortium (W3C) with a goal to have inter-operable specifications of pronunciation information which can be used for speech technology development. This specification provides the possibility of providing multiple pronunciations for the same orthography as well as multiple orthographies against an entry of single pronunciation in the PLS. Lexical phonology assumes that all word formation, including inflection, is carried out in the lexicon as discussed Clements & Keyser (1983). As the morphology and part of phonology are carried out in the lexicon, the nature of syllable needs to define in terms of nature of nucleus, as nucleus is considered to be a prosodic category. It also defines type of onset and coda and such definitions are language dependent. These features are not discussed in the current PLS 1.0 specification. Among Indo-Aryan languages, tonal feature of Punjabi makes it more complex. The major hurdle in creating PLS for Punjabi is to capture the pronunciation as properly understood by a native speaker. Thus the new elements need to be identified for making PLS morphologically and phonologically richer.

The theory of Generative Phonology Chomsky & Halle (1968), is concerned with generation of rules that apply to the phonemic level of representation to yield the phonetic level of representation. It treats the phoneme as a bundle of features. The generative phonological approach gives equal importance to theoretical concepts and principles and the facts of data analysis.

The primary concern of Generative Phonology is the development of the rules that deal with the pronounceability of the strings ‘generated’ by the syntactic component of the grammar.

The generative approach to phonological analysis begins by stating the syntactic structure, passes this on to phonology, which can use futher any relevant syntactic facts. According to this theory, words are fully syllabified at the level of lexical representation which constitutes inputs in to the phonological components. Thus the postulation of syllabic structure in the lexicon makes it possible to achieve significant simplification of phonological component.

The proposed research focus is to derive Punjabi phonological rules for applying these on lexicon element of PLS 1.0 and its XML codification. This organizing principle is expressed by placing all lexical phonological rules in the lexicon. Therefore PLS for Punjabi language within the W3C framework will be proposed which will be useful for the development of prosodic Punjabi TTS.

1.2 Objectives of the Thesis

Consistent specification of word pronunciation is critical to the success of many speech technology applications. Several guidelines have been reported to define the structure of a pronunciation lexicon, ranging from simple two-column ASCII lexicons. This gap has been bridged by the W3C PLS 1.0 Specifications which have been brought out as a broad specification for generation of pronunciation data in XML format for machine learning. This specification needs to be examined for its applicability for morphologically & phonetically richer Indian languages. The main objectives of the proposed research are as follows:

i. Adaptation of the W3C PLS 1.0 for evolving a framework capturing Punjabi language phonological features.

ii. Corroboration of the major linguistic aspects through analytical study of recorded speech signals for Punjabi Language.

iii. Identification of the challenges for designing of web based Machine-Readable Pronunciation Lexicon Specification in XML.

iv. Design of new lexeme elements and attributes to incorporate the identified features.

1.3 Lexical Phonology

Phonology deals with the abstract mental representation of sound rather than properties of the physical speech signal whereas morphology is concerned with the principles that regulate word structure in a language and how that structure relates to other components (e.g. syntax, phonology). The morphological structure of a complex word determines how the constituent morphemes of a word are realized phonetically. The phonological structure of a complex word reflects its morphological structure, but is not isomorphic to that structure. Thus morphological and phonological processes are tightly interrelated in speech production. During processing, morphological processes must combine the phonological content of individual morphemes to produce a phonological representation. Further, morpheme assembly frequently causes changes in a word's phonological well-formedness that must be addressed by phonology, hence morphology & phonology are closely interrelated. Phonological structure of a language covers the inventories of phonological units (in common terms, inventories of vowels, consonants, syllables and tones , prosodic organization (in common terms, the organization of speech forms from lower to higher levels i.e. segments→ syllables→ words→ phonological phrases→ intonational phrases) and relation of phonology with syntactic, semantic and pragmatic structures Pandey (2007).

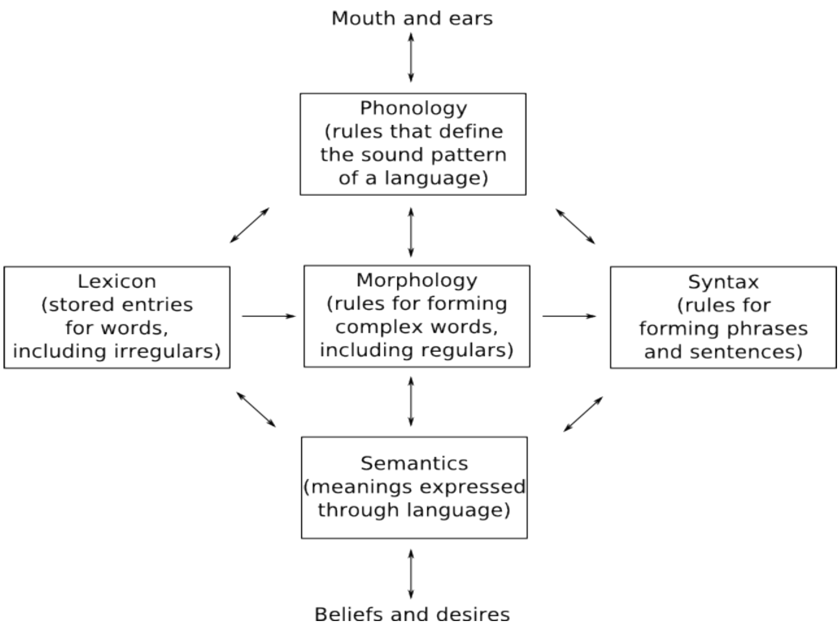


Fig 1/1: Morphology-Phonology Interface

According to the lexicalist hypothesis as proposed by Chomsky (1970), all word formation, including inflection takes place in the lexicon. The theory of lexical phonology seeks to explain the inter-relationships between morphology and phonology by allocating some of the phonological processes to the dictionary or lexicon in which the morphemes reside. The domains of both morphological and phonological rules within the lexicon are subdivided into strata which define both the type of morphological processes applicable and the mode of operation of the associated phonological rules as defined in the form of structured framework.

The phonological studies on Indian languages have been carried out in varied theoretical approaches. Majorly the framework of American structural linguistics has been used for this purpose. Such full length phonological studies can be seen in Kelkar (1968) which is based on a conception of language in which phonology manifests syntactic, semantic and pragmatic aspects of the linguistic knowledge of a sentence. Absolute phonological studies of Indian languages usually don't exhaustively cover all aspects of phonological structure. These generally follow the usual divide between segmental and suprasegmental phenomenon. There is a general lack of good quality descriptions of the phonologies of Indian languages.

Tones in Indian languages have received stray treatments Haudricourt (1971) & Burling (1992). The Punjabi language studies by Gill & Gleason (1969), Dulai & Koul (1980), Gill & H.S (1986), Singh (2001) , Singh (1991) , Arun & Bhaskar (1997), Bhatia (1993) etc cover a majority of the Linguistics rules in Punjabi language. Punjabi is highly tonal Haudricourt (1971) and the tones arise as a reinterpretation of different consonant series in terms of pitch. The phonological studies on Punjabi need to be further investigated.

1.4 Orthography of Punjabi

Punjabi is a modern Indo-Aryan language spoken primarily in the Punjab states of both India and Pakistan.

It is one of the Indic (Indo-Aryan) languages which gets distinguished from other languages of this family (other than Dogri) as it has developed tonal contrasts.

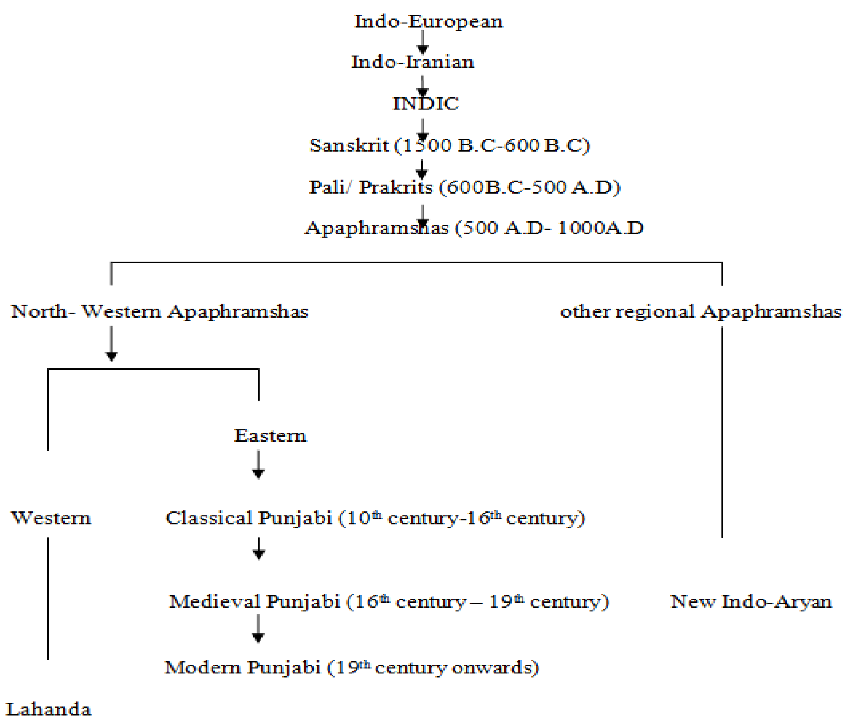


Fig 1/2: Family tree of Indo-Aryan Languages

A language usually refers to the spoken language, a method of communication. A script refers to a set of characters used to write one or more languages. Brahmi script is the oldest known writing system of Ancient India evolved in the beginning of the 4th century BCE. Brahmi inscriptions are found on edicts of Ashoka in north-central India. Indic scripts are descendants of Brahmi script and are abugida. These use a system of diacritic marks to associate vowels with consonant symbols. Indic scripts are typified by Devanagari and have two important characteristics: conjuncts and an orthographic syllabic structure. Each Indic based orthography has a set of common conjuncts that are used, along with a possible further set of rarely used conjuncts. Conjuncts / ligatures representing consonant sequences for Gurmukhi are given in the following example:

ਸ੍ + ਵ + ਰ = ਸ੍ਵਰ

Punjabi uses either Gurmukhi script (written from left to right) or Shahmukhi (written from right to left) script, a Perso-arabic script. The phonology discussed herein refers to Gurmukhi script as it is used by majority speakers across the globe. According to 2011 census of India, there are 27,704.236 Punjabi speakers in India; globally there are 120 million people who speak Punjabi. Punjabi is a tonal Language. The characters are normally aligned below the line of writing. Punjabi has concatenative morphology i.e. many words can be created using a root word and adding various morphemes. Punjabi language leans very heavily on the use of suffixes whereas use of prefixes is lesser. Word order is Subject Object Verb (SOV) and is fairly fixed.

Gurmukhi has thirty five /pɛ̃ti/ alphabets as per old orthography. Vowels other than /ə/ are indicated by accessory symbols (Vowel Matras) written around the consonant symbols. [ੳ] U+0A73 & [ੲ] U+0A72 are vowel bearers and are not used as independent vowels.

The characters as per Unicode 11.0 are listed in the following table.

S. No.	Characters	Characters with Code-Point
1	Vowels (referred as primary vowel) Vowel Matras (referred as secondary symbols of the vowel)	ਅ=U+0A05, ਆ=U+0A06, ਇ=U+0A07, ਈ=U+0A08, ਉ=U+0A09, ਊ=U+0A0A, ਏ=U+0A0F, ਐ=U+0A10, ਓ=U+0A13, ਔ=U+0A14 ◌ਾ=U+0A3E,ਿ◌=U+0A3F,◌ੀ=U+0A40,◌ੁ=U+0A41,◌ੂ=U+0A42, ◌ੇ=U+0A47, ◌ੈ=U+0A48,◌ੋ=U+0A4B,◌ੌ=U+0A4C
2	Consonants Tonemes	ਸ= U+0A38, ਸ਼=U+0A36, ਹ= U+0A39 , ਕ= U+0A15 , ਖ= U+0A16, ਖ਼=U+0A59, ਗ= U+0A17, ਗ਼=U+0A5A, ਙ= U+0A19, ਚ= U+0A1A, ਛ= U+0A1B, ਜ= U+0A1C, ਜ਼=U+0A5B, ਞ= U+0A1E , ਟ= U+0A1F, ਠ= U+0A20, ਡ= U+0A21, ਣ= U+0A23, ਤ= U+0A24, ਥ= U+0A25, ਦ=U+0A26, ਨ=U+0A28, ਪ=U+0A2A, ਫ=U+0A2B, ਫ਼=U+0A5E, ਬ= U+0A2C, ਮ= U+0A2E, ਯ= U+0A2F, ਰ=U+0A30, ਲ= U+0A32, ਲ਼=U+0A33, ਵ= U+0A35, ੜ=U+0A5C ਘ= U+0A18, ਝ= U+0A1D, ਢ= U+0A22, ਧ= U+0A27, ਭ= U+0A2D

Table 1/1: Vowels & Consonants with Unicode Code-Points

S. No.	Characters	Characters with Code-Point
1	Numerals	੦=U+0A66,੧=U+0A67,੨=U+0A68,੩=U+0A69,੪=U+0A6A, ੫=U+0A6B,੬=U+0A6C,੭=U+0A6D,੮=U+0A6E,੯=U+0A6F
2	Special Symbols	◌ਂ=U+0A02,◌ੰ=U+0A70,◌਼=U+0A3C,ੴ=U+0A74,◌ੱ=U+0A71,◌੍=U+0A4D, ◌ =U+25CC,◌ਃ=U+0A03,◌ਁ=U+0A01
3	Punctuation	।=U+0964,॥ =U+0965
4	Conjuncts	ਮ+ ◌੍ + ਹ –ਮ੍ਹ=U+0A2E+0A4D+0A39 ਪ+ ◌੍ + ਰ –ਪ੍ਰ=U+0A2A+0A4D+0A30 ਦ+ ◌੍ + ਵ –ਦ੍ਵ=U+0A26+0A4D+0A35

Table 1/2: Special Characters in Gurmukhi Script with Unicode Code-Points

Sorting Rules in Punjabi

I. The sorting order starts with primary vowels ਅ,ਆ,ਇ,ਈ,ਉ,ਊ,ਏ,ਐ,ਓ,ਔ

II. The words starting with vowels will then be combined along with the consonants in their alphabetical order

ੳ,ਅ,ੲ,ਸ,ਹ,ਕ,ਖ,ਗ,ਘ,ਙ,ਚ,ਛ,ਜ,ਝ,ਞ,ਟ,ਠ,ਡ,ਢ,ਣ,ਤ,ਥ,ਦ,ਧ,ਨ,ਪ,ਫ,ਬ,ਭ,ਮ,ਯ,ਰ,ਲ,ਵ,

ੜ,ਸ਼,ਖ਼,ਗ਼,ਜ਼,ਫ਼,ਲ਼

III. The consonants combined with first primary vowels and will be arranged in their alphabetical order

IV. The consonants combined with secondary symbols of the vowels.

V. The consonants combined with consonants according to alphabetical order i.e cluster formation.

VI. The consonants combined with the secondary symbols of the consonants.

Compounds

Compound word can be formed from already existing words by a process known as compounding. For example:

Simple Compounding - ਸਿਰ+ਦਰਦ /sɪr+dərd/= ਸਿਰਦਰਦ /sɪrdərd/

Hybridation Compounding - ਬੱਸ+ਅੱਡਾ /bəss+əḍḍa/= ਬੱਸਅੱਡਾ /bəsəḍḍa/

Reduplication Compounding - ਮੇਲ+ਮਾਲ /mel+mal/= ਮੇਲਮਾਲ /melmal/

1.5 Phonological Features of Punjabi

Phonology is concerned with how sounds function in relation to each other in a language. Punjabi literature reveals that the supra-segmental phonemes such as Tone, Nasalization and Stress are realized at the syllable level. There is abundance of geminated words in which stress co-occurs on the geminated consonant.

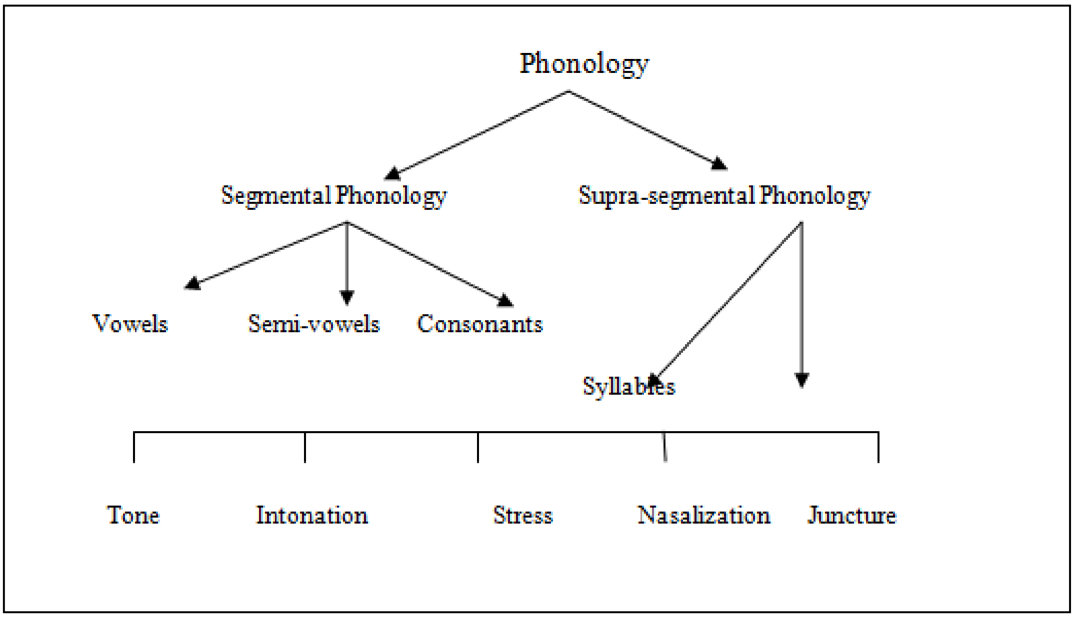


Fig 1/3: Punjabi Phonology

Within phonology, two branches of study are usually recognized: segmental and supra-segmental. Segmental phonology deals with discrete segments, such as phonemes, supra-segmental phonology deals with those features which extend over more than one segment.

Vowels:

Oral vowels: There are 10 vowels in Punjabi i.e. 7 long vowels viz /a/, /i/, /u/, /e/, /ɛ/, /o/ & /ɔ/ and 3 short vowels viz /ə/, /ɪ/ & /ʊ/ in Punjabi. Further these may be classified into two categories viz class I and class II vowels depending on their prominence. The class I vowels are phonetically less prominent and have laxer articulation then those of class II as discussed by Sharma (1971).

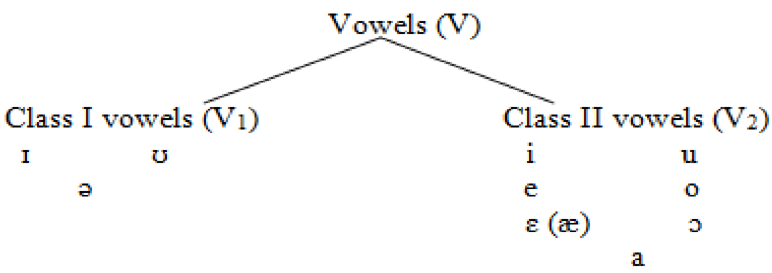


Fig 1/4: Vowels Categories (monophthongs)

This definition of V_1 and V_2 will be used in subsequent chapters of this thesis. It is also noted that the use of short vowels in initial position of word and use of long vowels in final position of the word is more prevalent.

Diphthongs:

Word	IPA	Diphthongs (V_d)
ਖੁਆ	/kʰʊa/	/ʊa/
ਲਿਆ	/lɪa/	/ɪa /
ਗਈ	/gəi /	/əi/

Nasal vowels: Correspondingly, there are 10 nasalized vowels i.e. viz /ã/, /ĩ/, /ũ/, /ẽ/, /ɛ̃/, /õ/, /ɔ̃/, /ə̃/, /ɪ̃/, /ʊ̃/.

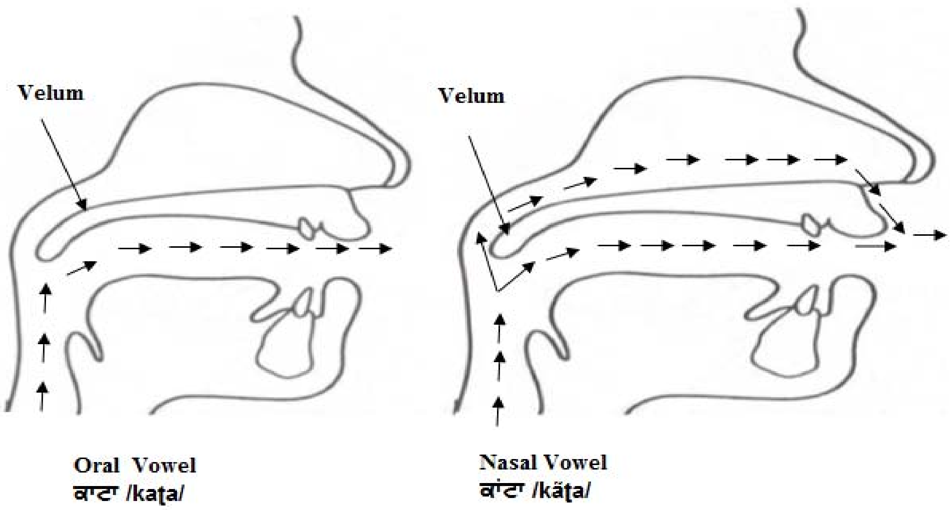


Fig 1/5: Example of oral and nasal vowel

The nasalization is phonemic and the opposition between nasal and oral is given a special technical status in the distinctive feature theory of phonology, where it works alongside other two-way contrasts as part of the complete specification of a sound system.

Some of these features are discussed below:

a) It helps in differenciating between grammatical forms e.g.

Word	IPA	Form
ਬੇੜੀ	/beɽi/	Singular
ਬੇੜੀਆਂ	/beɽiã/	Plural
ਘਰ	/kə̀r/	Noun
ਘਰੋਂ	/kə̀rõ/	Ablative case

b) When nasal consonants occur after the vowel in a word, the vowel is usually nasalized e.g.

Word	IPA	Meaning
ਦੇਣ	/dẽɳ/	Gift/ Blessing
ਖਾਣ	/kʱãɳ/	Mine

c) In addition, if the word ends with an open vowel, this vowel also gets nasalized e.g.

Word	IPA	Meaning
ਦੇਣਾ	/dẽɳã/	To give
ਖਾਣਾ	/kʱãɳã/	Food

d) If dipthong or tripthong occurs at the end of the word with nasal vowel in the end, all the prior vowels also get nasalized e.g

Word	IPA	Meaning
ਗਇਆਂ	/gĩã /	Have gone
ਆਇਆਂ	/ãĩã/	Have come
ਔਸੀਆਂ	/ ɔsĩã /	To wait eagerly

A similar phenomenon is observed in words containing ਵ /v/, being semi vowel.

The consonant sounds of Punjabi, classified according to their place of articulation and manner of articulation are as below:

Plosive(stop)	Bilabial (vluna) (vuna)	Labio-dental	Dental	Alveolar	Post-Alveolar	Retroflex	Palatal	Velar	Uvular	Glottal
Voiceless unaspirate	P (ਪ)		t (ਤ)			ʈ (ਟ)		k (ਕ)	q (ਕ਼)	
Voiceless aspirate	pʰ (ਫ)		tʰ (ਥ)			ʈʰ (ਠ)		kʰ (ਖ)		
Voiced unaspirate	b (ਬ)		d (ਦ)			ɖ (ਡ)		g (ਗ)		
Nasal	m (ਮ)		n (ਨ)			ɳ (ਣ)	ɲ (ਞ)	ŋ (ਙ)		
Trill				r (ਰ)						
Flap						ɽ (ੜ)				
Fricative		f (ਫ਼)		s z (ਸ) (ਜ਼)	ʃ (ਸ਼)			x y (ਖ਼) (ਗ਼)		h (ਹ)
Approximant		v (ਵ)					j (ਯ)			
Lateral Approximant				l (ਲ)		ɭ (ਲ਼)				
Affricates: Unvoiced unaspirated							tʃ (ਚ)			
Unvoiced aspirated							tʃʰ (ਛ)			
Voiced unaspirated							dʒ (ਜ)			

Table 1/3: Consonants IPA Chart

1.5.1 Syllable: Sounds are grouped in larger units. The most important of these is the syllable. The syllable (referred as S) is a structural unit and within that structure we can identify a sequence of consonants and vowels. Just as in grammar we can parse a grammatical structure; in phonology we can parse syllabic structure. The syllable is the most basic element and it has psychological reality as a unit that speakers of a language can identify. Speakers are able to count the number of syllables in a word and can often tell where one syllable ends and the next begins phonetically. It is claimed that when identifying syllables, listeners are responding to sonority. Sonority is the relative loudness of a segment as compared with others.

Each syllable has a single sonority peak. What is a syllable? There is no definition of the syllable that phoneticians or philologists currently agree upon yet the notion of a unit at a higher level than that of the phoneme has existed since ancient times. Sonority or prominence: this is where some sounds are said to have greater prominence than others and these form the basis of syllables. Syllable boundaries fall at points of weak prominence. This is governed by a principle determing underlying syllable division known as maximal onset principle. It states that intervocalic consonants are maximally assigned to the onsets of syllables in conformity with universal and language- specific.

The syllable is seen as a unit of neural programming rather than primarily muscular or acoustic events. If an error is made in the duration of a phoneme, the error is compensated for within the syllabic unit suggesting that articulatory events are programmed in terms of higher –level articulatory units rather than single phonemes.

Every syllable consists of at least a nucleus (N), which is typically a vowel. The nucleus may be preceded by an onset (O), consisting of one or more consonants and followed by a coda (Co), again consisting of one or more consonants. The constituents are in general assumed to be hierarchically organized as consisting of Onset and Rhyme/ Rime and the Rime consisting of the nucleus and the coda, as represented below:

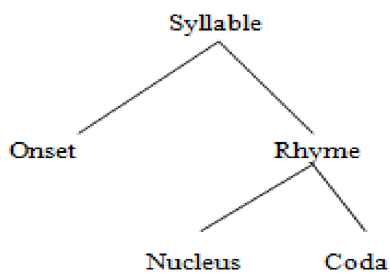


Fig 1/6: Components of Syllable

A syllable which ends in a vowel is called open and a syllable where the vowel is followed by one or more consonants is called closed. Here we describe some words from English & Punjabi language.

Open syllable ਜਾਓ /dʒao / (Punjabi)

No /no/ (English)

Closed syllable ਹਾਕਮ /hakəm/ (Punjabi)

Odd /oɖ/ (English)

The syllable structure of Punjabi

The canonical syllable structure is represented byPandey (2014):

(C) (C) V (C) (C)

The valid combinations are elaborated below:

Monosyllabic Words: V, VC, CV, CVC

Di-syllabic Words: VCV, CVCV, VCVC, CVV, CVCV, CVV

Tri-syllabic Words: VCVCV, CVCVCV, CVCVCVC

The frequency of disyllabic words is maximum in Punjabi however monosyllabic words are also found in abundance. There are plenty of trisyllabic words and few polysyllabic words.

1.5.2 Tone: Most of the languages of the world which are tonal languages use tone in a systematic fashion to express either lexical or grammatical distinctions. There is no standard way in which tones are marked, either in conventional orthographies or in linguistic representations.

Most of the world's tone languages in Africa and the America, have relatively modern spelling devised by missionaries or linguists, in which tone is usually marked by some kind of diacritic within an alphabetic writing system.

According to Gill and Gleason (1969:48) "There is one tone onset on every word---- the occurrence of a tone may be taken to mark a phonologic word, generally equivalent to a morphologic word."

Punjabi is highly tonal Haudricourt (1971) and this is the contrastive feature of Punjabi (other than Dogri) among Indo-Aryan languages. Punjabi doesn't have contour tones as are found in mandarin. There are five tonal characters and three types of tone i.e. high-tone /ó/, low-tone /ò/ and mid-tone /ō/. Synchronically the tone placement interacts with accent/stress. In the production of tones there is neither friction nor stoppage of air in the mouth. These are pronounced always concurrently with a syllable. In the production of low-tone, there is a considerable amount of constriction in the larynx along with some creakiness. The fall in pitch is followed by a rise, not to the same level in all the cases. The pitch of the voice is raised and falls down in the same syllable in a monosyllabic word but in polysyllabic words the fall is realized on the tail syllable which follows the onset syllable. In mid-tone words, the pitch remains fairly level which may rise towards the end. The rise is not necessarily realized in all the cases.

Joshi (1968: 48) defines pitch as, " *a sensation, perceived by the listener and referable to a scale, as well as being related to the frequency with which the vocal cords of speaker open and close during the utterance and which is measurable by instrumental techniques."*

High frequency of the fundamental is related to high pitch and low frequency is related to low pitch. In Punjabi speech, as in other languages, it is the relation of the pitch of one syllable or word to another in the clause that is important and not the actual pitch.

1.5.3 **Stress:** Stress is the degree of prominence of a syllable and degree of force with which a syllable or a word is uttered. The usual distinction between stressed and unstressed syllables is, the former being more prominent than the latter (and marked in transcription with a raised vertical line [ˈ]). Stress systems can be divided into two types: metrical and prominence-driven. In prominence driven systems, syllables with high sonority nucleus i.e. long vowel, onsets or any of a no of other properties convey more stress.

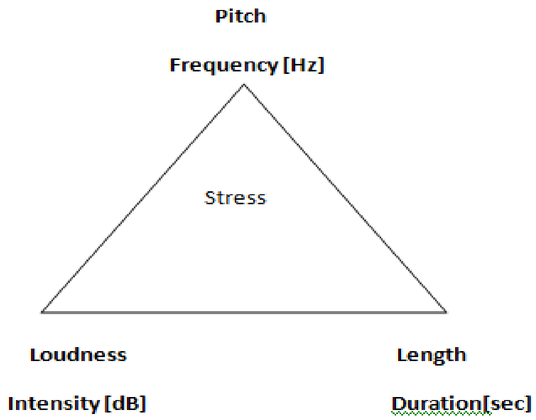


Fig 1/7: Phonetic correlates of Stress

According to Krishnan (2003), stress placement in Punjabi has a three way syllable weight distinction as monomoraic light syllables (L), bimoraic heavy syllables (H) and trimoraic super-heavy syllables (S) which have a long vowel and a coda or a short vowel followed by two coda consonants. He also attested that tonal alternations have been observed viz the falling tone becoming a falling-rising tone in certain derived environments. The experimental study by Nara (2015) reported that F_0 as well as duration is used as a marker of stress in tonal words. There is only primary stress in Punjabi. The syllable with the longest rhyme such as a long vowel, receives stress.

1.6 Pronunciation Lexicon

1.6.1 Pronunciation Lexicon for Language Learning

The lexicon is the bridge between a language and the knowledge expressed in that language Sowa (2005). Dictionary, a book or electronic resource that lists the words of a language (typically in alphabetical order) and gives their meaning, or equivalent words in a different language, often also provide information about Pronunciation, origin, and usage or a reference book on a particular subject. Readers use dictionary to learn the exact Pronunciation of a word, however it may have several Pronunciations. Words belong to different syntactic categories which determine the distribution i.e. the context in which they can occur. The types of dictionaries such as phonological, morphological, syntactical, semantic, etc. depend upon the phonology, morphology, meaning, etc. of the items. Root word is used to be given as the basic entry in a common purpose dictionary because it is impossible to put all inflectional or derivational forms.

Printed Dictionaries: These can be termed as monolingual/bilingual/trilingual or multilingual dictionary. Monolingual Dictionary: Oxford Advanced Learner's Dictionary, COBUILD's Dictionary of English Language, Shabdkosh (Punjabi-Punjabi Dictionary) etc for understanding of the language usually contains information about parts of speech, irregular inflected form, definition of meaning in the same language, and often some pronunciation information etc.

A bilingual dictionary is consulted for transforming into and understanding a second language. Bilingual dictionaries carry a list of translation and Pronunciation equivalents in its target language. Trilingual dictionary has one source language with Pronunciation and more than one target language. The terms in multiple languages are mapped taking one language as source language in a Multilingual Dictionary. It may contain more information inline with other dictionaries.

e-Dictionaries: An electronic dictionary is a resource that contains a library of words and their meanings, spellings, Pronunciation and etymologies. It is used in background of other programs, such as word processors.

Some dictionaries can also serve as thesaurus or translation tools, such as English-Hindi dictionary, etc. These days e-Readers, tablets, and smartphones also have e-dictionary capabilities. Some of these also have feature of recorded Pronunciation.

Online Dictionaries: An online dictionary is a dictionary that is accessible via the Internet through a web browser. These may be in audio or video forms. Online dictionaries available in mostly Indian languages provide Pronunciation also e.g. http://dictionary.cambridge.org/

1.6.2 Punjabi Dictionaries with Pronunciation Feature

Punjabi dictionary is available in the form of monolingual and bilingual (English & Punjabi). It provides the full information like lexicon, meaning, Pronunciation etc.

Printed Dictionaries

i. Punjabi-English dictionary written under the supervision of Joshi & Gill (Ed) (1994) contains about 40,000 Punjabi words, phrases and idioms. It also contains grammatical information and pronunciation of principal words in IPA.
ii. English-Punjabi dictionary by Singh & Sandhu (Ed) (1979) on the pattern of Webster's Third New International Dictionary for arrangement of Lexical data with Pronunciation.
iii. Punjabi-English & English-Punjabi dictionary written by Goswami (2000) covers 25,000 entries. It provides meaning, idioms, Pronunciation etc.

e-Dictionaries

The Punjabi e-dictionary is available for handheld devices. It provides the information of thesaurus, Pronunciation, translation, synonyms-antonyms, etc.

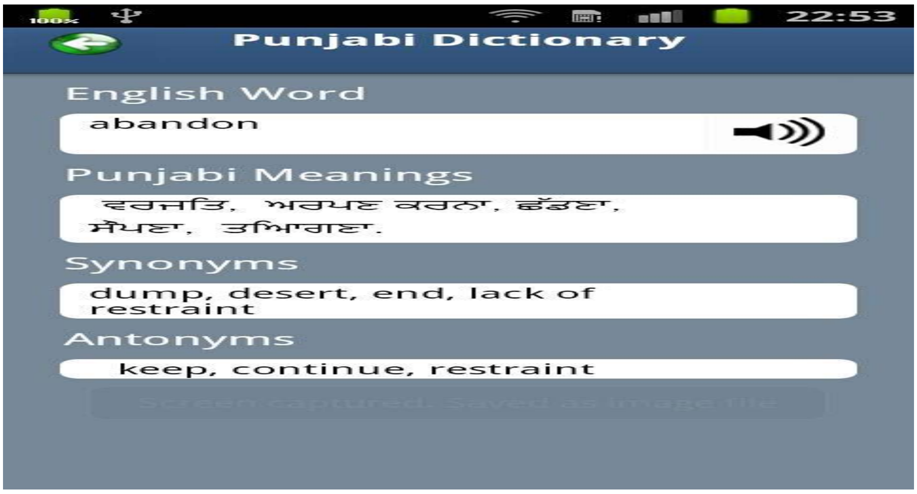


Fig 1/8a: Punjabi e-dictionary

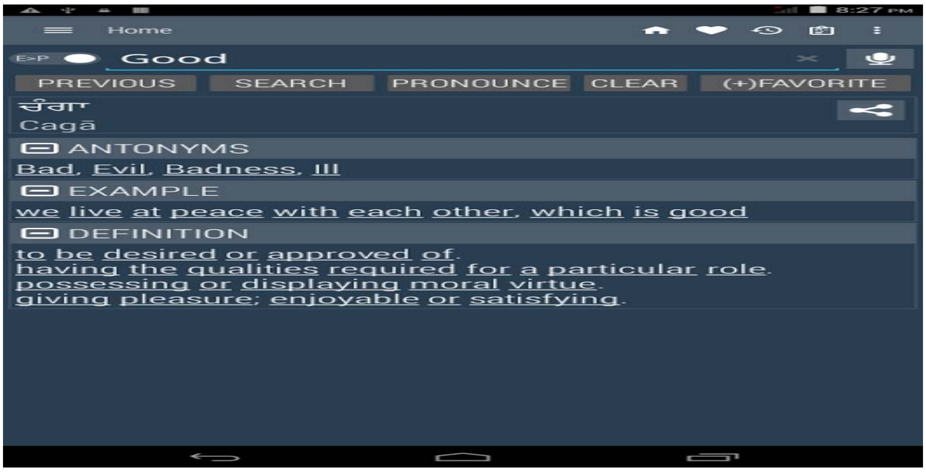


Fig 1/8b: Punjabi e-dictionary

Online Dictionaries: It is a dictionary which is available on the internet and can be accessed through a web browser or a mobile device, primarily by using the search facility. Most of these provide pronunciation also. Some of the websites offering these are <Dic.learnpunjabi.org>, <yourdictionary.com>, <Dictionary.refernce.com>, <Thefreedictionary.com> etc. <Tamilcube.com> provides online dictionaries from English to Multiple Indian Languages including Punjabi.

1.6.3 Machine Readable Pronunciation Lexicon

Pronunciation Lexicon for use in Text- to -Speech systems: Pronunciation Lexicon for machine learning is required for development of speech systems as it represents the interface between acoustic and speech layer. For example in Text-to-Speech (TTS) synthesis, phonemic transcriptions are required for the selection of the proper units to generate the desired waveform. TTS systems are developed based on following approaches (a) corpus based concatenative synthesis which concatenate speech units (waveform) from a database known as unit selection synthesis Murthy etal (2013) (b) the statistical parametric synthesis, the source-filter model (Klatt Synthesizer) and (c) Statistical acoustic model viz HMM (Hidden Markup Model) based synthesis.

Most TTS systems use a combination of pronunciation lexicon and rules. The TTS systems mainly use grapheme-to-phoneme rules as the main Pronunciation mechanism however these also provide Pronunciation lexicon for exceptional words for which rules aren’t applicable. The data size of such lexicon may be large. The TTS engine refers to the lexicon and generates the Pronunciation by rules if the word isn’t found in the lexicon. Sample data of such Lexicon for Punjabi is as below:

Word	IPA
ਭੂਮਿਕਾ	/pùmIka/
ਭਾਅ	/pà/
ਫਿਰ	/fIr/
ਭੱਜਣ	/pə̀dʒdʒəɳ/
ਬੈਠੀ	/bɛʈ̠ʰi/
ਪੜ੍ਹੀਆਂ	/pəɽíã/
ਬੁੱਧ	/bʊ́dd/
ਨੀਂਹ	/nĩ́/
ਨੱਚਣ	/nət̠ʃt̠ʃəɳ/

Table 1/4: Sample Words with Pronunciation for TTS

Pronunciation Lexicon for Machine Learning: Syntactic word is considered as the smallest unit in a prosodic hierarchy tree. TTS requires large amount of pronunciation lexicon containing morpho-phonological information. It uses three different methods to learn rules specific to a language.

i. Manually written rules
ii. Probabilistic methods
iii. Machine learning methods

The Machine learning approach is most widely used these days. The prosodically rich PLS data can be used to develop language specific models to enhance the efficacy. Hence the sample data given in Table 1/4 needs to be augmented with supra-segmental information such as stress etc. may be useful for this purpose.

1.7 W3C Pronunciation Lexicon Specification (PLS 1.0)

PLS is designed to enable interoperable specification of Pronunciation information for both speech recognition and speech synthesis engines within voice browsing applications. It helps developers in supporting the accurate specification of Pronunciation information for international use through the use of language tag as provisioned.

W3C have developed a recommendation of Pronunciation Lexicon Specification (PLS) and its current version is PLS 1.0 (2008) produced by Voice Browser Working Group of W3C. The specification covers the multiple Pronunciations and multiple orthography in the XML structure at the lexicon level thus providing the flexibility of creating language specific PLS documents. The Meta tags feature is available for describing the domain and end use. PLS specification provides a framework and guideline which can be tailored to the needs of a specific language and consequently the XML tag set can be defined to build the PLS data using IPA as UTF 8 representation.

PLS can be used by Text to Speech (TTS) and Automatic Speech Recognition (ASR) Engines and can have a wide variety of applications like voice browsers, pedagogical tools etc. The Pronunciation Lexicon markup language enables consistent platform for independent control of Pronunciation for use by voice browsing applications. Thus this specification can be extended to all other human languages by examining the language-specific requirements. The Pronunciation Lexicon markup language consists of the following elements and attributes:

Elements	**Attributes**	**Description**
<lexicon>	version xml:base xmlns xml:lang alphabet	root element for PLS
<meta>	name http-equiv content	element containing meta data
<metadata>		element containing meta data
<lexeme>	xml:id role	the container element for a single lexical entry
<grapheme>		contains orthographic information for a lexeme
<phoneme>	prefer alphabet	contains Pronunciation information for a lexeme
<alias>	Prefer	contains acronym expansions and orthographic substitutions
<example>		contains an example of the usage for a lexeme

Table 1/5: XML Structure of W3C PLS 1.0

1.7.1 Review of Indian Efforts on PLS

An initial work on development of Pronunciation Lexicon Mandal, Lata et al (2010) on Use of Part of Speech (POS) and morphological information for resolving Multiple Pronunciation in Pronunciation Lexicon Specification (PLS) for Indian Languages has been carried out. The work has been done using Bengali as a Case Study, which was presented in W3C Workshop on Conversational Applications, June 2010, USA. Using example of Bengali word সরল /ʃorlo/ (moved) and /ʃɔrol/ (easy), the paper proposes to use the POS along with morphological information for resolving multiple pronunciations which will result in reducing the size of the lexicon. This can be used to choose the proper pronunciation among multiple pronunciations of the same orthography. Text-To-Speech (TTS) systems rely on lexicons, which contain pronunciation information for many words. PLS lexicons provide control over the text-to-speech (TTS) playback rendering on conforming reading systems. The proposed morphological features inside PLS lexicon makes voice of TTS more natural.

1.7.2 Review of International Efforts on PLS

SI-PRON

In Slovenian language, occurrence of multiple orthographies is rare but multiple pronunciations are common. The lexical stress can be located on almost any syllable obeying hardly any rules. It contains all the lemmas from the dictionary of Standard Slovenian (SSKJ), the most frequent inflected word forms found in contemporary Slovenian texts. The lexicon file contains the orthography, corresponding pronunciations, lemmas and morphosyntactic descriptors of lexical entries in a format based on requirements. SI-PRON pronunciation lexicon developed over 1.4 million lexical entries. It contains a collection of over 190 context-sensitive and context-free grapheme-to-allophone rules.

It used “x-sampa-SI-reduced” phonetic alphabet, a subset of the X-SAMPA set as defined for Slovenian Gros et al (2006).

Swedish Pronunciation Lexicon

A Swedish Pronunciation Lexicon consisting of 8529 words for TTS/ASR has been developed. It has been developed based on PLS format, in addition the data has also been stored in a tab separated format. The delivery comes in two formats namely (a) a tab-separated format and (b) an XML format. It follows the SAMPA conventions. In the current version of Swedish lexicon, there are no special diphthong phoneme symbols. The tag-set used for part of speech information is similar to the one used in Stockholm corpus (SUC). The lexicon is lacking of two forms in the genitive i.e. proper noun and adjective genitive forms.

Finite State Pronunciation Lexicon for Turkish

Similar work has been reported for Turkish, named as Finite State Pronunciation Lexicon which has approximately 7,50,000 words. The pronunciation is encoded using SAMPA. Turkish, being an agglutinating language with extremely productive inflectional and derivational morphology has an essentially infinite lexicon. Another important phonological feature of Turkish language is Stress. The system produces a parallel representation of the pronunciation and the morphological analysis of the word form so that morphological disambiguation can be used to disambiguate pronunciation. The computation of the position of the primary stress depends on interplay of any exceptional stress in root words and stress properties of certain morphemes and requires that a full morphological analysis be done Oflazer (2003).

1.7.3 Gaps in PLS 1.0 Specification

The current version of PLS 1.0, the broad based base line specification which addresses the requirements of Latin script based languages only however cites few examples for Japanese and Chinese also. The requirements of many other global languages such as Indian languages haven't been discussed.

In Indian languages, grammatical information is relatively encoded in its morphology than syntax unlike English where the grammatical information is an integral part of syntax. The tonal language like Punjabi has concatenative inflectional morphology. Hence, PLS 1.0 needs to be revisited with respect to following:

i. The provision to encode script information is currently not there and some languages use more than one script.
ii. It also needs to add some features, such as morphological & syntactic information associated with pronunciations.
iii. It does not have provision encode borrowed words.

The task of constructing a large pronunciation lexicon is very tedious and time-consuming, therefore there is a need to revisit current specification of PLS from perspective of Indian languages, specifically Punjabi and propose additional extension of PLS 1.0 to mainly deal with multiple pronunciations, descriptions of script, morpho-syntactic descriptions and other language specific features such as origin, script of the languge, POS tags, stem etc.

1.8 Research Methodology

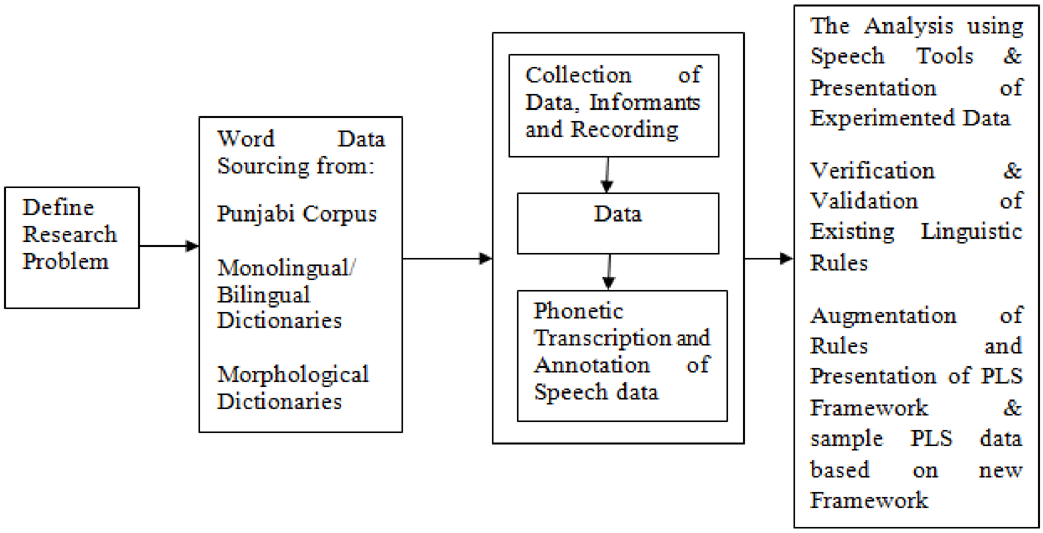


Fig 1/9: Methodology of Research

The present research involves collection of data, recording, data segregation, annotation, experimental study and analysis.

1.8.1 Sources of Data & Data Collection

(1) The data has been sourced from Punjabi corpus and published Punjabi Dictionaries. The criteria for selection of data can be broadly categorized into:

i. The words containing five tonemes in the initial, medial and final syllable

ii. The words containing consonant /h/ and conjuncts of /ɦ/ i.e. ਹ & ੍ਹ in the initial, medial and final syllable

iii. Non-tonal di-syllabic, tri-syllabic and some poly-syllabic words

iv. Words containing Geminated consonants

v. The words containing same vowel in different positions of the words

vi. The words containing schwa vowel

vii. The words containing nasalized vowels

viii. Sentences for study of release vowels

(2) Root words were selected from the dictionaries and its POS variations were obtained from online Punjabi Morphological Analyzer Tool for generating sample XML data.

1.8.2 Informants and Recording

Patterns of pitch variation are lexically significant in Punjabi hence are to be examined. The present study is on Malwai dialect of Punjabi language. Pronunciation Lexicon (PLS specification of W3C) being the scope of current research, the phonetically rich & frequently occurring words of Punjabi were collected for phonological analysis covering all phonemes, tonemes,consonant /h/ and conjuncts of /ɦ/ and non-tonal words of Punjabi. The frequently used words cannot be used for study of prosodic features such as tone, stress etc. analysis and data will be specifically designed so that it fully represents the tone patterns. Word selection will be across monosyllabic, disyllabic, trisyllabic and polysyllabic for complete coverage.

Ten informants (4 male and 6 female) between 25-40 age group belonging to the rural, town and city background were identified. These informants are from Malwai region of Punjab covering Bhawanipur, Kapurthala, Mansa, Patiala, Ludhiana etc. Recording of data will be done by these informants who are native speakers of Punjabi. The prosodic features are highly variable and depend on a complex set of factors, including speaker variables hence speakers were selected from across the Malwai region. What is high with regard to pitch for one speaker, may be low for another. Hence the averaging of observations over ten informants will facilitate fair investigation of the linguistic features. Representative data viz total of 4000 words across 10 speakers and 50 sentences across 8 speakers is to be used for prosodic study. Data will be recorded in the laboratory through good quality audio recording devices in standard speech and noise free environment having SNR>=45db as per standard procedure for speech corpora development based on the ITU recommendations. The informants to repeat each word of the word list thrice.

All recorded data will be segregated with the help of Goldwave Tool as it is a professional digital audio editor. The middle samples of the isolated words as recorded will be free from any contaminating contextual influences and will be used for investigations. All the segregated data will be used for the measurements of the pitch, intensity, duration, formants etc. of the recorded samples.

1.8.3 Data Analysis and Presentation

The annotation of the recorded speech will be carried out. The label "transcription" is used to refer to any symbolic representation of the significant side of documented speech events. Types of transcription are orthographic, phonemic and phonetic transcriptions of segmental information, transcription of prosody and of paralinguistic and non-linguistic phenomenon. The use of phonetic transcription is a faithful rendition of variation in pronunciation which may turn out to have relevance for the description of sociolects or dialects Gippert et al (2006). All the recorded speech data transcribed phonetically and will be tabulated to get the nature of varitaions in pronunciation. The annotation of the recorded speech data at phoneme level will be carried out using the PRAAT software package since it is a very flexible tool to do speech analysis. The values of pitch floor and pitch ceiling of 128-390 Hz will be used. This tool will also be used for analysis of the F_0 contour and the slope of the contour over the pitch area of the associated vowel. The spectrographic analysis of all the male & female samples will be carried out. Data recording of the above given parameters will be done. Punjabi literature reveals that the supra-segmental phonemes such as Tone, Nasalization and Stress are realised at the syllable level, hence will require annotation at syllable level also. There is abundance of geminated words in which stress co-occurs on the geminated consonant, which will also be examined. For the analysis of the Punjabi tones, release vowel quality etc, fundamental frequency and formants of the associated vowel will be studied. MATrix LABoratory (MATLAB) algorithm will be developed to get mean pitch and duration. It is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features.

Graphs will be plotted for sample words exhibiting pitch contour, duration, intensity and formants. The analysis will be presented on acoustic features of Punjabi. Pronunciation lexicon specification for Punjabi language within W3C framework will be proposed based on above proposed analysis.

The parameters recorded for analysis will be following scientific methodology given below for corroboration of results:

Acoustic →	**Auditory** →	**Phonological Category**
▪ Fundamental frequency ▪ Formants ▪ Duration ▪ Intensity ▪ Pauses/silence	▪ Pitch ▪ Length ▪ Loudness ▪ Stress ▪ Grouping ▪ Voice quality	▪ Tone ▪ Quantity (Vowel duration, Gemination) ▪ Lexical stress ▪ Levels in syllable hierarchy

Table 1/6: Parameters for analysis

The acoustic characteristics of spectrograms will be corroborated with auditory parameters and will be tabulated. This experimental data will be scientifically analysed for establishing the phonological parameters with references to PLS.

1.8.4 Assumptions

i. It is assumed that the work carried out will be, by and large, applicable to all other Indo-Aryan Languages except for the specific features of tone, gemination etc. specific to Punjabi.

ii. The research work will be carried out on the words recorded by native Punjabi speakers from Malwai region of Punjab.

iii. It is assumed that the speakers are the representatives of the major Punjabi community of Malwai region of Punjab.

iv. The research findings will be reported based on the analysis of data recorded by 10 speakers (4 male & 6 female) and it is assumed that this can be extrapolated for reporting the research findings.

v. The parameters selected for acoustic analysis is selected on the basis of review of International research efforts in this area.

vi. The syllable definitions vary from one source to the other as literature review. Therefore the syllable definitions of light syllable, heavy syllable and super heavy syllable will be defined for the current scope of research.

vii. For stress analysis, the complete coverage of di / tri / poly-syllabic words will be done on the basis of various combination of syllables as per above syllable definitions.

viii. The study of stress in disyllabic words to be reported on the basis of Linear Regression Analysis.

ix. The stress findings for the tri-syllabic & poly-syllabic words is extrapolated on the basis of the analysis carried out for di-syllabic words and also based on experimental work for small set of data.

x. Phonological study of schwa vowel to be carried out to report variations in it's behavior in different contexts and also as release vowel based on limited set of data.

xi. It is assumed that new PLS framework within W3C guidelines proposed based on the acoustic analysis of limited set of data will be largely applicable for Punjabi Language.

xii. The PLS data developed on the basis of proposed framework will be of immense benefit to TTS and ASR researchers for building Punjabi speech systems.

xiii. Drawing examples from international efforts, it is assumed that computer scientists can further develop finite state machines for faster generation of PLS data based on the proposed framework.

1.9 Organization of the Thesis

The Thesis is organized as follows. In Chapter 2 Literature Review on Tonogenesis of Punjabi will be discussed. The experimental verification and validation of tonal features of Punjabi will be reported in Chapter 3. Chapter 4 will focus on the lexicon stress and the stress resulting due to the presence of tone and gemination. Chapter 5 will discuss the phonetic and phonological analysis of schwa vowel and also some other findings on release vowel. The morpho-syntactic features such as POS based lexical variations and other co-articulation features will be described in Chpater 6. The suprasegmented features discussed in the previous chapters will be presented in Chapter 7 as lexeme elements, attributes & rules for marking supra-segmental features. These features will be represented in the XML format for presenting the PLS framework (PLS 2.0) for Punjabi language within W3C framework. As per this, sample XML examples of Punjabi data are also given for reference. Chapter 8 will present the theoretical & practical work done alongwith research findings and path for future research.

Chapter 2

Tonogenesis of Punjabi: Literature Review

2. Introduction

Tone is the use of pitch in a language to distinguish lexical or grammatical meaning – that is, to distinguish or to inflect words as corroborated by Pike & Welmers (*1948 &1959*):

> *"... having significant, contrastive, but relative pitch on each syllable" [Pike 1948:3]*

> *"... in which both pitch phonemes and segmental phonemes enter into the composition of at least some morphemes" [Welmers 1959:2]*

While Pike originally saw tone as a contrastive feature on each syllable or other tone-bearing unit (TBU), Welmers' definition insists on the morphological nature of tone: tone is not a property of syllables, as expressed by Pike, but rather of morphemes, not all morphemes need to have a TBU- they may be "tonal morphemes". Tone being supra-segmental in nature, the tone features as described below are 'overlaid' on segments and are not inherent to the definition of segments.The term tone language has traditionally been used to refer to those languages which use the feature of tone to distinguish between lexical items. A syllable is pronounced with different tones in order to differentiate meaning. Clark & Yallop (1990), in "Tone Languages", tone is a feature of the lexicon being expressed as prescribed pitches for syllables or sequences of pitches for morphemes or words and in some cases, it may distinguish the meanings of words, thus tone is a significant part of a syllable. Linguists working within the Generative Phonology paradigm look for a set of features for characterizing tone and other prosodic phenomena of a language. Most tone languages have a number of rules that modify tones when spoken in a sequence i.e when spoken in normal phrases rather than in isolation.

Within the generative tradition, the study of word-prosodic typology was greatly influenced by McCawley (1968 &1970), who attempted to set up a principled distinction between tone vs. pitch-accent systems based both on distributional properties and rule types (tones tend to assimilate, accents tend to dissimilate or reduce). A survey of subsequent literature reveals that the terms "accent", "pitch accent" and "tonal accent" have generally been used to refer to tone systems which are defective in the sense of restricting tones by number of contrasts or by position: "A pitch-accent system is one in which pitch is the primary correlate of prominence and there are significant constraints on the pitch patterns for words." Bybee et al (1998:277).

Tone exhibits long-distance effects within and across words i.e. the tone of one word migrates several syllables or words to its right. The word level tones are assigned by rule.

Tone bearing unit (TBU) can be anyone of the following:

- **a.** The entire syllable (or the voiced part of it)
- **b.** The rime portion of the syllable (but not the onset portion)
- **c.** The mora (including the onset)
- **d.** The moraic segment (the segment in the rime)

There is general consensus that in both tonal and non-tonal languages, the tone melodies that are present are best analyzed as consisting of sequence of one or more tones (generally called High/Mid/Low). In almost all cases, the rising and falling tones encountered on a single syllable (known generally as contour tones or dynamic tones) are best analyzed as being either allophonic variants of level tone, or more commonly as being the realization of a sequence of two level tones. It is difficult to draw a sharp boundary between tonal and non-tonal languages as described by Goldsmith (1994):

a. A length of the span of each tone melody is roughly the size of a word in a tone language, where as in a non-tonal language, its size ranges between that of syntactic phrase and that of a sentence.

b. The tone melody of an utterance in a tone language is composed of the tone melodies that are directly contributed by the lexical items in the utterance and to slightly lesser extent by a syntactic constructions present in the sentence, whereas the tone melody of an utterance in a non-tone language is generally determined by the information structure of the sentence.

c. Tone languages generally have phonological rules that modify the tone melody depending on the tones found around them as well as on the syntactic structure in which they occur.

Tone systems are found in approximately 50% of the languages of the world. The greatest concentrations of "tone languages" are found in Sub-Saharan Africa, East and Southeast Asia, South central Mexico and parts of Amazonia and New Guniea. The study of tone has influenced the history of phonology and has contributed to the understanding of languages in general and in particular for study of syntax-phonology. Tone systems have properties which surpass segmental and metrical systems.

Tone cannot be studied the same way as other phonological phenomenon. As in the case of voicing nasality vowel length and other phonological contrasts the normal technique is to first elicit individual words to determine the phonetic properties and ultimately the phonemic contrasts. In case of tone, it yields tonal minimal pairs and / or require specific contexts or "frames" in which the full range of contrasts can be discerned.

Welmers (1959), describes discrete level tone system as one where the pitch value of the different tones are maintained in approximately as standard relationships to each other. He also introduced the notion of down step, which is the lowering process in tonal phonology which can be applied to the second of the two high tone syllables. This means that the choice of tone after a high tone syllable.

After low tone, the tone of the next syllable can only be low or high. After high tone, however, the next tone can be low, the high or down stepped high (that is a pitch slightly lower than the preceding high but not as low as it would need to be counted as a low tone). A high tone after down stepped high is on the same level as that down stepped high. A phonological feature called up step has also been discovered. Gill H.S. & Gleason (1969), deeply analyzed place of articulation & manner of articulation in the context of tones and concluded that tone system in Punjabi language is well developed & established.

2.1 How to Measure Tone

The melody of an utterance is communicated chiefly by movements in time of the pitch of the voice. Pitch as such is a perceptual concept. It is phonetic correlate of the vocal folds during the voicing of segments. Pitch changes can occur due to variations in laryngeal activity and can occur independent of stress change. They are associated with the rate of vibration of the vocal folds. Because each opening and closing of the vocal folds causes a peak of air pressure in the sound wave, we can estimate the pitch of a sound by observing the rate of occurrence of the peaks in the waveform. To be more exact, we can measure the frequency of the sound in this way. Frequency is a technical term for an acoustic property of a sound – namely, the number of complete repetitions (cycles) of variations in air pressure occurring in a second. The unit of frequency measurement is the hertz, usually abbreviated as Hz. If the vocal folds make 220 complete opening and closing movements in a second, we say that the frequency of the sound is 220 Hz. The pitch of a sound is an auditory property that enables a listener to place it on a scale going from low to high, without considering its acoustic properties. In practice, when a speech sound goes up in frequency, it also goes up in pitch. For the most part, at an introductory level of the subject, the pitch of a sound may be equated with its fundamental frequency $F_{0.}$ Tone is observed through this change in pitch over an utterance.

According to Carnochan (1964) *"Pitch is a sensation, perceived by listener and referable to a scale, as well as being related to the frequency with which the vocal cords of the speaker open and close during the utterance and which is measurable by instrumental techniques."*

2.1.1 Methods and Apparatuses for Experimental Phonetics

There are two methods which are used to study speech sounds:

Direct Observational Method: In this method, the investigator relies upon his personal impressions and observations. He observes and listens to a subject in the act of speech and then tries to describe the physiological processes involved in the pronunciation of a particular speech sound. In this method, the degree of accuracy depends on the experience and training of the observer engaged in research. The literature survey reveals some accurate descriptions of the articulatory structures of speech sounds given by few phoneticians who have made use of this method. But now greater emphasis is laid on empirical evidence to verify and confirm the findings of the phoneticians.

Instrumental Methods: These methods are preferred over observational methods as these eliminate the possibilities of subjective distortions which could be introduced by a phonetician. However, the method of observation has not lost its significance since experienced phoneticians still use it. It doesn't exclude but presupposes instrumental methods. Thus speech should be investigated by combining both the techniques to get the best results. Instrumental methods may be divided into methods investigating articulation and methods of physical analysis of speech sounds, the nature of stress and intonation. The experimental work in this thesis will focus on physical analysis.

2.1.1.1 Types of Instrumental Methods

Recording the pitch and the intonation contour of spoken words and sentences has been focused by phonetic and linguistic research for a long time.

It is well recognized that a sufficient description is not possible by human hearing alone. Instead, experiments and measuring devices had to be developed for pitch analysis. “Pitch determination is one of the most important but also most delicate problems in speech analysis”. This statement from the standard book on “electronic means in this field” Hess (1983.3) describes a scientific problem which was known long time before the computer found its way into the phonetic laboratories, phoneticians become aware of the importance of pitch measurement approx. The choronology of various techniques is as under:

a) Pneumatic Kymograph: This mechanism was utilized for examining the physical aspects of speech in the first laboratories of experimental phonetics. Air motions caused by the speech sounds were changed into mechanical vibrations of the stylus which left the traces of the recorded speech on the turning drum of the kymograph for example a kymogram as shown in figure below:

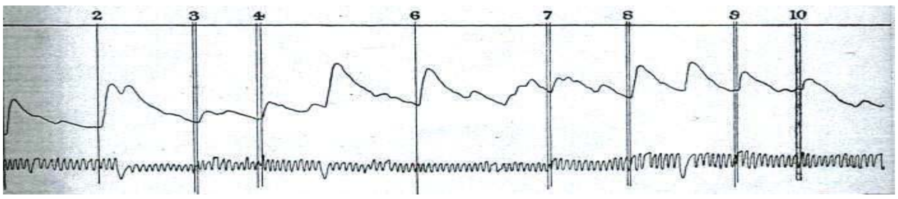
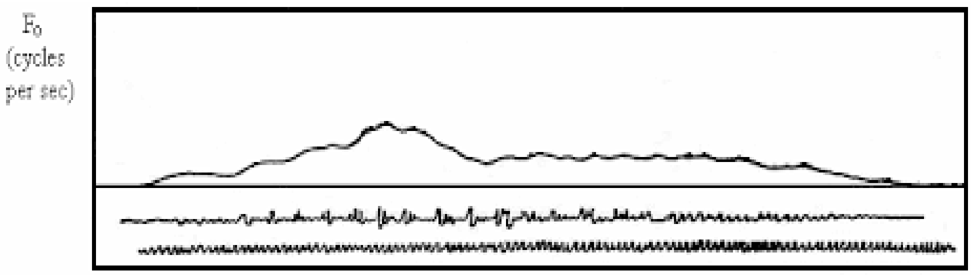


Fig 2/1: Kymogram

The investigations of pitch analysis using these devices offered a lot of problems and was time changing, hence it was replaced by an electronic kymograph registering speech wave and singling out the main acoustic parameters of speech-fundamental tone (melody). The time marker below the kymogram made it possible to calculate the duration of the speech signal



t (msec)

Fig 2/2: Electro-Kymogram

b) Intonograph: It is an electronic device which registers speech signal as a sound wave and signals out the main acoustic characteristics. The following main physical characteristics of speech can be separated and registered on the intonogram:

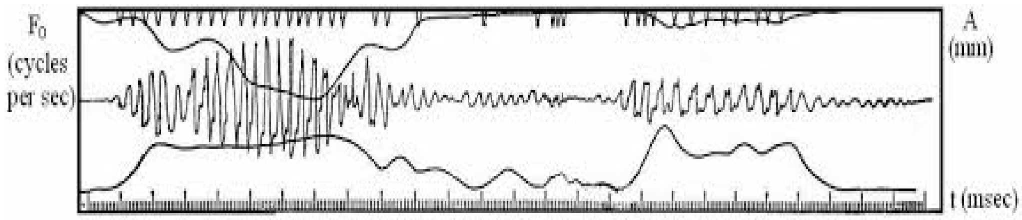


Fig 2/3: Intonogram

- Fundamental frequency (measured in cycles per second) is marked by a curve at the bottom of the intonogram. The higher the curve of the fundamental frequency rises, the higher is the fundamental frequency. The control signs of the fundamental frequency are situated at the upper line of the intonogram.
- Intensity (measured in mm, conventional unit is db) is marked by a curve in the upper part of the intonogram. The lower the curve of intensity falls, the bigger is its meaning.
- Time marker makes it possible to calculate the duration of the utterance or its parts, measured in msec.
- The intonograph makes it possible to investigate intonation and stress as well as other phonetic phenomena.

c) Spectrograph: It gives the opportunities to speech investigators for the study of physical characteristics of speech and acoustic method on the borders of sounds in speech etc in the form of a spectrogram, which has time along the horizontal axis, frequency along the vertical axis, and the amplitude of the signal at any given time is shown as a grey level. Conventionally, black is used to signal the most energy, while white is used to signal the least energy.

These are of two types:

- Wide-band Spectrogram: A Spectrogram produced using an analysis scheme which emphasizes temporal changes in the signal: with short-time spectrum calculations (about 3ms) or highly damped analysis filters (about300hz).
- Narrow-band Spectrogram: A spectrogram produced using an analysis scheme which emphasizes frequency changes in the signal: with long-time spectrum calculations (about 20ms) or lightly damped analysis filters (about 45hz).

d) **Kay Sonograph:** It is a workstation for speech analysis, a powerful tool for speech-scientists or other speech professionals. It produces real time speech analysis on a high resolution display monitor. One-screen waveform editing and speech parameter extraction help to analyse speech and select segments for further work. Both narrow and wideband spectrographic analysis can be performed in real time. These analyses can be edited, stored and printed.

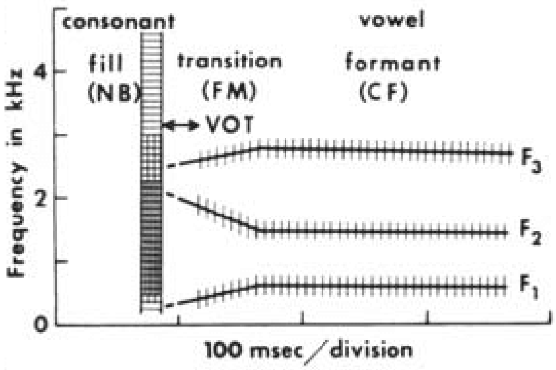


Fig 2/4: Kay sonogram

e) **Computer:** It is an electronic device which can simultaneously acquire, store in memory, analyse and display speech signals and it also produces the required results from the stored data. Computer speech programmes provide all the possibilities for phonetic professionals. They are a powerful tool for acoustic analysis of all the phonetic phenomena of speech as it can combine the results of two main types of analysis-intonographic and spectrographic.

In the upper part of the computer intonogram, speech is recorded in the form of a sound wave. In the middle part of intonograms overall fundamental frequency in the form of a curve is recorded. The higher the curve rises, the higher the meaning of the fundamental frequency is. In the lower part of the intonogram, amplitude & the intensity of the speech signal is recorded. The bigger the intensity of the speech signal is, the higher the impulses of the intensity rise.

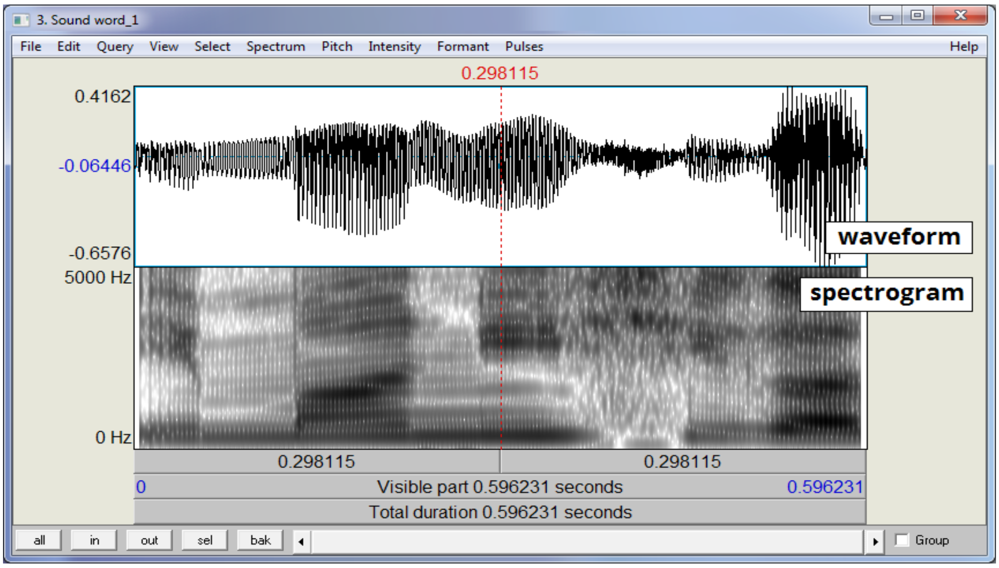


Fig 2/5: Computer Intonogram

Praat: It is a software tool using which one can study the acoustic characteristics of a sound file by viewing and measuring the sound files waveform and spectrogram. Pitch range settings in PRAAT are the most important parameters used in pitch analysis. As described, the pitch floor determines the window length and the pitch ceiling restricts the values being used during the analysis. The optimal default values of pitch floor and pitch ceiling are 75-500 Hz. This tool can be used for acoustic analysis by documenting various parameters of the sound waveform such as value and slope of F_0, Formants, Intensity, Duration etc.

Gold Wave: It is a professional digital audio editor that plays, records, edits, processes and converts audio on the computer. Gold Wave includes a complete set of audio processing features.

An intuitive and customizable user interface makes editing easy. An independent Control window provides direct access to audio devices. It contains controls for playback, rewind & fast forward, recording, volume, balance and speed. Real-time visuals display the sound during playback and recording. A multiple document interface (MDI) allows several files to be opened at one time, simplifying file-to-file editing.

Matlab (matrix laboratory)**:** It is a fourth-generation high-level programming language and interactive environment for numerical computation, visualization and programming. It has powerful built-in routines that enable a very wide variety of computations. It also has easy to use graphic commands that make the visualization of results immediately available. Specific applications are collected in packages referred to as toolbox.

2.2 The Analysis of Pitch Patterns in Tone Systems

Tone is a linguistic term that refers to a phonological category that distinguishes two words or utterances and is only relevant for languages in which pitch plays some sort of linguistic role. It is established through research studies that the vibrations of the vocal cord result in change of pitch and this change of pitch is used to distinguish words. The change of tone results in distinctive word formation. Tone in the linguistic domain gets mapped to F_0 in phonetic domain. F_0 is an acoustic term referring to the speech signal of the lexical items and reflects how many pulses per second are contained in the signal. The perception of tone must be dependent in whole or in part on pitch perception, and thus on fundamental frequency. The speech signal must contain large enough F_0 fluctuations, to be perceptible as pitch differences. Therefore tone is an inherent expression of pitch that contrasts with other expressions of pitch. Tone is neither pitch variation within a defined perceptual space nor a system of pitches expressed relative to a single segment in segmentally based minimal pairs and it is phonetically analyzed relative to other F_0 segments that are in sequence with rather than looking at it as a segmental attachment.

The various features of any tonal system can be broadly categorized as:

General Criteria		Specifies
a.	Number of level tones	• At least four, possibly five
b.	Contour tones	• Rising, falling, convex, concave • Sometimes result of combining two or more levels
c.	Contour tones contrasts	• Two or three
d.	Common alternations	• Assimilation & dissimilation, simplification and formation of contour
e.	Tonal markedness	• In a two level tone system, low is usually unmarked. • In a three level tone system, mid is usually unmarked • Level tones are less marked than contours.
f.	Tonal and laryngeal features	• Low tone associated with voicing, and especially • High tone associated with voicelessness

Table 2/1: Features of Tonal System

Thus the acoustic properties of speech signal relate to the phonological information which the signal conveys. The vibration of vocal folds is periodic and is known as phonation. Several aspects of phonation waveform combined together result in the spectrum. The slope of the spectrum represents voice quality i.e. rate of airflow during phonatory cycle. All native language speakers exhibit variation in duration & amplitude from cycle to cycle phonation. The phonation waveforms and spectra represent idealizations of natural speech; hence can be used for phonological studies.

The pitch of the speech signal is the perceptual correlate of frequency, the higher the frequency, the higher is the pitch. The pitch contours can be studied using spectrogram of speech signal of native speakers using s/w tools as described in section 2.1.1.1e. Thus F_0 contours of recorded words can be analyticaly examined to study the tonal characteristics of a language.

The phonetic facts for publishing linguistic data on tones are plots of fundamental frequency over time. There has been a concensus among various linguistic theories that tone is always transcribed on the syllable nucleus, which is usually a vowel. Thus tone may be phonetically realized on any voiced sonorant segment in the syllable.

2.2.1 Types of Tones and Notations

Tone is primarily the contrastive use of pitch in grammar and lexicon, including movement from level to level. The first question is what are the fundamental pitch levels? The simplest systems have a two-way contrast between higher and lower pitch, H and L. In a tone language, distinctive pitch levels and contours along with vowels and consonants serve to make up a word. Such languages vary as to how many phonologically relevant tones they have. In contour-tone languages, at least some of the tones must be described in terms of pitch movements such as rises and falls or more complex movements such as rise-falls. This is characterized by many tone languages of south-east Asia. The nature of tones can thus be broadly categorized as:

2.2.2 Register Tones

Register-tone languages use tones that are level i.e. they have relatively steady-state pitches which differ with regard to being relatively higher or lower. This is characterized in many tone languages in West Africa. Register Tones are small no. of tones which are illustrated over vowels e.g. á, à and ā e.g. high, low and mid (level) tones. These symbols don’t give an impression of the pitch movement.

These symbols are further combined to get combinations of high and low i.e. falling (high + low) etc. Gur, Atlantic Mande, Dogon, Nilo-Saharan, Chadic and Cushtic languages usually have two level tones. Examples of 3-level languages are Angas, Peki Ewe, Ebira, Kasem, Kotoko, Kpelle, Logo, Mbay, Yoruba and Ibibio. Kotoko has the 3-tone system H M L. The representation of Register Tones is illustrated below:

e̋ ˥ Top
é ˦ High
ē ˧ Mid
è ˨ Low
ȅ ˩ Bottom
Tone terracing
ꜛ Upstep
ꜜ Downstep

Fig 2/6: Register Tone Levels

In some languages (Shonna, Kipare, Mbololo Taita, Miya), syllables are either H or L, without phonological rising tones, which involve F_0 movement from level to level.

2.2.3 Contour Tones

Contour tones are clusters of level tones which have been widely adopted by African phonologists, but it has met considerable scepticism from Chinese phonologists e.g. Yip (1989), Bao (1990), Cahn (1991). Contour tones pose two problems for distinctive feature theory. First, if contour tones are basic units, they require trajectory features such as rise and fall, or a modified version of it, as shown:

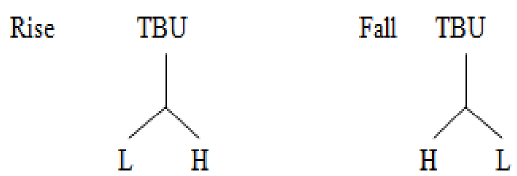


Fig 2/7: Model of Contour Tone Units

Many languages have phonological contour tones. Some allow contour tones only on long syllables, for example Hausa and many Bantu languages (Tachoni, Dembwa Taita) have just falling tone and only on long syllables. Many languages have contours on short vowels, thus Gen and Temne have H, L, Rising and Falling tones; Angas has 3 tone levels and the 4 rising and falling contours which do not end with Mid tone; Benchnon Wedekind (1983) has 5 levels but only one contour, a 4-3 rising tone. These languages lack long syllables.

Languages with four tone levels are much less common and include Bariba, Anlo Ewe, Grebo, Igede, Kamba and wobe. Five levels are quite rare, occurring in Benchnon and the Santa dialect of Dsan and only Chori is reported to have six. The Santa dialect of Dan Bearth & Zemp (1967), Filk (1997) which has 5 levels and contrastive length, allows one short contour (2-3 fall) but 5 long contours (rises 3-2,3-1 and falls 1-5,2-5,3-5), way fewer that the 20 possible contours. The representation of Contour Tones is illustrated below:

ě	˩˥	Rising
ê	˥˩	Falling
e᷄	˦˥	High rising
e᷅	˩˨	Low rising
e᷇	˥˦	High falling
e᷆	˨˩	Low falling
e᷈	˧˦˨	Peaking
e᷉	˧˨˦	Dipping

Fig 2/8: Contour Tone Levels

These pitch movements are represented on a 5-point scale (1= lowest & 5 = highest) by means of tone letters consisting of a vertical reference line on the right preceded by a line indicating pitch. Often the tone is also explicitly described by a series of numbers on the 5-point scale. It is basically a stylized representation however lacks in details of actual pitch contours.

Tone Sandhi is easy to represent using tone numbers. Mandarin, Cantonese and Thai from Asian Region belong to this category. The major characteristics of Yip (2001) and Barrie's (2007) proposal for contour tones in Chinese languages are as follows. First, as is generally assumed for Chinese, contour tones are unitary entities, with only one tonal root node. Second, only one register feature [±upper] is specified for the whole contour tone. Third, only the tonal onset, but not tonal offset, is specified for the pitch feature [±raised]. That is, this is a one-target proposal, with only the tonal onset explicitly and fully specified cf. the two- target unitary-entity proposal in Yip (1989). Forth, a [contour] feature (Barrie) or an unspecified "rebound" (Yip) signals a contour tone. All these properties are illustrated by the following examples, based on Barrie's system.

S. No.	**Tone**	**Onset**		**Offset**	
		[±upper]	**[±raised]**	**[±upper]**	**[±raised]**
1.	High –Level 55	+	+	+	+
2.	Mid –Level 33	+	-	+	-
3.	Low- Level 22	-	+	-	+
4.	High –Rising 25	-	+	+	+
5.	Low- Rising 23	-	+	+	-
6.	Low- Falling 21	-	+	-	-

Table 2/2: Chinese (Cantonese) Tone Levels

2.2.4 Standard Notation in IPA

The IPA consists of a universal set of symbols representing distinctive sound of the world's languages and is used to show pronunciation in many dictionaries (International Phonetic Association 1999).

The IPA chart consists of several sections such as vowels, Pulmonic consonants and non- pulmonic consonants. The IPA chart can be a useful tool for teaching the basics of speech production, as it shows at a glance commonalities and differences between the articulations of various speech sounds.

Different notations were being followed in Asia, Africa and America etc. to denote the tone thus IPA was devised by Henry Sweet (1889), to standardize this notation of various diacritics applied over segmental representations. Most of the world tonal languages have 5 levels of pitch heights which have been provisioned in IPA Chart for transcription. However, there are few exceptions such as African Languages (Chori, Benchnon etc.), Asian languages viz. Chao etc. IPA provides diacritics for (upstep) (⇧) and downstep (⇩) to facilitate representation of desired no. of tonal heights. The various tone contours are also provisioned as below:

Level			Contour		
e̋	˥	Extra high	ě	˩˥	Rising
é	˦	High	ê	˥˩	Falling
ē	˧	Mid	e᷄	˧˥	High rising
è	˨	Low	e᷅	˩˧	Low rising
ȅ	˩	Extra low	e᷈	˧˦˧	Rising falling
ꜜ	Down step		↗	Global rise	
ꜛ	Up step		↘	Global fall	

Table 2/3: Register & Contour Tone Levels in IPA

These IPA notations will be used for data representation in this Thesis.

2.3 Function of Tones

Phonological theories are sharply divided into two areas: segmental and prosodic. Segmental phonology focuses on “melody”: speech sounds (segments), their internal composition and external interactions.

One of the greatest discoveries by Trubetzkoy (1939) & Jakobson (1941) in this area is that segments consist of features and it is through these that segments interact with each other. Segmental phonology is therefore concerned with phonological features, how are they organized inside segments and between segments. Prosodic phonology focuses on aspects of the sound system “above” the level of segments, such as timing, tone, stress and rhythm. Research into the nature and patterning of these phenomena suggests that speech sounds are not just arranged linearly, but are hierarchically organized into prosodic structure: segments into moras and syllables, syllables into metrical feet, metrical feet into prosodic words, prosodic words into phonological phrases, and so on. The prosodic structure is as given below:

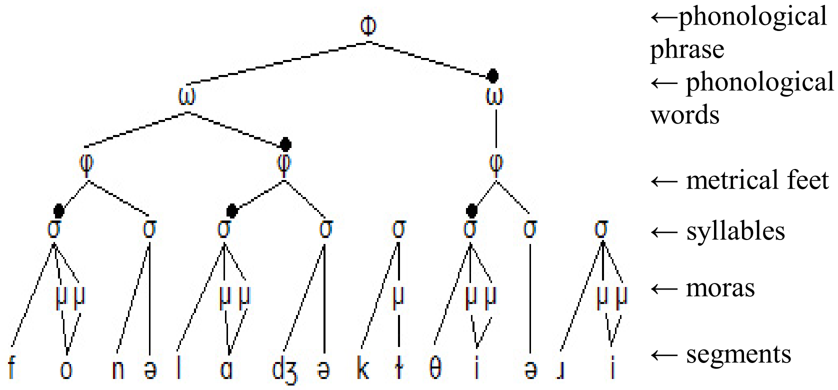


Fig 2/9: Segmental Phonology

A tone system has lexical, morphological and syntactic functions. Tone systems have properties which surpass segmental and metrical systems. This is especially true of the long-distance effects that tone exhibits both within and across words, as when the tone of one word migrates several syllables or words to its right. Some tonal phenomena have no segmental or stress analogues, thus there is a need to understand how tone systems work.

Thus the role of Segmental phonology is not limited to only syllable structure and the distribution of the consonant and vowel phonemes but also covers the tones and tone sandhi, leading to a tone system viz. a system of six to eight contrastive tones at the lexical level. The functions of tone include the restrictions on the lexical tone system according to the part of speech and Tonal sandhi viz. the tones mark signifies grammatical contrasts in addition to lexical units which is a cue used in syntactic and discourse structure.

Based on this, tonal languages of the globe can be divided into two categories i.e. Asian Tone languages in which tone is primarily limited to lexical function (Type A languages). African and Central American tone languages in which the tone spreads to neighboring syllables and exhibits segmental morphology and have polysyllabic roots (Type B languages). However there are some languages like Japanese which don't fall under any of these categories as every word in Japanese has a fixed tone pattern.

2.3.1 Lexical Level Tone Function

The role of tone is limited primarily to lexical function & it does not exhibit at morphology level and thus do not have lexical contrast. These languages have more phonemic tone and tone sandhi rules involve predictable replacement of one tone for another rather than spreading of a tone onto neighboring syllables. There is no use of segmental morphology however syntactically defined tone sandhi compounds may be present. Minor (closed) word classes marked by tone may differentiate lexical meaning. Predominantly monosyllabic roots are found in such languages. Phonological word-building resources are determined by non-tonal contrasts however a set of vocabulary is governed by tone function. Most Asian tone languages belong to this category except for Hakha Chin or Lai language which has exceptional features of type B although it is spoken in some parts of Asia viz. Mizoram in eastern India & Burma, small number of speakers in Bangladesh. Tone is lexically contrastive in Japanese. Punjabi can be clearly categorized as Type A language.

2.3.2 Morphological Level Tone Function

These languages (Type B) exhibit all types of Tone functions as discussed for Type A languages however in addition to that, these also make major use of tone in morphological processes such as tonal derivation, inflection etc. Polysyllabic roots are found and these languages exhibit derivational and inflection segmental morphology. Thus Major (open) word-classes are characterized by different tone inventories or alternation of tone patterns. Number of possible syllables X and their syllable position within the non-tonal words is comparatively high. Tone Sandhi is Syntagmatic.

Tone Sandhi is governed by a number of rules that modify tones when spoken in a sequence, i.e when spoken in normal phrases rather than in isolation. One of the most well-known cases is Mandarin Chinese wherein two Tone-3 syllables occur in sequence, the first one is changed to Tone 2 as explained in the examples given below:

mai hau chou	chi shuei guo	wo hen ho
3 3>2 3	1 3>2 3	3 3>2 3
buy good wine	eat water fruit	I very good

Each word consists of 3 syllables. They are spoken first as isolated syllables (without sandhi) and then as a phrase (with sandhi). The tone of the middle syllable changes in each case from Tone 3 to Tone 2 (indicated by “3>2").

Most of the Languages of African and Central American region belong to this category. Word-building in type B languages uses tonal morphology.

2.4 Study of Tone in Different Language Families

A language family is a group of languages that are related to their descendents from a common ancestor. All natural languages of the world have historical base. The boundary of linguistic ancestry is always not clear as the languages come into contact with each other due to conquest or trade or through other means and they tend to borrow the features from the languages with which they do not have any historical relationship.

The common ancestor of a language family can be identified by the Comparative Linguistics which studies the historical and genetic relationship between languages. The regularity of sound change is the pre-requisite for the comparative method. It implies that when a certain sound X changes in one word, the same change X tends to take place in all words where sound X occurs, or in all words where sound X occurs in a particular context e.g. sound cluster from / kʈ / latin undergoes a change as below:

- Latin **/ kʈ /** > Portugese **/ jt /**
- Latin **/ kʈ /** > Spanish **/ tʃ /**
- Latin **/ kʈ /** > Italian **/ tt /**
- Latin **/ kʈ /** > Romanian **/ pt /**

The branching structure of a family free is based upon shared changes. These changes distinguish the group from related languages. Suffix -ic is used to designate languages families and major groups such as Turkic whereas Turkish is a language.
Languages are often characterized as tonal or non-tonal. Tonal languages utilize pitch to distinguish lexical items, whereas non-tonal languages do not use pitch distinctively. Tonal languages are further divided into tone languages and pitch-accent languages. In tone languages, the tone of each syllable is unpredictable and, therefore, must be specified in the lexicon. No syllable in tone languages is considered more prominent than any other.

In pitch-accent languages, by contrast, the specification of some accent location is sufficient to predict the tonal configuration, or melody, of the entire word. Therefore, the syllable on which such an accent falls is considered more prominent than other syllables. It can also be said that moving from one tone to the next in tone languages is a syllable- level phenomenon, whereas such a movement in pitch-accent languages is a word-level phenomenon.

Japanese and Korean languages aren't specifically covered under any language family hence are being discussed here.

In standard Japanese, the only distinctive melodic characteristic of a phrase is the location of the syllable, if any, where the pitch drops. The tone pattern of a Japanese word is predictable as can be seen from following example where syllables are separated by a hyphen, where H is a high tone and L is a low tone as seen in the following example:

kɑ-ki-gɑ -H-L-L 'oyster'
kɑ-ki-gɑ -L-H-L 'fence'
kɑ-ki-gɑ -L-H-H 'persimmon'

Thus, for a given word form, there are only as many possible tonal patterns as there are syllables (ignoring unaccented word). Thus a tri-syllabic word has three possible tone patterns. Accent, unlike stress, may not necessarily be accompanied by greater duration or amplitude. Apart from its effect on pitch, accent is hardly felt by native Japanese speakers. Pitch can be predicted from accent marks as follows: the pitch is high up to the first mora of the accented syllable (or up to the end of the phrase, if is unaccented, its first mora is low pitched).

Korean language made use of tones until late 16^{th} century. It contained a system of denoting the four tones by placing one or two dots on the left of the letter. Until around 20^{th} century, it was common for Koreans to distinguish certain words by pronucing them for a little longer. These vestiges of tone are today unnoticed even by Koreans themselves.

Depending on the morphological category of the morpheme, its dictionary entry will specify either the syllable, if any, on which it contributes an accent (nouns, postpositions, verb inflections) or merely whether or not it contributes an accent (verbs, adjectives). The rules apply in such a way as to yield outputs in which each phrase has at most one accent. Some accent rules make one accent predominate over others whereas others attract accent into a given position.

2.4.1 Niger-Congo Languages

It is largest language family of world and has 1436 languages. It covers mainly the different types of African languages. Many of these languages have phonological contour tone which is exhibited on long syllable. In some languages short syllable only have level tone and other have contour on short vowel. The main branches are:

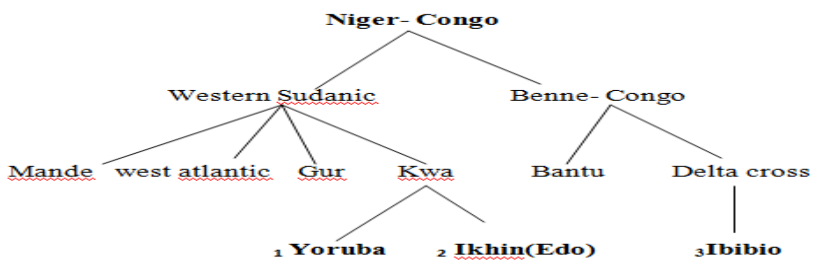


Fig 2/10: Niger-Congo Languages

2.4.1.1 Yoruba Language (Register) has three phonemically distinctive tones-H, M, and L. H occurs in word-initial position only in marked consonant-initial words, which reveal an implicit initial vowel when preceded by another word in genitive construction. Most words start with a vowel, which is L or M but not H. Except for this minor tonotactic restriction, tones occur freely in lexical representations, without apparent restrictions on word melodies.

So there are three possible tonal patterns for monosyllables, nine possible tonal patterns for disyllables. Lexical tone contrast in such words is indicated in the following example:

S. No.			Word-1 H	Word -2 M	Word -3 L
1			rá "to disappear"	ra "to rub"	rà "to buy"
2	Word	H	Pákó "plank"	Kése "mythological place name"	Pákò "chewing stick"
3		M	Okó "hoe"	Oko "husband"	Okò "vehicle"
4		L	Ìlú "town"	Ìlu "opener"	Ìlù "drum"

Table 2/4: Tone levels in Yoruba

2.4.1.2 Ikhin (Edo) Language (Register) is spoken in Ikhin, Edo, Nigeria. Ikhin has terraced level tone system having two basic tones viz. high and low. The following minimal pairs of words get differentiated only by tonal contrast:

S. No.	Word 1 HL	Word 2 LL
1	Ákì "Toad"	àkì "Market"
2	ɔ́kpà "Cock"	ɔ̀kpà "One"
3	ɛ́dà "High"	ɛ̀dà one"River"

Table 2/5: Tone levels in Ikhin

2.4.1.3 Ibibio Language (Register) has three tones (high, low and falling). The falling tone only occurs on final syllables, giving the following combinations in two-syllable words:

<table>
<tr><td colspan="4">**Tone on First Syllable**</td></tr>
<tr><td rowspan="4">**Tone on Second Syllable**</td><td colspan="2">**Word 1 H**</td><td>**Word 2 L**</td></tr>
<tr><td>**H**</td><td>á kp á
| “expanse of ocean”</td><td>à kp á
| “ first”</td></tr>
<tr><td>**F**</td><td>á kp â n
| “square woven basket”</td><td>à kp ȏ
| “ rubber tree”</td></tr>
<tr><td>**L**</td><td>á k ù
| “priest”</td><td>à kp à
| (small ant)</td></tr>
</table>

Table 2/6: Tone levels in Ibibo

2.4.2 Austric Languages

The Austric proto-language has been identified by some with the Hoabinhian archaeologicali industry dating from the late Pleistocene to mid-Holocene (roughly 6,000 to 12,000 years ago). Primary Hoabinhian sites have been identified in Sumatra, Thailand, Laos, Myanmar and Cambodia, while isolated inventories of stone artefacts displaying Hoabinhian elements have been found in Nepal, South China, Taiwan and Australia. Except for Nepal and Australia all of these areas are home to Austric languages and there is evidence that Austric may formerly have been spoken in the Himalayan foothills also.

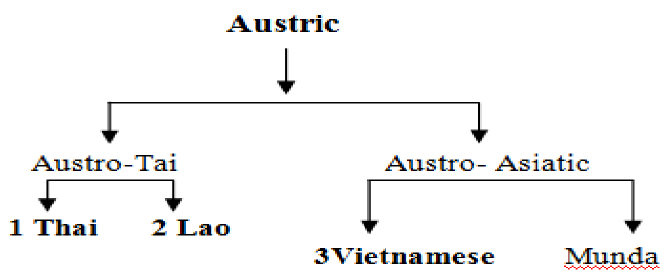


Fig 2/11: Austric Languages

2.4.2.1 Thai (Contour) Language is a tonal language. Tones are the core of the language, they are essential, as important as any vowel or any consonant. Tones distinguish the meaning of one word from another.

Each syllable is pronounced with one of five distinct tones- middle, low, falling, high or rising. The middle tone starts at a middle pitch level, rises slightly and returns to mid-level. The low tone starts low and gradually falls even lower. The falling tone starts high and falls to a low pitch. The high tone rises to a peak and then drops. The rising tone starts at mid-level and gradually rises.

S. No.	**Word 1 M**	**Word 2 L**	**Word 3 F**	**Word 4 H**	**Word 5 R**
1.	mai "mile"	Mài "new"	mâi "not"	mái "wood"	mǎi "no?"
2.	kha: "a glass"	kha: "galangal"	kha: "slave"	kha: "to engage in trade"	kha: "leg"

Table 2/7: Tone levels in Thai

2.4.2.2 Lao (Contour) Language is an isolating tone language where most syllables form individual morphemes. There is only eight bound derivational morphemes Enfield (2007). Tone varies significantly depending on the Lao dialect; Lao linguists identified five tones on long and three tones on short vowels.

S. No.	**Word 1 L**	**Word 2 M**	**Word 3 F**	**Word 4 H**	**Word 5 R**
1.	k^hà: "slave"	k^ha: "galangal"	k^hâ: "commerce"	k^há: "stuck"	k^hǎ: "leg"

Table 2/8: Tone levels in Lao

2.4.2.3 Vietnamese (Contour) Language is the official language of Vietnam. Vietnamese is based on melodious syllables and stressed accent. It is a monosyllabic language with each articulated sound carrying a certain meaning. There are five types of tones and a mid-level non-tone.

Word 1 L	Word 2 H R	Word 3 M Dipping R	Word 4 L F	Word 5 L F Short	Word 6 H R Glottal stop
ma “ghost”	Má “cheek”	mả “tomb”	mà “but”	mạ “young rice”	mã “horse”

Table 2/9: Tone levels in Vietnamese

Tones are realized by a complex of pitch and voice quality features. In particular, glottalization plays an important role in the production and perception of the broken and glottalized tones. The falling tones have been described by some researchers as accompanied by a breathy voice quality. The low falling tone has also been described as accompanied by light final laryngealization.

Vietnamese tones are not subject to phonological tone sandhi (i.e. the realization of a tone is not affected by the surrounding tonal environment), tonal realization in connected speech is subject to phonetic coarticulation effects.

2.4.3 Indo-European Languages

It is one of the largest language families in the world havingten branches of living languages. Out of these, three are primarily spoken in India i.e Armenain, Iranian and Indo-aryan (Indic). The most widely spoken Indo-European languages are Spanish, English, Hindustani, Portuguese, Bengali, Russian and Punjabi (over 100 million speakers each). The next widely spoken languages are German, French and Persian. Germanic languages possess a number of defining features compared with other Indo-European languages.

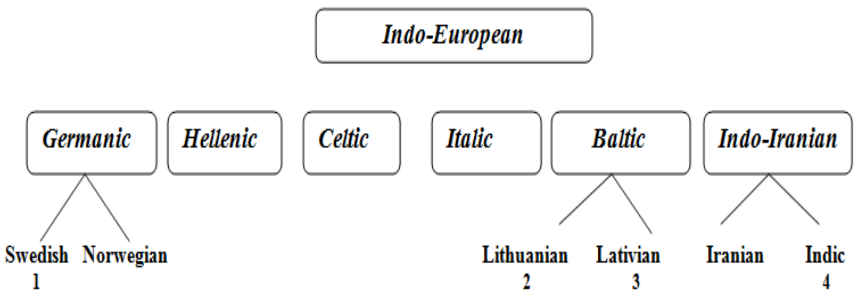


Fig 2/12: Indo-European Languages Families

2.4.3.1 Swedish Language (Register) is a pitch accent language which has two distinctive accents related to the different syllabic structures. Acute and grave accents often distinguish meaning. Monosyllabic words and words with the stress on the last syllable receive the acute accent. It can occur in any accented syllable regardless of position.

Acute Accent (accent1):

1. Monosyllabic words including their declination, e.g. /húset/
2. Words which start with an unstressed syllable, e.g. / bətála /

Grave Accent (accent2):

It never occurs in the last syllable of a word. Therefore it occurs only in polysyllabic or at least dissyllabic words.

S. No.	**Word 1** **Acute accent H**	**Word 2** **Grave accent L**
1	Slútet "the end"	slùtet "Close perf. part of att sluta"
2	Váken "the ice hole"	Vàken "awake"
3	Skállen "the brak"	skàllen "the skull"
4	Égen "own"	ègen "peculiar"

Table 2/10: Tone levels in Swedish

2.4.3.2 Latvian Language (Register) is a Baltic language, hence it exhibits syllable tones (also called syllable accents or syllable intonations). There are three types of tones viz. level, falling, and broken tones (B) which are associated with a syllable having a long vowel, diphthong or a combination of a short vowel plus sonorant (so-called diphthongal sequences) respectively.

S. No.	Word 1 L	Word 2 F	Word 3 B
1	mĩt "change"	mìt "exist"	mît "tread"
2	aũksts "cold"	-	aûksts "high"
3	-	ràuks "pucker"	raûks "yeast"
4	val̃ks "tether"	-	val̂ks "humid"

Table 2/11: Tone levels in Latvian

For syllable tones, an obstruent occurring after a short vowel has no bearing on syllable structure and it could as well be absent from it, as syllables of this kind would have no distinctive tone in either case and are therefore called short.

Type of vowel	**Word**	**Type of vowel**	Word
riñda	'row, line'	lazda	'hazel'

2.4.4 Sino-Tibetan Languages

This family has around 300 members and has 5-main branches viz. Tibetic (Bodic, Burmic, Bai, Karenic and Sintic).

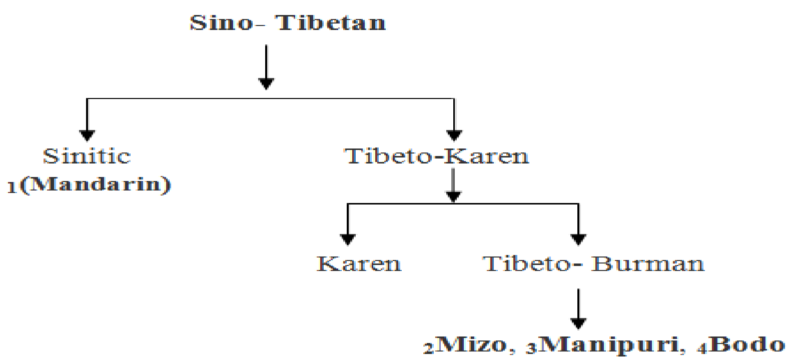


Fig 2/13: Sino-Tibetan Languages

2.4.4.1 Mandarin (Contour) belongs to contour language family. In order to differentiate meaning, the same syllable can be pronounced with different tones. Mandarin's tones give it a very distinctive quality, but the tones can also be a source of miscommunication if not given due attention. Mandarin is said to have four main tones and one neutral tone (or, as some say, five tones).

The first tone is flat just like walking on a flat smooth road.

The second tone rises like going up hill.

The third tone falls and rises like riding on a roller coaster

The fourth tone goes down fast all the way.

The fifth neutral tone short and lightly spoken, and can be seen in the use of the word “ma” at the end of a sentence to make it a question. Each tone has a distinctive pitch contour which can be graphed using the Chinese 5-level system.

S. No.	**Word 1** **L**	**Word 2** **R**	**Word 3** **F R**	**Word 4** **F**	**Word 5** **N**
1	媽 mā “mother”	麻 má “numb”	馬 mǎ “ horse”	罵 mà “scold”	嗎 ma “question word”
2	bī “force”	bí “nose”	bǎ “compare”	bì “wall”	bi

Table 2/12: Tone levels in Mandarin

2.4.4.2 Mizo Language (Contour) is a Tibeto-Burman language spoken in India, Bangladesh and Myanmar. Its tone system has been described and analyzed by native speakers (Chhangte 1986; Fanai 1989, 1992) as having four tones. Chhangte describes the Mizo tone inventory as including High, Rising, Falling, and an unmarked tone, where the unmarked is phonetically mid or low. Fanai also describes the four tones of Mizo as High, Low, Rising and Falling where the Low tone can also have an allophonic variation realized as an extra low tone. The four tones in Mizo can surface in monosyllabic, disyllabic and trisyllabic words.

S. No.	Word 1 H R	Word 2 F R	Word 3 H F	Word 4 L R	Word 5 L F
1	Lŭ̃m "bushy"	Lŭm "to cheer up"	Lùm "to leave"	Lŭ̀m "warm"	Lûm "roll down"
2	tsán "joint"	tsăn "To wait"	tsàn "To warp"	tsán "Bird's tail"	Tsàn "alone"
3	búk "hut/camp"	bŭk "To tip up"	bùk "To weigh"	búk "Sound of sudden incident"	bùk "bushy"
4	bók "knob"	bŏk "Swaying to one side"	bòk "Temporary village"	bók "also"	bòk "To lie down"

Table 2/13: Tone levels in Mizo

2.4.4.3 Manipuri Language (Register) is a tonal language and has lexically significant & contrastive but relative pitch on each syllable. There are three types of tone viz. Falling, rising and level Inder Singh (1975), Chetan Singh (1976)**.** Spectrographic analysis of Manipuri words reveals that phonemically only two tones are realised because the level tone occurring in certain words in isolation is replaced by rise-fall when preceded by roots containing the final tone.

S. No.	Word 1 L	Word 2 Level
1	kə̀nbə̀ "Hard"	kənbə "To protect,etc
2	tàbə̀ "to hear"	tabə "to fall,etc
3	mì "man"	mi "Shadow"
4	Khòŋ "Leg"	Khoŋ "Canal"

Table 2/14: Tone levels in Manipuri

Level tone occurs in monosyllabic as well as polysyllabic words. It has two allotones viz. Level, unmarked in transcription and rise-fall marked as /^/.

S. No.	Word 1 Low	Word 2 Low Rising falling
1	/mə̀ +pu/ "His/her + to bring"	[mə̀pû] "His/her mode of bringing"
2	/mì +siŋ/ "Man+ Marker of plurality'	[mìsîŋ] "Men"
3	/sə̀+mu/ "Animal +black"	[sə̀mû] "Elephant"

Table 2/15: Allophonic variations of level tone in Manipuri

The four possible tonal sequences in Manipuri as discussed in chapter III of Shodhganga are:

Tonal sequence	Word	Meaning
Level + Level	/kəbok/	parched rice
Level + Fall	/kaphòy/	pomegranate
Fall + Fall	/khàbə̀/	bitter
Fall + Level	/thə̀moy/, [thə̀môy]	heart

Table 2/16: Tonal sequences in Manipuri

2.4.4.4 Bodo Language (Register) is a Tibeto-Burman language which is tonal. It is spoken mainly in the northern parts of the State of Assam in India. Garo, Boro, Rabha, Tiwa and Kokborok all belong to the Bodo subgroup. Boro is the major dialect. Linguistic development in Bodo is relatively new, hence there is dearth of proper research of its tonal phenomenon however the available research is summed up below.

Bhattacharya (1977) described maximum four tones in Bodo language i.e. neutral, high, mid and low. Neutral tone is dependent on associated tone viz L/M/H and the quality of vowel whether centralized or more lax. In high tone, the level of pitch contour is level or rising and the quality of vowel is closer and tense.

In mid tone, the level of pitch contour is level or falling and the quality of vowel is medium as to closeness and tenseness. In the low tone, the level of pitch contour is falling and the quality of vowel is open and lax.

S. No.	**Word 1** **L**	**Word 2** **M**	**Word 3** **H**
1	ai˨ income	-	ai˦ / ai˦ goddess / mother
2	Dan˨ month	Dan˧ to cut	Dan˦ gift
3	-	eo˧ / eo˧ to plough / to fry	eo˦ to clear by cutting
4	k^{h}a˨ to test bitter	k^{h}a˧ / k^{h}a˧ to pluck / to tie	-
5	On˨ to open	On˧ / On˧ to love / powder of rice	-

Table 2/17: Four way tone levels in Bodo

Weidert (1987) also identifies the presence of tone in Bodo and opines that the tone patterns in Bodo are dependent on the syllable types and the consonantal specification of the syllable coda. Boro (1991) identifies a two-way tone system in Bodo which he describes as the rising and the falling tones.

S. No.	**Word 1** **L**	**Word 2** **H**
1	dəi water	də́i- lay egg
2	təi- die	tə́i blood
3	Hor Night	Ór fire
4	ka- tie	ká- bitter
5	seo- rot	sáo- burn

Table 2/18: Two way tone levels in Bodo

Sarmah (2004) examined the autosegmental nature of tones using Optimality Theory. He advocated constraints viz ALIGN-L (DT, PRWD) says that each default tone should align with the left edge of the domain. Whereas ALIGN-R (PRWD, LT) says that the left edge of the domain should be specified with a lexical tone. However it needs further investigations.

2.5 Indic Languages

The Indo-Aryan or Indic languages are the dominant language family of the Indian subcontinent. They constitute a branch of the Indo-Iranian languages itself, a branch of the Indo-European languages family. Indo-Aryan speakers form about one-half of all Indo-European speakers (about 1.5 of 3 billion), and more than half of all Indo-European languages recognized by *Ethnologue*. While the languages are primarily spoken in South Asia, pockets of Indo-Aryan languages are found to be spoken in Europe and the Middle East. The largest in terms of native speakers are Hindustani (Hindi-Urdu, about 329 million), Bengali (242 million), Punjabi (about 100 million), Dogri (4 million) and other languages, with a 2005 estimate placing the total number of native speakers at nearly 900 million.

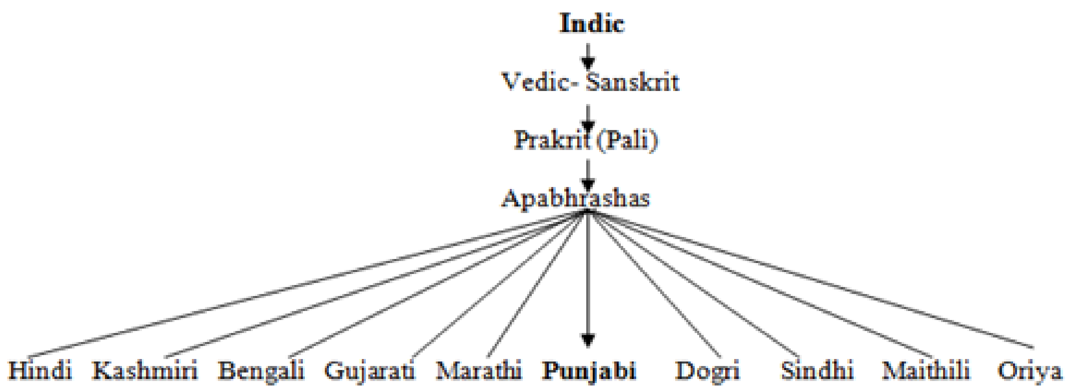


Fig 2/14: Family of Indic languages

The Punjabi dialect continuum has clearly been determined to possess tonal features, although it has no genetic connection with other tonal languages, including those that are geographically proximate, such as Tibetan and Chinese. However Dogri is another tonal language in this family. Ghai (1991) studied phonetics and phonology of Dogri monosyllabic words & few disyllabic words and stated that the vowel quantity plays a position in the configuration of rules for stress in Dogri. The stress is phonetically realized by duration and pitch movement. Further she states that it is the stress feature that determines the place of the word tone. Tones in Dogri are due to tonemes and only single tone occurs on a simple word. She reported three tones in Dogri namely mid level, falling and rising tone. Kaul (2017) experimentally observed the tone in Dogri words. She also verified that the vowel bearing the falling-rising tone is the longest in duration.

S.No.	IPA	Meaning	Tone	Average vowel duration of the nucleus
1	/că/	Peep	Falling-rising	0.42
2	/cā/	Tea	Mid	0.33
3	/cà/	Desire	Low	0.16

Table 2/19: Tone levels in Dogri

2.6 Summary

The literature survey of tonal languages of the various language families has been studied in detail to understand the types of tone and tone variations within and across languages. The presence of tone has been discussed in Punjabi and Dogri only among Indic Languages. Tones in Punjabi language and its experimental verification will be discussed in detail in the next chapter.

Chapter 3

Tonogenesis of Punjabi: Experimental Observations

3. Introduction

Punjabi lexicon has closer ties with early Vedic Sanskrit & has also assimilated a wide array of words and expressions from Arabic and Farsi. The presence of pitch contours in Punjabi has been discussed by various linguists.

Linguist	A	B	C	D
Bailey, T, G(1914)	Low rising	Ordinary	High falling	
Behal, K,C(1957)	Falling	Even	Rising	
Sampat, K.S (1964)	Falling	Level	Rising	
Gill, H.S & Gleason, H.A.(1969)	Low	Mid	High	
Joshi, S.S(1973)	Tone 1	Tone2	Tone3	
Sandhu, B.S.(1974)	High	Level	Low	
Malik, A.N(1994)	High-falling	Level	Low- rising	Rising falling

Table 3/1: Eminent linguists' description of Punjabi tones

Joshi (1987) established through research studies that the vibrations of the vocal cords results in change of pitch and this change of pitch is used to distinguish words. Tone is observed only on one syllable and may co-occur with stress on it. If the class I vowel occurs in the first syllable, tone gets extended to the second syllable.

Although one word has one tone only but phonetically its effect is observed across syllables.

Singh (2001) Punjabi has a lexically significant contrastive pitch accent (tone) which it makes use of to distinguish words which otherwise have identical phonetic form. The use of pitch by Punjabi to differentiate the meaning of various lexical items i.e. words, establishes it as a tone language beyond any doubt. The author has studied the prosodic features in Paninian linguistics and has evolved the Moraic-Model for representing the prosodic features. Especially study on tones in Punjabi has been carried out in which he has identified presence of three tones in Punjabi.

Sangha (2014) the low tone is characterized by lowering the voice below the normal pitch and then rising back in the following syllable. In the high tone the pitch of the voice rises above its normal level falling back at the following syllable. The level tone is carried by the remaining words. Thus there is a need to examine the lexical tone in this context in Punjabi. Low tone and high tone can occur in monosyllabic, disyllabic and trisyllabic environments. Following Examples illustrate that tone plays a significant role in the Punjabi lexicon as is evident from the minimal pairs given in the table:

S. No.	**[ਕ] /k/**			**[ਪ] /p/**		
1	ਘੋੜਾ	/ kòra/	‘Horse’	ਭਾੜਾ	/ pàra/	‘Fare’
2	ਕੋੜਾ	/ kōra/	‘Whip’	ਪਾੜਾ	/ pāra/	‘Difference’
3	ਕੋਹੜਾ	/ kóra/	‘Leper’	ਪਾੜ੍ਹਾ	/ pára/	‘Student ’

Table 3/2: Tonal Minimal Pairs in Punjabi

Thus Punjabi has three tones viz low tone /ə̀/, high tone /ə́/, and mid tone /ə̄/. Any vowel can be a tone carrier, however schwa is used as an example here.

The mid tone is never represented since it is predictable by rules of redundancy; if a vowel does not have any tone specification at the level of phonetic representation, by default it carries a mid tone. The tone placement also interacts with accent/stress. The low tone must be on the same syllable as the accent Bhatia (1993). Generally not more than one tone can occur in a single Punjabi word.

Tones in Punjabi can be broadly discussed under two categories:

Tone Arising from Supra-Laryngeal Consonants

Punjabi has five voiced and aspirated consonants which are represented orthographically as: **ਘ /gʱ/, ਝ /ɖʒʱ/, ਢ /ɖʱ/, ਧ /dʱ/, ਭ /bʱ/** also known as murmured consonants. These have disappeared and resulted into a tone. The tone is remnant of historically voiced aspirated consonants. If the murmured consonant was at the beginning of a word, it left behind a low tone; at the end, it left behind a high tone. If there was no such consonant, the pitch was unaffected; however, the unaffected words are limited in pitch and did not interfere with the low and high tones. That produced a tone of its own, mid tone. The historical connection is so regular that Punjabi is still written as if it had murmured consonants, and tone is not marked. The written consonants tell the reader which tone to use. A phoneme that is distinguished from another phoneme only by its tone is called Toneme.

The tones in Punjabi arise as reinterpretation of different consonant series in terms of pitch viz four stops: **ਘ /gʱ/, ਢ /ɖʱ/, ਧ /dʱ/, ਭ /bʱ/** and one affricate: **ਝ /ɖʒʱ/** and these five consonants are called Tonemes. The rules for characterization of Tonemes are described in the table below taking Toneme ਘ /gʱ/ as an example as these are well documented in the linguistic studies.

Toneme	Word/ Meaning	Position of Toneme	Nature of Tone	Toneme Substitution	IPA Transcription
ਘ	ਘਰ/ Home	Initial	Low /ə̀/	[k] (voiceless unaspirate)	/kə̀r/
ਘ	ਮਘਾਉਣਾ/ to Burn	Medial	Low /ɑ̀/	[g] (voiced unaspirate)	/məgàɪa /
ਘ	ਮਾਘ/ Name of the month	Final	High /á/	[g] (voiced unaspirate)	/még/

Table 3/3: Tone Marking Rules (Tonemes)

Independent Tone

Sandhu (1968), discussed that the aspiration effect of [ਹ] /h/ in Pali, Prakrit and Apbhransh got developed into the tone system in Punjabi during middle Indo-Aryan period. Bailey (1914), stated that the tone resulting from the middle ਹ /h/ occurs at the last syllable and in some cases it occurs on previous syllable. Tisdall (1953), identified that in 'ਕਿਹਾ /keha/ & ਰਿਹਾ /reha/, the pronunciation of consonant /h/ [ਹ] is very weak and it does not act like an independent character.

Singh (1991), consonant ਹ /h/ is used in all word positions i.e. in initial, medial or final syllable. If ਹ /h/ occurred at the end of words then it is not pronounced and ends with breathy force, which shows the occurrence of tone e.g. ਪੀਹ /pí/ Grind; ਚਾਹ /tʃá/ Tea. Similarly the ਹ /h/ occurring in the middle position also acts a tone e.g. ਸਹਿਜ /sɛ́dʒ/ Slowness; ਇਹਨਾਂ /énã/ these.

Sangha (1999), /h/ in initial position is pronounced as a consonant and is non-tonal e.g. ਹਾਣੀ /haɳi/ companion; ਹੌਲੀ /hɔli/ slow. The consonant ਹ /h/ in the end of the word is realised as a high tone. The tone due to ਹ /h/ in the medial position could be high or low depending on the context.

Thus the tone rules are summarised below:

consonant	**Position of consonant /h/ in a word**	**Word / Meaning**	**Nature of tone**	**IPA transcription**
ਹ /h/	Final	ਚਾਹ / Wish	High /á/	/tʃá/
	Medial	ਇਹਨਾਂ / These	High /é/	/énã/

Table 3/4: Tone Marking Rules (Consonant /h/)

Conjuncts of /ɦ/ consists of pairin /ɦ/ e.g. ਪੜ੍ਹ /pə́ɖ/ to study. It does not occur in the initial syllable. The pronunciation of pairin /ɦ/ in medial and final syllable is so weak that it is perceived as a tone as illustrated in the examples below:

consonant	**Position of /h/ in a word**	**Word / Meaning**	**Nature of tone**	**IPA transcription**
Conjuncts of /ɦ/	Final	ਪੜ੍ਹ / To study	High /ə́/	/pə́ɖ/
	Medial	ਖਰ੍ਹਵਾ / Rough	High /ə́/	/kʰərə́va/
		ਸਲ੍ਹਾਬਾ / Seepage	Low /à/	/səlàba/

Table 3/5: Tone Marking Rules (Conjuncts of /ɦ/)

3.1 Methodology

Tone is observed through the change in pitch viz fundamental frequency F_0 as discussed in section 2.1. The methodology followed for experimental study of tones is as below:

3.1.1 Criterion for Data Collection: The frequency analysis of corpus of 1 lakh sentences reveals that frequency of:

a) words containing a toneme/s is about 10-15%

b) words containing consonant /h/ is 15-20%

c) words containing conjuncts of /ɦ/ is 1-5%

Thus the data needs to be designed specifically for experimental work for tonal analysis as discussed in section 1.8.1**.** Word selection criteria will vary in context of:

A) For Tone arising from Supra-Laryngeal Consonants, words with each of five tonemes in initial, medial and final syllable of the word will be compiled ensuring the phonetic coverage in terms of various vowels, dipthongs, nasalization, gemination and other co-articulation parameters such as occurrence of Toneme as onset/ coda in above contexts across Monosyllabic, Disyllabic, Trysyllabic and Polysyllabic words.

B) For Independent Tones, the words containing consonant /h/ in initial, medial and final syllable of the word will be compiled to examine the tonal characteristics. Conjuncts of /ɦ/ do not occur in the initial syllable hence words containing conjuncts of /ɦ/ in medial and final syllable will be compiled.

Data recording specifications were followed as elaborated in section 1.8.2

3.1.2 Data Annotation using Praat Tool: The procedure to annotate the data in this tool is listed below:

- Load a recorded wave file (.wav extension) by selecting “Read from file”. The file will appear in the objects list.
- Click on “Annotate” and select “To Text Grid”.

- The created TextGrid will appear in the object list of the object window. Selects both audio file and TextGrid file and click on “Edit”.
- The speech wave form gives information about the duration (horizontal axis) and loudness (vertical axis) of each part of the recording. In the spectrogram one can see the energy (shade of grey or black) at each point in time (horizontal axis) and each frequency (vertical axis).

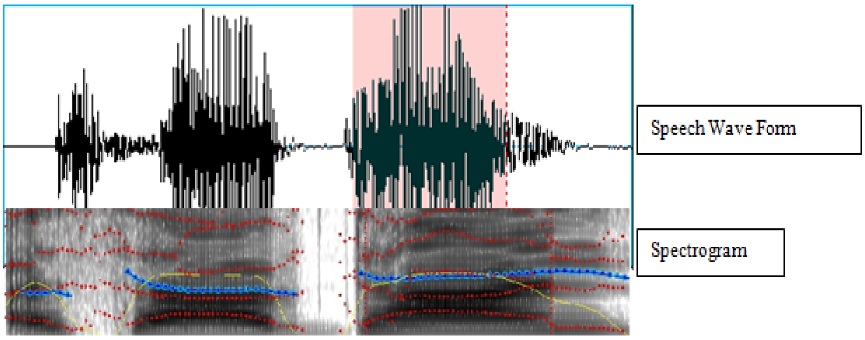


Fig 3/1: Waveform & Spectrogram

- Formants (in red colour), the intensity curve (Yellow in Color), the pitch curve (Blue in Color) and the spectrogram (Gray part in Spectrogram) can be displayed or turned off, by clicking on the corresponding buttons on the top bar of the window.
- For setting a boundary (i.e. marking the beginning or end of a phoneme, syllable etc.) click on the appropriate place in the spectrogram. A blue circle appears on the tier. Boundary can be created by clicking on the circle.

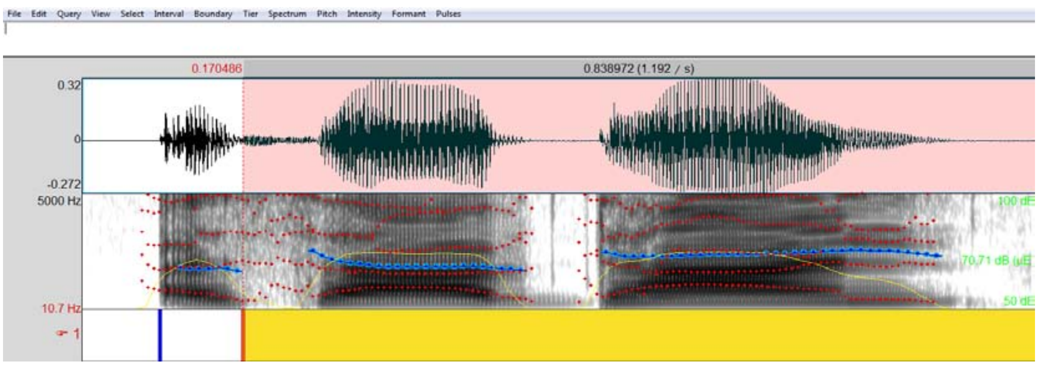


Fig 3/2: Boundary Tier for Phoneme Marking (bottom layer)

- After having created a second boundary, IPA transcription can be added for the given phoneme. Click on the grey button underneath allows it to play back this particular part of the recording. This button also gives the exact duration, pitch and intensity of the respective phoneme/syllable.

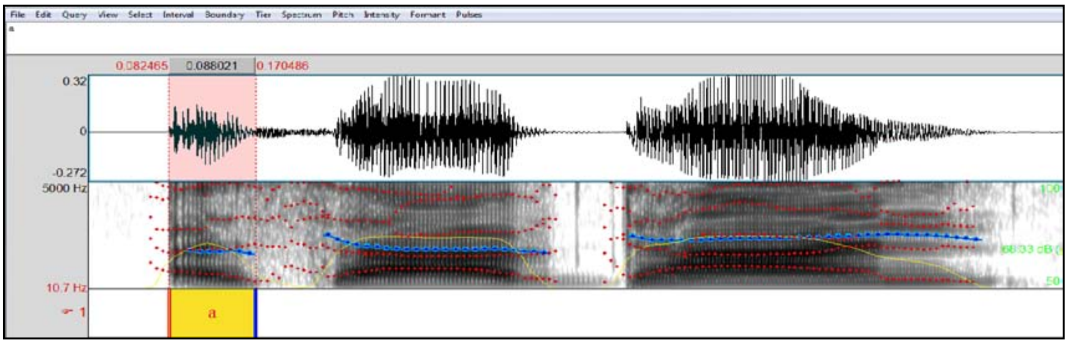


Fig 3/3: IPA Transcription Marking of Phonemes

- Click the save button to save the file with .Collection extension in the given path.

The first layer of Praat annotation tool was used for phoneme level annotation. Syllable marking can be done by adding second layer following the same procedure. Some samples were not annotated due to improper recording (IP) i.e. presence of noise or some other factor impacted the recording such as incorrect pronunciation including non-tonal (NT) pronunciation due to error by informant etc. These samples are limited to 10 % of the data and will be ignored for presentation of the data.

3.1.3 Acoustic Parameters: The spectrographic analysis of all the samples will be carried out using praat tool. After identification of the vowel bearing tone (TBU) in a word being analysed, F_0 contour and the slope of the contour over the pitch area of the TBU will be examined by recording of the parameters such as F_0, slope of pitch of the (TBU), quarter wise slope data of the pitch curve. The data sheets for each word will be recorded. The fundamental frequency is speaker dependent hence F_0 can be analyzed for speaker variations also. The quarter-wise slope data will be correlated to detect the contour of the tone over duration of the TBU.

The PRAAT graphs will be reported in the thesis. Some samples of Independent tone as discussed by Lata et all (2013), were verified using the MATLAB tool for which the code used for plotting the graphs is given at the end of appendix C.

The higher the slope of the pitch variation across TBU, the stronger is the tone pronounced by the speaker, which is generally the case with native speakers. Non-native speakers or urban speakers sometimes pronounce tonal words with weak tone. The onset of tone and realization of allotones will also be examined. The effect of tone on other syllables within a word also needs to be studied. Any single tone in a tonal language is susceptible to a good deal of variation owing to contextual compulsions. These patterns may also vary across mono-syllabic, di-syllabic, tri-syllabic and poly-syllabic words. Variations within a word may occur due to co-articulation and other factors as discussed below:

- The distance in tongue movement/ movement of lips between consecutive phonemes/syllables depending on the place of articulation and manner of articulation.
- The sonority of vowel bearing the tone.
- Variations across Tonemes & variations in Independent tone across words containing consonant /h/ and conjuncts of /ɦ/.
- The variations due to presence of gemination and dip- thongs.
- Speaker variations such as speaker dependency (stylistic variations / geographic variations etc) while recording, age variations of speakers, the trend of loss of tone among urban speakers and non- native speakers.
- Speakers may differ both in pitch height and in pitch range hence articulation of tone may vary from speaker to speaker.

3.1.4 Notations to Represent Tone: Symbol [o] has been used in the following table to denote a tone bearing vowel. Following IPA symbols will be used in the thesis for marking tone in the representation of Punjabi PLS data.

S. No.	Types of tone	IPA	Notation
1.	High tone / Rising	ó	LH
2.	Low tone / Falling	ò	HL
3.	Rising Falling	ô	LHL
4.	Falling Rising	ǒ	HLH

Table 3/6: Tone Marking Symbols

3.2 Experimental Analysis of Tone arising from Supra-Laryngeal Consonants

Keeping in view the frequency of occurrence of words as discussed in section 3.1.1, the data samples were drawn for analysis as tabulated below:

S. No.	Toneme	Mono syllabic	Disyllabic		Trisyllabic			Polysyllabic		Total
			Initial	Final	Initial	Medial	Final	Initial	Medial	
1.	ਘ	8	10	9	1	7	-	1	-	36
2.	ਝ	9	8	8	3	5	-	-	1	34
3.	ਢ	8	4	7	4	6	4	-	-	33
4.	ਧ	4	8	11	1	5	3	-	1	33
5.	ਭ	3	6	7	1	3	1	1	-	22
	Sub-total	32	36	42	10	26	8	2	2	158
	Total	**32**	**78**		**44**			**4**		

Table 3/7: Size of Data Samples of Tonemes

The word list of tonemes is given in Appendix A.

Data Collation and Presentation

The spectrographic analysis using PRAAT of all the male & female samples was carried out. The duration, fundamental frequency (F_0), quarter wise slope of the vowel associated with the Tone (TBU) have been recorded. The observations on contour of the tone over TBU have been tabulated. The tabulation of data has been done for various categories of words across the male and female speakers capturing the variety of acoustic environments as per Table 3/7 for studying the nature of the tone associated.

Recording of Data Sheets

The phoneme level annotated data of above samples was used for recording various acoustic parameters. A sample data sheet is given below:

Sample Data Sheet: ਬੁੱਝੋ **/bʊ́dʒo/**

Male Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU(HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
M1	149	353	140	147	154	155	LH	0.08
M2	227	328	220	225	227	236	LH	0.07
M3	204	462	184	200	212	218	LH	0.10
M4	157	287	148	156	161	161	LH	0.07
Average	**184**	**358**	**173**	**182**	**193**	**193**	**LH**	**0.08**

Table 3/8: Data Sheet of Male Speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	**25%**	**25%**	**25%**		
F1	246	501	232	247	251	253	LH	0.07
F2	278	545	259	279	287	288	LH	0.10
F3	277	812	244	280	293	293	LH	0.09
F4	284	803	265	282	292	297	LH	0.06
F5	320	719	296	319	332	332	LH	0.09
F6	275	451	265	276	280	280	LH	0.08
Average	**280**	**639**	**260**	**281**	**289**	**291**	**LH**	**0.08**

Table 3/9: Data Sheet of Female Speakers

The sample data sheets for each category of Tonemes are given in Appendix B.

The rules reported as per literature review in section 3 will be corroborated and the variations discovered will be elaborately discussed.

3.2.1 Monosyllabic Words

These words have been analysed under two categories depending on whether Toneme is appearing as coda or onset.

Words with Toneme as Coda:

S. No.	Word Text & IPA	Duration			F_0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
	ਘ										
1	ਡਿੰਘ /ɖĩ́g/	0.24	0.29	0.27	213	315	264	329	315	322	LH
2	ਤਾਂਘ /tã́g/	0.33	0.39	0.36	209	296	253	308	276	292	LH
3	ਪੀਂਘ /pĩ́g/	0.31	0.39	0.35	224	318	271	246	216	231	LH
4	ਊਂਘ /ṹg/	0.33	0.32	0.33	240	313	277	326	397	362	LH
5	ਮਾਘ /mág/	0.29	0.29	0.29	202	268	235	244	238	241	LH
	ਝ										
1	ਸਾਂਝ /sã́dʒ/	0.32	0.42	0.37	209	303	256	278	560	419	LH
2	ਬੋਝ /bódʒ/	0.28	0.31	0.30	205	294	250	282	364	323	LH
3	ਉਂਝ /ʊ̃́dʒ/	0.19	0.26	0.23	211	308	260	429	432	431	LH
4	ਬਾਂਝ /bã́dʒ/	0.30	0.38	0.34	206	278	242	290	351	321	LH
	ਢ										
1	ਸੁੰਢ /sʊ̃́ɖ/	0.21	0.26	0.24	220	309	265	317	307	312	LH
2	ਵੱਢ /ʋə́ɖɖ/	0.13	0.15	0.14	197	286	242	452	497	475	LH
	ਧ										
1	ਯੁੱਧ /jʊ́dd/	0.12	0.14	0.13	213	308	261	432	522	477	LH
2	ਕੰਧ /kə̃́d/	0.21	0.26	0.24	215	304	260	334	339	337	LH
	ਭ										
1	ਜੀਭ /dʒíb/	0.27	0.29	0.28	223	310	267	400	360	380	LH

Table 3/10: Contour of Tone in Monosyllabic Words with Toneme as Coda

The rising tone is observed in all words. Sample word ਤਾਂਘ /tã̌g/ Anxiety:

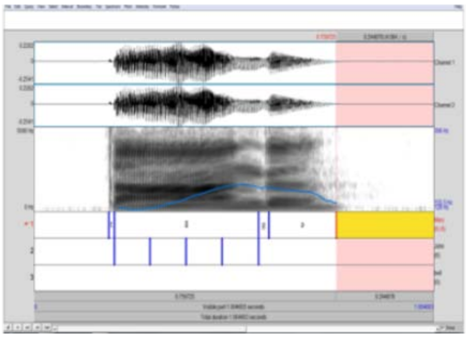


Fig 3/4: Male Sample - LH

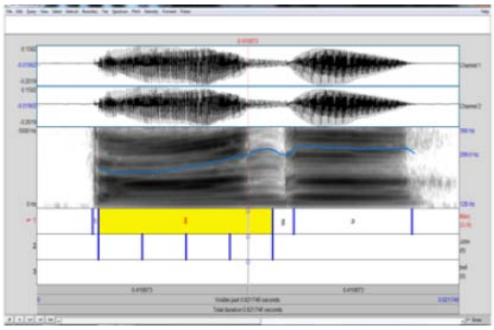


Fig 3/5: Female Sample - LH

Words with Toneme as Onset:

S. No.	Word Text & IPA	Duration			F_0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
	ਘ										
1	ਘਰ /kə̀r/	0.18	0.20	0.19	206	294	250	277	364	321	HL
2	ਘੁਸ /kùs/	0.38	0.31	0.35	233	320	277	327	416	372	HL (50%) HLH (50%)
	ਝ										
1	ਝੱਗ /tʃə̀g/	0.13	0.17	0.15	234	298	266	280	459	370	HL
2	ਝਾਉ /tʃǎũ/	0.50	0.48	0.49	212	304	258	184	400	292	HLH
3	ਝੂਠ /tʃùʈʰ/	0.29	0.29	0.29	232	314	273	314	393	354	HL (40%) HLH (60%)
	ਢ										
1	ਢਿੱਡ /ʈìɖɖ/	0.12	0.14	0.13	233	316	275	608	633	621	HL
2	ਢੇਰ /ʈèr/	0.29	0.29	0.29	198	297	248	288	419	354	HL
3	ਢੋਲ /ʈòl/	0.32	0.36	0.34	223	303	263	226	272	249	HL (50%) HLH (50%)
4	ਢੰਗ /ʈə̃̀g/	0.23	0.27	0.25	219	300	260	288	279	284	HL
5	ਢਾਈ /ʈǎi/	0.45	0.46	0.46	205	301	253	190	321	256	HLH
6	ਢੂਈ /ʈǔi/	0.44	0.41	0.43	221	328	275	249	293	271	HLH
	Contd..										

S. No.	Word Text & IPA	Duration			F$_0$			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	
	ਧ										
1	ਧੰਨ /tə̀n/	0.15	0.16	0.16	231	308	270	273	427	350	HL
2	ਧੜ /tə̀ɽ/	0.19	0.23	0.21	228	299	264	282	371	327	HL
3	ਧਿਆਨ /tìan/	0.21	0.12	0.17	222	300	261	173	297	235	HL (50%) HLH (50%)
4	ਧੂੰਆਂ /tũ̌ã/	0.51	0.52	0.52	217	315	266	257	366	312	HLH
	ਭ										
1	ਭੁੱਖ /pʊ̀kkʰ/	0.14	0.12	0.13	230	322	276	653	891	772	HL
2	ਭੁੰਢ /pʊ̃̀ɖ/	0.30	0.29	0.30	230	319	275	244	352	298	HL

Table 3/11: Contour of Tone in Monosyllabic Words with Toneme as Onset

Falling tone is observed in the majority of the words. Example word ਝੱਗ /tʃə̀g/ Foam:

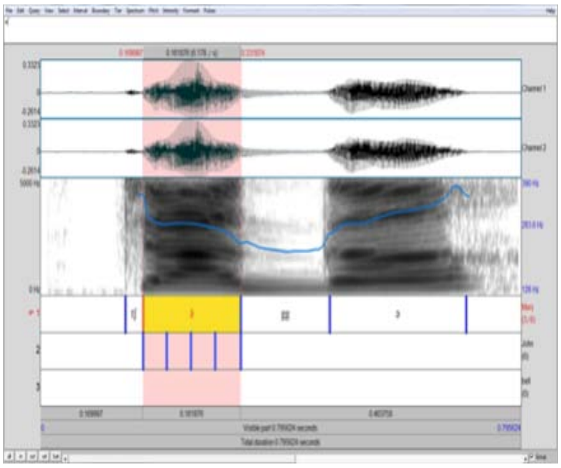


Fig 3/6: Male Sample - HL

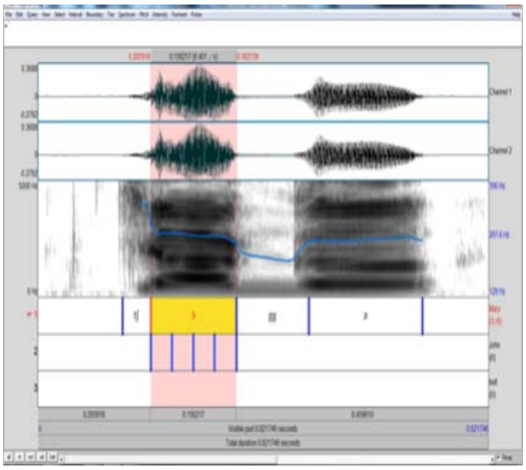


Fig 3/7: Female Sample - HL

3.2.2 Di/ Tri/ Poly-syllabic Words with Toneme as Onset in Initial Syllable

S. No.	Word Text & IPA	Duration			F0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
	ਘ										
1	ਘੋੜਾ /kòɖa/	0.20	0.21	0.21	210	284	247	298	294	296	HL
2	ਘੜੀ /kəɽi/	0.13	0.13	0.13	220	300	260	415	400	408	HL
3	ਘੱਸਾ /kə̀ssa/	0.08	0.07	0.08	213	307	260	655	479	567	HL
4	ਘਾਹੀ /kàhi/	0.17	0.20	0.19	211	285	248	349	330	340	HL
5	ਘੁੰਡੀ /kʊ̃̀ɖi/	0.20	0.23	0.22	221	306	264	492	475	484	HL
6	ਘਿੱਗੀ /kìggi/	0.09	0.09	0.09	226	312	269	782	670	726	HL
7	ਘੁੰਨਾ /kʊ̃̀na/	0.09	0.07	0.08	243	324	284	670	441	556	HL
8	ਘੇਰਾ /kèra/	0.21	0.22	0.22	218	293	256	281	297	289	HL
9	ਘੌਲੀ /kɔ̀li/	0.18	0.19	0.19	233	296	265	317	335	326	HL
10	ਘੋਟਾ /kòʈa/	0.13	0.14	0.14	226	299	263	566	486	526	HL
11	ਘੂਰਨਾ /kùrəna/	0.19	0.18	0.19	235	315	275	359	375	367	HL
	ਝ										
1	ਝੰਡਾ /tʃə̃̀ɖa/	0.18	0.21	0.20	221	290	256	336	403	370	HL
2	ਝਾੜੂ /tʃàɽu/	0.22	0.25	0.24	221	290	256	251	348	300	HL
3	ਝਿੜਕ /tʃiɽək/	0.11	0.14	0.13	240	320	280	323	448	386	HL
4	ਝਾਂਜਰ /tʃã̀dʒər/	0.22	0.26	0.24	213	290	252	357	433	395	HL
5	ਝੋਲੀ /tʃòli/	0.18	0.23	0.21	232	301	267	319	388	354	HL
6	ਝੂਠਾ /tʃùʈʰa/	0.16	0.18	0.17	234	300	267	522	549	536	HL
7	ਝੌਂਪੜੀ /tʃɔ̃̀pəɽi/	0.19	0.20	0.20	227	304	266	463	464	464	HL
8	ਝਗੜਾ /tʃə̀gəɽa/	0.11	0.13	0.12	229	305	267	487	665	576	HL
9	ਝੁਕਣਾ /tʃʊ̀kəɳa/	0.10	0.09	0.10	240	318	279	937	833	885	HL
	Contd..										

S. No.	Word Text & IPA	Duration			F0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
	ਢ										
1	ਢੱਕਣ t̪ə̀kkəɳ/	0.07	0.07	0.07	228	313	271	835	576	706	HL
2	ਢਿੱਲਾ /t̪ìlla/	0.09	0.08	0.08	235	328	282	503	552	528	HL
3	ਢਾਬਾ /t̪àba/	0.13	0.15	0.14	215	299	257	426	502	464	HL
4	ਢਾਡੀ /t̪àɖi/	0.14	0.17	0.16	223	304	264	420	463	442	HL
5	ਢਿੰਢੋਰਾ /t̪ɪ̃̀ɖòra/	0.13	0.15	0.14	211	311	261	477	495	486	HL
6	ਢਿਲਕਵਾਂ /t̪ìlkəʋã/	0.07	0.08	0.08	240	335	288	517	566	542	HL
7	ਢਹਿਣਾ /t̪ə̀heɳa/	0.09	0.12	0.11	225	310	268	537	352	445	HL
8	ਢੂੰਢਣਾ /t̪ũ̀ɖ́ ɳa/	0.17	0.20	0.19	231	304	268	476	488	482	HL
	ਧ										
1	ਧੋਬੀ /tòbi/	0.14	0.16	0.15	227	319	273	454	463	459	HL
2	ਧਨੁਸ਼ /tə̀nʊʃ/	0.06	0.08	0.07	224	320	272	386	506	446	HL
3	ਧੰਦਾ /tə̃̀da/	0.20	0.24	0.22	221	298	260	312	446	379	HL
4	ਧਨਾਢ/tə̀naɖ/	0.05	0.04	0.05	232	322	277	449	678	564	HL
5	ਧਰਮ /tə̀rəm/	0.11	0.14	0.13	235	308	272	348	424	386	HL
6	ਧੁੰਨੀ /tʊ̃̀ni/	0.11	0.08	0.10	242	339	291	458	529	494	HL
7	ਧੁੰਦਲਾ tʊ̃̀dəla/	0.15	0.16	0.16	228	312	270	507	600	554	HL
	ਭ										
1	ਭੰਗੀ /pə̃̀gi/	0.17	0.22	0.20	206	320	263	309	429	369	HL
2	ਭੌਂਦੂ /pɔ̃̀du/	0.23	0.25	0.24	226	309	268	332	454	393	HL
4	ਭਿੱਜਣਾ /pìdʒdʒɳa/	0.09	0.08	0.09	263	309	286	870	883	877	HL
5	ਭਸੂੜੀ /pə̀suɽi/	0.07	0.06	0.06	237	320	279	585	953	769	HL
6	ਭ੍ਰਿਸ਼ਟਾਚਾਰ /prìʃʈatʃar/	0.08	0.08	0.08	224	315	270	583	764	674	HL

Table 3/12: Contour of Tone in Di/ Tri/ Poly-syllabic Words with Toneme as Onset in Initial Syllable

The toneme as onset in the initial syllable of the word always bears a falling tone observed on the nucleus of the syllable e.g. ਢੱਕਣ /ʈə̀kkəɳ/ Cover

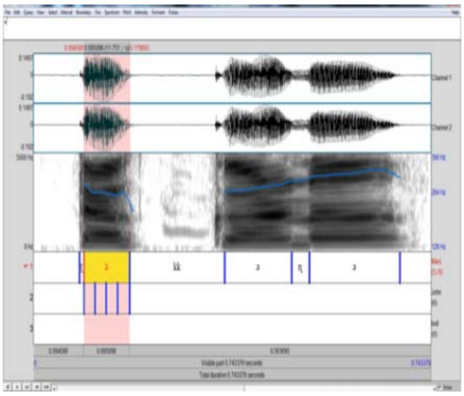


Fig 3/8: Male Sample - HL

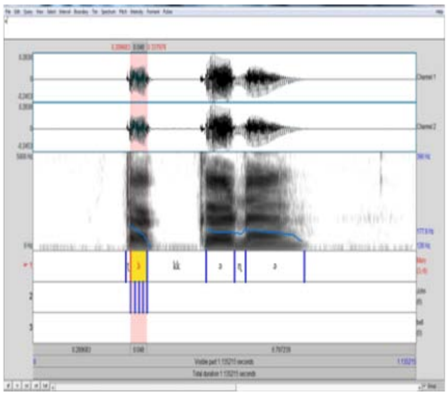


Fig 3/9: Female Sample - HL

Discussion

It has been discussed in literature survey that the toneme as onset in initial syllable leads to falling tone which is corroborated for mono/di/tri/poly-syllabic words as is evident from Table 3/11 & 3/12. There is no reference in the literature about toneme as coda in the initial syllable but experimentally rising tone has been observed in case of monosyllabic words (refer table 3/10). Falling-rising tone has been observed in words having dipthong as an open vowel however it is observed in 50% of the speakers only in case of closed syllable as can be seen in ਧਿਆਨ /tìan/ as an example.

In a monosyllabic word with toneme as onset and coda both, the toneme in coda gets substituted by corresponding voiced unaspirated consonant due to articulatory constraints e.g. ਭੁੰਢ /pù̃ ɖ/. Such words occur very infrequently.

The relevant Praat graphs are given in Appendix C.

The observations are summed up below:

S. No.	Acoustic environment	Tone observed	Allotones
1	Monosyllabic with tonemes as coda	Rising tone	-
2	Mono/ Di/ Tri/ Poly-syllabic with tonemes as onset • Dipthong in open syllable	Falling tone -	Falling-rising Falling-rising

Table 3/13: Tone Rules (refer Data Tables: 3/10, 3/11 & 3/12)

3.2.3 Tri/ Poly-syllabic Words with Toneme in Medial Syllable

S. No.	**Word Text & IPA**	**Duration**			**F_0**			**Slope**			**Contour of tone**
		M avg	**F avg**	**Avg**	**M avg**	**F avg**	**Avg**	**M avg**	**F avg**	**Avg**	**M & F**
	ਘ										
1	ਤਾਂਘਣਾ /tãgə́ṇ̣a /	0.08	0.08	0.08	225	319	272	264	467	366	LH
2	ਨਿਘਰਨਾ /nɪgə́rna/	0.10	0.10	0.10	223	313	268	290	327	309	LH
3	ਉਲੰਘਣਾ /ʊlə̃gə́ṇ̣a /	0.08	0.08	0.08	217	310	264	241	333	287	LH
4	ਊਂਘਣਾ /ũgə́ɳa/	0.09	0.25	0.17	232	317	275	291	414	353	LH
5	ਪੰਘਰਨਾ /pə̃gə́rna/	0.09	0.11	0.10	229	304	267	228	339	284	LH
6	ਨਿਘਾਰਨਾ /nɪgàrna/	0.24	0.23	0.24	206	296	251	212	300	356	HL
7	ਪੰਘੂੜਾ /pə̃gùɽa/	0.19	0.20	0.20	216	306	261	220	427	324	HL
8	ਖੰਘਾਲਣਾ /kʰə̃gàlɳa/	0.17	0.17	0.17	218	278	248	221	267	244	HL
	Contd..										

S. No.	Word Text & IPA	Duration			F_0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
	ਝ										
1	ਰਿੱਝਣਾ /rɪʤ ə́ɳa/	0.09	0.08	0.09	227	315	271	262	492	377	LH
2	ਸਾਂਝੀਦਾਰ /sãdʒídar/	0.10	0.10	0.10	212	301	257	335	482	409	LH
3	ਬੁੱਝਣਾ /bʊdʒə́ɳa/	0.08	0.09	0.09	228	309	269	198	406	302	LH
4	ਸਮਝਦਾਰੀ /səmdʒə́da ri/	0.06	0.09	0.08	210	307	259	269	382	326	LH
5	ਗਿਝਾਉਣਾ /gɪdʒàʊɳa/	0.23	0.27	0.25	216	302	259	161	258	210	HL
6	ਉਝਾਰਨਾ /ʊdʒàrna/	0.21	0.22	0.22	218	288	253	237	323	280	HL
	ਢ										
1	ਢੂੰਢਣਾ /ʈũ̀ɖə́ɳa /	0.08	0.08	0.08	210	286	248	192	238	215	LH
2	ਸੰਢਣਾ /sə̃ɖə́ɳa /	0.07	0.07	0.07	228	328	278	238	300	269	LH
3	ਹੰਢਣਸਾਰ /hə̃ɖə́ɳsar/	0.07	0.08	0.08	225	312	269	279	484	382	LH
4	ਸੁੰਢੋਲਾ /sʊ̃ɖèla/	0.17	0.18	0.18	226	306	266	275	349	312	HL
5	ਢਿੰਢੋਰਾ /ʈĩ̀ɖòra/	0.20	0.24	0.22	214	297	256	200	371	286	HL
6	ਬੁਢਾਪਾ /bʊɖàpa/	0.15	0.16	0.16	214	285	250	519	592	556	HL

Contd..

S. No.	Word Text & IPA	Duration			F$_0$			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
	ਧ										
1	ਕਿਧਰੋਂ /kɪʤ́ rõ/	0.05	0.06	0.06	244	320	282	289	526	408	LH
2	ਗੰਧਲਾ /gə̃ʤ́ la/	0.06	0.05	0.06	228	319	274	249	354	302	LH
3	ਚੌਧਰਪੁਣਾ /tʃɔdə́rpʊɳ a/	0.06	0.05	0.06	237	318	278	291	589	440	LH
4	ਅੰਧੇਰਾ /ə̃ʤ̀ ra/	0.19	0.20	0.20	222	304	263	204	336	270	HL
5	ਸਧਾਰਨ /sədàrən/	0.21	0.23	0.22	221	296	259	161	274	218	HL
	ਭ										
1	ਰੰਭਣਾ /rə̃bə́ɳ /	0.08	0.06	0.07	245	321	283	162	377	270	LH
2	ਲੱਭਣਾ /ləbbə́ɳa/	0.07	0.07	0.07	234	317	276	253	430	342	LH
3	ਨਿਭਾਉਣਾ /nɪbàʊɳa/	0.22	0.22	0.22	227	311	269	201	286	244	HL

Table 3/14: Contour of Tone in Tri/ Poly-syllabic Words with Toneme in Medial Syllable

It is observed from the above table:

- The medial syllable containing short vowel and toneme results in rising tone e.g. ਗੰਧਲਾ /gə̃də́la/ Muddy

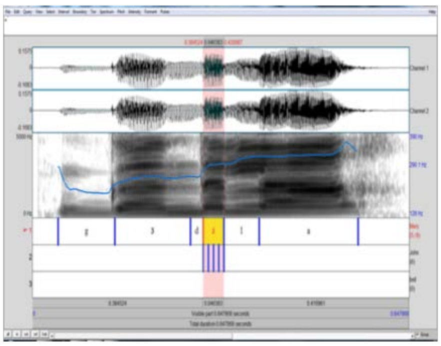


Fig 3/10: Male Sample - LH

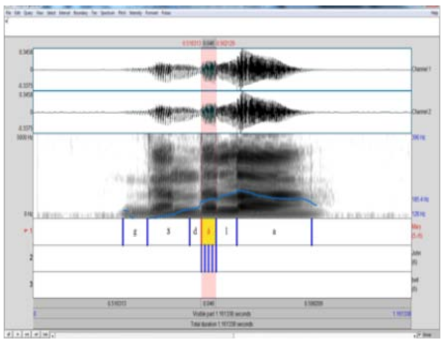


Fig 3/11: Female Sample - LH

- The medial syllable containing long vowel and Toneme results in falling tone e.g. ਸਧਾਰਨ /sədàrən/ Simple

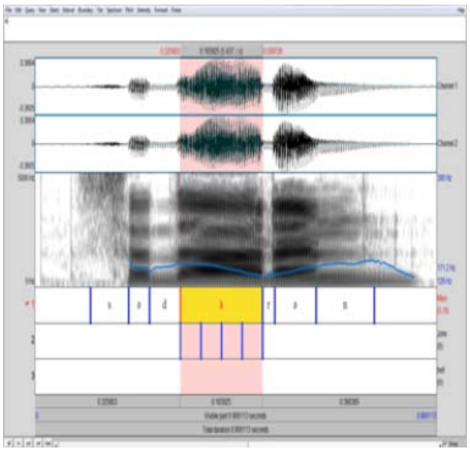


Fig 3/12: Male Sample - HL

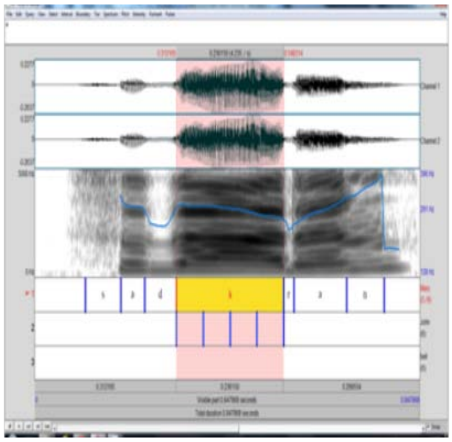


Fig 3/13: Female Sample - HL

Discussion

The rising / falling tone is observed in case of tonemes in medial syllable depending on whether the TBU is short / long vowel respectively.

The observations are summed up below:

S. No.	Acoustic environment	Tone observed	Allotones
1	Tri / Poly-syllabic with tonemes in medial syllable and short vowel as TBU	Rising	-
2	Tri / Poly-syllabic with tonemes in medial syllable and long vowel as TBU or dipthong (long + short)	Falling	-

Table 3/15: Tone Rules (refer Data Table: 3/14)

3.2.4 Di-syllabic Words with Toneme in Final Syllable

S. No.	Word Text & IPA	Duration			F_0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
	ਘ										
1	ਨਿੱਘਾ /nígga/	0.07	0.06	0.07	190	278	234	401	417	409	LH
2	ਕੰਘੀ /kə̃́gi/	0.06	0.22	0.19	209	300	255	283	233	258	LH
3	ਬੱਘੀ /bə́ggi/	0.07	0.07	0.07	193	263	228	287	293	290	LH
4	ਲਘੂ /lə́gu/	0.08	0.09	0.09	195	273	234	193	363	278	LH
5	ਅਨਘੜ /ənk ə̀ɽ/	0.13	0.16	0.15	219	306	263	404	343	374	HL
6	ਨਿਘਾਸ /nigăs/	0.39	0.39	0.39	216	299	258	186	386	286	HLH
7	ਚਿੰਘਾੜ /tʃĩgăɽ/	0.39	0.34	0.37	210	280	245	144	241	193	HLH
	ਝ										
1	ਹੰਝੂ /hə̃́dʒu/	0.16	0.19	0.18	193	278	236	349	243	296	LH
2	ਬੁੱਝੇ /bʊ́ dʒo/	0.08	0.08	0.08	194	280	232	358	639	499	LH
3	ਜੰਝੂ /dʒə̃́dʒu/	0.17	0.21	0.19	191	270	233	237	300	269	LH
4	ਅਝੱਕ /ətʃə̀kk/	0.12	0.13	0.13	229	313	271	511	488	500	HL
5	ਸੁਝਾਅ /sʊ̆dʒa/	0.45	0.36	0.41	203	301	252	180	287	234	HLH
6	ਸੁਝਾਈ /sʊdʒăi/	0.47	0.42	0.45	206	299	253	174	378	276	HLH
	ਢ										
1	ਸੀਂਢਲ /sĩɖ́ l/	0.10	0.13	0.12	207	247	277	146	254	200	LH
2	ਬੀਂਢਲ /bĩɖ ə́l/	0.15	0.16	0.16	235	331	283	146	228	187	LH
3	ਸੰਢਾ /sə̃́ɖ a/	0.18	0.21	0.20	205	318	262	227	341	284	LH
4	ਗੁਆਂਢਣ /gʊãɖ ə́ɳ/	0.08	0.13	0.11	226	336	281	190	268	229	LH
5	ਕੰਢਾ /kə̃́ɖa /	0.16	0.21	0.19	199	313	256	184	410	297	LH
6	ਚੂੰਢੀ /tʃṹɖi/	0.21	0.24	0.23	231	324	278	269	338	304	LH
	Contd..										

S. No.	Word Text & IPA	Duration			F$_0$			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
7	ਬੁੱਢਾ /bóɖɖa/	0.08	0.07	0.08	189	278	234	484	619	552	LH
8	ਗੁਆਂਢੀ /gʊə̃ɖi/	0.28	0.32	0.30	217	285	251	195	268	232	LH
9	ਧਨਾਢ /tə̀naɖ/	0.33	0.36	0.35	221	307	264	170	284	227	HL (60%) HLH (40%)
10	ਹੰਢਾਊ /hə̃ɖǎu/	0.44	0.43	0.44	219	285	252	165	318	242	HLH
11	ਕਢਾਈ /kəɖǎi/	0.48	0.45	0.47	223	300	262	162	348	255	HLH
	ਧ										
1	ਇੱਧਰ /ɪddə́r/	0.10	0.15	0.13	236	331	284	241	225	233	LH
2	ਮਧੁਰ /mədʊ́r/	0.17	0.17	0.17	195	334	265	219	304	262	LH
3	ਦੁਧੀਆ /dʊdîa/	0.38	0.36	0.37	229	318	274	207	291	249	LHL
4	ਅੱਧਾ /ə́dda/	0.30	0.23	0.27	224	268	246	238	547	393	LH
5	ਸੰਧੀ /sə̃́di/	0.17	0.21	0.19	205	304	255	228	312	217	LH
6	ਖਾਧਾ /kʰáda/	0.11	0.12	0.12	169	273	221	351	344	348	LH
7	ਗਧਾ /gə́da/	0.9	0.10	0.10	185	279	232	264	355	310	LH
8	ਗਿੱਧਾ /gídda/	0.06	0.06	0.06	184	279	232	457	571	514	LH
9	ਗੁੱਧਾ /gódda/	0.06	0.07	0.07	196	287	242	393	573	483	LH
10	ਪ੍ਰਧਾਨ /prədǎn/	0.35	0.38	0.37	191	295	243	149	239	194	HLH
11	ਕੰਧੂਈ /kə̃dǔi/	0.41	0.39	0.40	201	323	262	165	261	213	HLH
	ਭ										
1	ਦੁੱਭਰ /dʊbbə́r/	0.11	0.17	0.14	222	335	279	165	313	339	LH
2	ਗਰਭ /gərə́b/	0.11	0.15	0.13	187	292	240	219	413	316	LH
3	ਦੁਰਲੱਭ /dʊrlə́bb/	0.10	0.10	0.10	191	283	237	232	334	283	LH
	Contd..										

S. No.	Word Text & IPA	Duration			F0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
4	ਨਾਭੀ /nábi/	0.15	0.15	0.15	192	273	233	258	214	236	LH
5	ਟੋਭਾ /ʈóba/	0.15	0.13	0.14	209	292	251	217	349	283	LH
6	ਦੜਭਾ /də́ɽba/	0.0.09	0.11	0.10	208	264	236	232	275	254	LH
7	ਨਿਰਭੈ /nírbe/	0.11	0.10.	0.11	197	284	243	235	367	301	LH
8	ਅਭਿਆਸ /əbĭas/	0.40	0.41	0.41	189	302	246	184	369	277	HLH
9	ਗੰਭੀਰ /gə̃bì r/	0.27	0.30	0.29	222	295	259	208	420	314	HL

Table 3/16: Contour of Tones in Di-syllabic Words with Toneme in Final Syllable

The majority of the words reflect rising / falling tone depending on the context as per detail given below:

- Rising tone is observed in words having open final syllable. It is also observed that tone doesn't reflect on the open vowel in the end of a word and it shifts to the prior vowel e.g. ਨਾਭੀ /nábi/ Navel

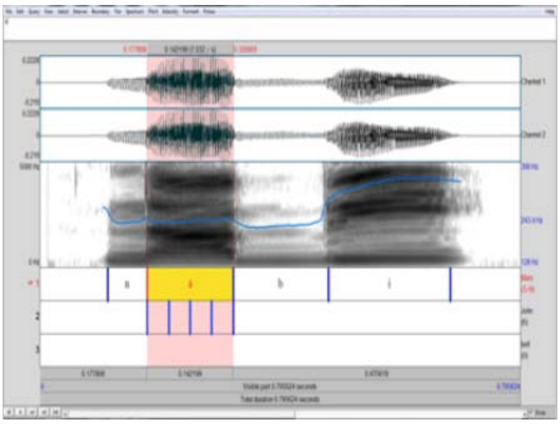


Fig 3/14: Male Sample - LH

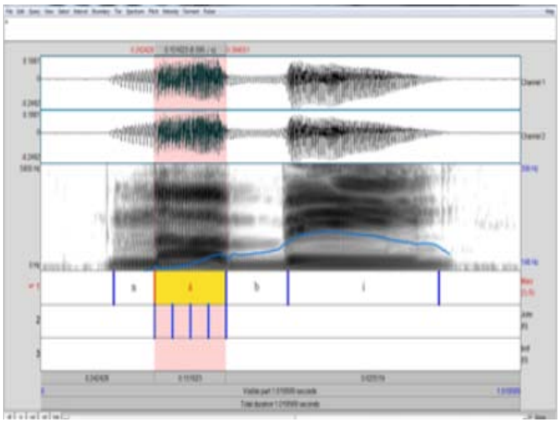


Fig 3/15: Female Sample - LH

- Falling tone is observed in words having closed final syllable e.g.
  ਗੰਭੀਰ /gə̃bìr/ Serious

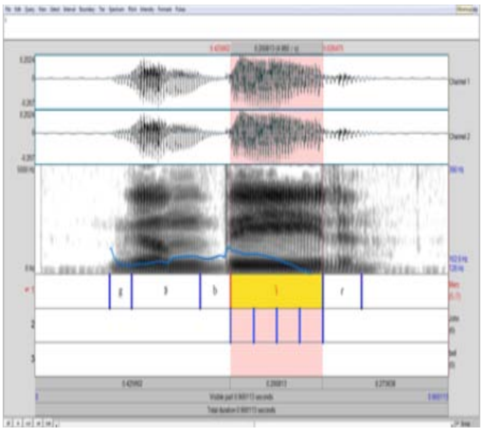


Fig 3/16: Male Sample - HL

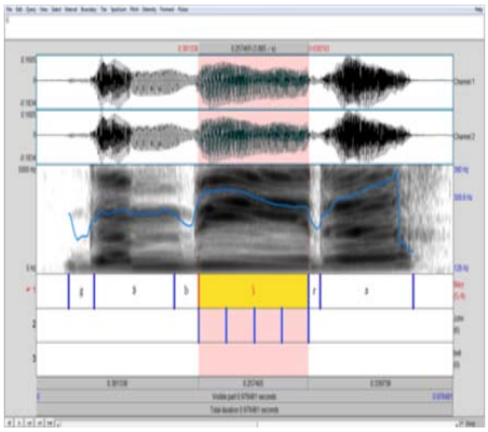


Fig 3/17: Female Sample - HL

Discussion

Rising tone has been observed in words having open final syllable. In addition, the tone gets shifted to prior vowel as investigated. Falling tone has been observed in words having closed final syllable. Falling-rising tone has been observed in words having dipthong (short + long) and (long + long) with an exception in ਦੁਧੀਆ /dʊdìa/ where rising-falling tone is observed. Falling-rising tone is observed in case of long vowel being TBU due to fricative, flap and nasal coda.

The observations are summed up below:

<table>
<tr><th rowspan="2">S. No.</th><th rowspan="2">Acoustic environment</th><th colspan="2">Tone observed</th><th rowspan="2">Allotones</th></tr>
<tr><th>Tone contour</th><th>Shifting of tone on prior vowel</th></tr>
<tr><td>1</td><td>Di-syllabic with toneme in final open syllable
• Dipthong (long + long)</td><td>Rising tone

Rising - falling</td><td>Yes</td><td>-</td></tr>
<tr><td>2</td><td>Di-syllabic with toneme as onset in final closed syllable
• Dipthong (short + long) and (long + long) and flap / fricative / nasal coda</td><td>Falling tone

Falling - rising</td><td>Not applicable</td><td>HLH</td></tr>
</table>

Table 3/17: Tone Rules (refer Data Table: 3/16)

3.2.5 Tone Patterns in Composite Words

S. No.	Word Text & IPA	Duration			F0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
1	**ਘ - ਘੱਲੂਘਾਰਾ /kə̀llukàra/**										
	ਘੱਲੂ /kə̀llu/ +	0.07	0.07	0.07	232	302	267	608	500	554	HL
	ਘਾਰਾ/kàra /	0.15	0.17	0.16	223	301	262	216	339	278	HL
	ਝ -ਝੁਨਝਨਾ /tʃòntʃə̀na/										
1	ਝੁਨ /tʃòn/ +	0.11	0.10	0.11	237	329	283	452	506	479	HL
	ਝਨਾ/tʃə̀na /	0.07	0.07	0.07	225	288	257	233	332	283	HL
	ਝ -ਰਿਮਝਿਮ /rɪmtʃim/										
2	ਰਿਮ /rɪm/ + ਝਿਮ /tʃim/	0.15	0.13	0.14	231	329	280	267	317	292	LH
	ਧ - ਨਾਮਧਾਰੀ /namtàri/										
1	ਨਾਮ /nam/ + ਧਾਰੀ /tàri/	0.15	0.16	0.16	226	317	272	254	338	296	HL
	ਭ - ਭੈਭੀਤ /pɛ̀pìt/										
1	ਭੈ /pɛ̀/ +	0.15	0.12	0.14	223	305	264	248	428	338	HL
	ਭੀਤ /pìt/	0.20	0.22	0.21	225	280	253	332	565	449	HL
	ਝ & ਘ - ਉਝਬੁਘ /ʊ́dʒbʊ́g/										
1	ਉਝ /ʊ́dʒ/ +	0.06	0.04	0.05	217	284	251	509	739	624	LH
	ਬੁਘ /bʊ́g/	0.09	0.10	0.09	226	321	286	185	564	338	LH

Table 3/18: Contour of tones in Composite Words

The tone rules as discussed in previous sections are fully applicable to the constituent members of the composite words. An example word is ਝੁਨਝੁਨਾ /tʃòntʃəna/ Sound making toy is shown below:

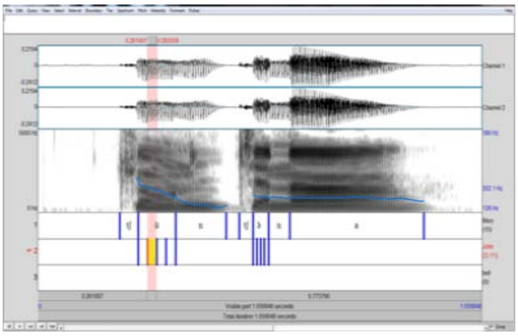


Fig 3/18: Male Sample - HL

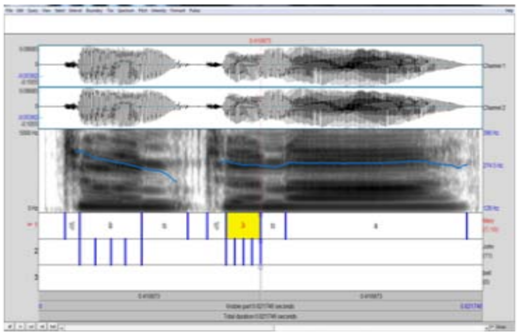


Fig 3/19: Female Sample - HL

3.2.6 Research Findings on Tone arising from Supra-Laryngeal Consonants

- As per literature survey the toneme in initial position leads to falling tone which has been corroborated experimentally and holds good for mono/ di/ tri/ poly-syllabic words with toneme as onset in the initial syllable. However falling-rising allotone has been observed in 50% cases. Falling-rising tone has been observed in all cases having dipthong as coda.
- In addition falling tone has also been observed in tri / poly-syllabic words with toneme in medial syllable and long vowel as TBU and dipthong (long + short). Falling tone has been observed in di-syllabic words with toneme as onset in final closed syllable. However falling-rising tone has been observed in dipthong (long + short) & (long + long) and flap / fricative / nasal coda.
- Mono-syllabic words with toneme as coda in initial syllable testify rising tone and rising tone has also been observed in tri / poly-syllabic words with toneme in medial syllable and short vowel as TBU.
- In addition rising tone has also been observed in di-syllabic words with toneme in final open syllable. Rising-falling tone has been observed in dipthong (long + long vowel).

These findings are summed up in the table below:

Occurrence of Toneme in	**Acoustic environment**	**Tonal Variations**
Initial syllable	1. Monosyllabic with toneme as coda 2. Monosyllabic with toneme as onset • Dipthong	LH (100%) HL (50%), HLH (50%) HLH (100%)
	Tri / Poly-syllabic with toneme as onset	HL (100%)
Medial syllable	1. Tri-syllabic with toneme and short as TBU 2. Tri-syllabic with toneme and long vowel as TBU or dipthong (long + short vowel)	LH (100%) HL (100%)
Final syllable	1. Di-syllabic with toneme in final open syllable With Dipthong (long + long) 2. Di-syllabic with final closed syllable • Toneme as onset • Toneme as coda • Dipthong (short + long) and (long + long) and flap / fricative / nasal coda	LH (100%) (tone shifts to prior vowel) LHL (100%) HL (100%) HL (60%), HLH (40%) HLH (100%)

Table 3/19: Rules for Tone arising from Supra-Laryngeal Consonants

3.3 Experimental Analysis of Independent Tones

In this case, the words containing consonant ਹ /h/ in Initial/Medial/Final syllable and conjuncts of /ɦ/ in the medial/final syllable only were gathered as conjuncts of /ɦ/ in the initial syllable doesn't orthographically occur. Initial /h/ is extensively used in orthography and as per literature survey it is considered non-tonal, which will be verified. The data sampling for study of independent tones is as below:

Words Consisting of	**Mono syllabic**	**Disyllabic**		**Trisyllabic**			**Polysyllabic**		**Total**
		Initial	**Final**	**Initial**	**Medial**	**Final**	**Initial**	**Medial**	
Consonant /h/	15	15	16	6	16	3	-	3	74
Conjuncts of /ɦ/	1	-	6	-	8	-	-	2	17
Sub-Total	16	15	22	6	24	3	-	5	91
Total	16	37		33			5		

Table 3/20: Size of Data Samples for study of Independent Tones

The corresponding word lists are given in Appendix A.

Data Collation and Presentation

The spectrographic analysis using PRAAT of all the male & female samples was carried out. The duration, fundamental frequency (F_0), quarter wise slope of the vowel associated with the Tone (TBU) have been recorded. The observations on contour of the tone over TBU have been tabulated. The tabulation of data has been done for two categories of words (consonant /h/ & conjuncts of /ɦ/) capturing the variety of acoustic environments as discussed in section 3.1.3 for studying the nature of the tone associated accross the male and female speakers.

These tones can be broadly divided into two categories:

3.3.1 Tone Variations Associated with Consonant /h/

Recording of Data Sheets

The phoneme level annotated data of above samples was used for recording various acoustic parameters as discussed in section 3.1.3. Sample data sheets are given below:

Sample Data Sheet 1 (consonant /h/): ਤਬਾਹ /təbâ/

Male Speakers	F_0 in (Hz/sec)	Slope in (Hz/sec)	Cross – Sectional slope of TBU (Hz/sec)				Contour of Tone	Duration of TBU
			25%	*25%*	*25%*	*25%*		
M1	167	244	134	169	188	177	LHL	0.45
M2	245	168	232	241	257	249	LHL	0.40
M3	217	156	212	224	220	211	LHL	0.43
M4	170	318	175	171	183	150	LHL	0.29
Average	**200**	**222**	**188**	**201**	**212**	**197**	**LHL**	**0.39**

Table 3/21: Data Sheet of Male Speakers

Female Speakers	F_0 in (Hz/sec)	Slope in (Hz/sec)	Cross – Sectional slope of TBU (Hz/sec)				Contour of Tone	Duration of TBU
			25%	*25%*	*25%*	*25%*		
F1	269	202	247	257	276	296	LH	0.35
F2	296	524	270	275	307	334	LH	0.27
F3	287	457	245	257	297	349	LH	0.37
F4	300	224	269	293	317	321	LH	0.39
F5	352	194	322	346	369	370	LH	0.40
F6	252	232	241	246	255	266	LH	0.23
Average	**293**	**306**	**266**	**279**	**304**	**323**	**LH**	**0.34**

Table 3/22: Data Sheet of Female Speakers

Sample Data Sheet 2 (conjuncts of /ɦ/): ਖੁਲ੍ਹਣਾ /kʰuləɳa/

Male Speakers	F_0 in (Hz/sec)	Slope in (Hz/sec)	Cross – Sectional slope of TBU (Hz/sec)				Contour of Tone	Duration of TBU
			25%	25%	25%	25%		
M1	189	180	183	188	192	193	LH	0.08
M2	274	44	273	273	274	274	LH	0.08
M3	254	226	248	254	257	258	LH	0.09
M4	225	223	219	222	228	231	LH	0.08
Average	**236**	**168**	**231**	**234**	**238**	**239**	**LH**	**0.08**

Table 3/23: Data Sheet of Male Speakers

Female Speakers	F_0 in (Hz/sec)	Slope in (Hz/sec)	Cross – Sectional slope of TBU (Hz/sec)				Contour of Tone	Duration of TBU
			25%	25%	25%	25%		
F1	289	309	279	285	292	300	LH	0.09
F2	318	490	306	315	323	330	LH	0.07
F3	329	407	316	326	334	339	LH	0.08
F4	307	204	302	308	310	310	LH	0.07
F5	328	235	321	325	331	335	LH	0.08
F6	299	190	294	296	301	305	LH	0.09
Average	**312**	**306**	**303**	**309**	**315**	**320**	**LH**	**0.08**

Table 3/24: Data Sheet of Female Speakers

3.3.1.1 Monosyllabic Words

S. No.	Word Text & IPA	Duration			F_0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
1	ਖੋਹ /kʰó/	0.43	0.35	0.39	212	319	266	229	348	289	LH (60%) LHL (40%)
2	ਗਾਹ /gá/	0.51	0.31	0.41	192	284	238	191	361	276	LH (60%) LHL (40%)
3	ਆਹ /á/	0.37	0.25	0.31	192	271	232	242	373	308	LH (50%) LHL (50%)
4	ਚਾਹ /tʃá/	0.43	0.34	0.39	200	300	250	347	319	333	LH (50%) LHL (50%)
5	ਛੋਹ /tʃʰó/	0.42	0.32	0.37	199	299	249	220	598	409	LH (50%) LHL (50%)
6	ਵਾਹ /vá/	0.31	0.29	0.30	192	276	234	216	502	359	LH (50%) LHL (50%)
7	ਲੋਹ /ló/	0.43	0.29	0.34	217	287	252	214	472	404	LH (30%) LHL (70%)
8	ਕੋਹ /kó/	0.48	0.29	0.39	199	311	255	188	434	311	LH (20%) LHL (80%)
9	ਖੂਹ /kʰú/	0.43	0.33	0.38	219	310	265	231	541	386	LH (20%) LHL (80%)
	Concluding the nature of tone across above 9 words										LH (50%) LHL (50%)
10	ਢੋਹ /ʈǒ/	0.44	0.36	0.40	201	298	250	297	420	359	HL (30%) HLH (70%)
11	ਢਾਹ /ʈǎ/	0.36	0.36	0.36	199	283	241	250	380	315	HL (20%) HLH (80%)
12	ਸਹਿ /sě/	0.24	0.22	0.23	198	289	244	333	522	428	LHL (30%) HLH (70%)

Table 3/25: Contour of Independent tone in Mono-syllabic Words

The tone variations may be seen from the following examples:

- ਚਾਹ /tʃâ/ To wish – observed LH in 50% of the speakers and allotone LHL in rest 50% of the speakers

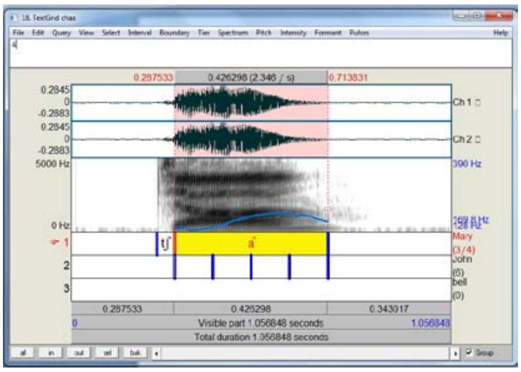


Fig 3/20: Male Sample - LHL

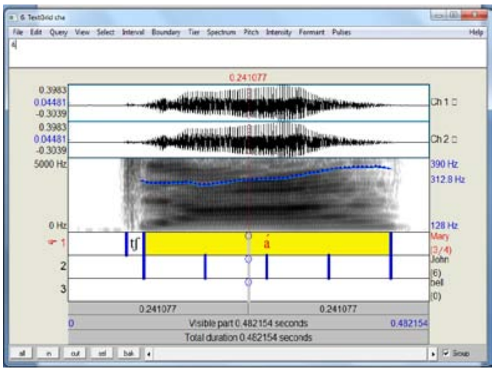


Fig 3/21: Female Sample - LH

- ਢਾਹ /ṭă/ Fall - allotone HLH observed in 80% of the speakers, toneme being onset of the monosyllabic word whereas HL is seen only in 20% of the speakers

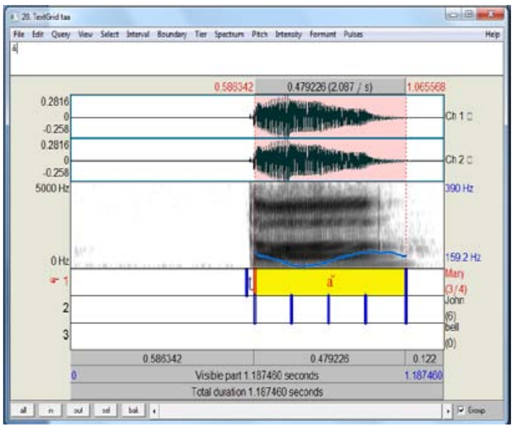


Fig 3/22: Male Sample - HLH

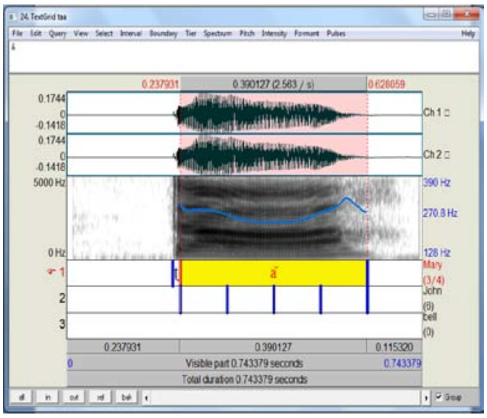


Fig 3/23: Female Sample - HLH

Discussion

The tones reported by linguists as discussed in section 3 indicate high tone in ਚਾਹ /tʃá/. The data above indicates that consonant /h/ when orthographically attached as a coda in the monosyllabic words results in allotone (LHL) in 50% of the speakers. The variation in tone pattern observed due to onset being a toneme reflects the presence of falling tone coupled with allotone HLH in 75% cases. The fricative onset in case of ਸਹਿ /sɛ̌/ leads to two allotones viz LHL in 30% speakers and HLH in 70% speakers.

The above observations are summed up below:

S. No.	Acoustic environment	Tone observed	Allotones
1	Monosyllabic with consonant /h/ as coda	Rising tone	Rising-falling in 50% of the speakers
2	Monosyllabic with consonant /h/ as coda and toneme as onset	Falling tone	Falling-rising in 75% of the speakers
3	Monosyllabic with consonant /h/ as coda and fricative consonant as onset	-	Rising-falling in 30% Falling-rising in 70% of the speakers

Table 3/26: Tone Rules (refer Data Table: 3/25)

3.3.1.2 Di-syllabic Words (with consonant /h/ as coda in initial syllable)

S. No.	Word Text & IPA	Duration			F_0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
1	ਇਹਨਾਂ /énã/	0.15	0.16	0.15	142	252	197	171	326	248	LH (40%) NT (60%)
2	ਆਹਲਾ /ála/	0.18	0.13	0.15	141	230	185	155	149	152	LH (50%) NT (50%)
	Composite word: ਸਹਿਸੁਭਾ /sɛ̆subà/										
1	ਸਹਿ /sɛ̆/ + ਸੁਭਾ/subà/	0.20	0.18	0.19	182	264	223	414	441	427	HLH (60%) NT (40%)

Table 3/27: Contour of Independent Tone in Di-syllabic Words (with consonant /h/ as coda in initial syllable)

Discussion

The tone reported by linguists taking ਇਹਨਾਂ /énã/, as an example, as discussed in section 3 indicate high tone considering presence of orthographic consonant /h/ being in the medial syllable, however as per the hypothesis of word categorization followed in the present investigation, orthographically consonant /h/ is onset in the initial syllable of this disyllabic word. Rising tone is observed in 40% of the speakers. It is observed while annotating the data that 60% of the speakers (50% male & 50% female) have articulated consonant /h/ which reveals the trend of loss of tone amaong some speakers. Similarly it is observed that 50% of the speakers have recorded ਆਹਲਾ /ahəla/ as non-tonal and rising tone is observed in the rest.

ਸਹਿ /sɛ̌/ is monosyllabic (first part of the composite word viz ਸਹਿਸੁਭਾ /sɛ̌subà/) which was discussed in section 3.3.1.1. Accordingly HLH tone has been observed in 60% of the speakers and rest of the speakers has pronounced the consonant /h/.

The above observations are summed up below:

S. No.	Acoustic environment	Tone observed	Allotones
1	Di-syllabic with consonant /h/ as coda in initial syllable	Rising	-
2	Composite word with consonant /h/ as coda in initial syllable	-	Falling-rising

Table 3/28: Tone Rules (refer Data Table: 3/27)

3.3.1.3 Di / Tri-syllabic Words (with consonant /h/ as coda in final syllable)

S. No.	Word Text & IPA	Duration			F_0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
1	ਤਬਾਹ /təbá/	0.39	0.34	0.40	200	293	264	222	306	217	LH (60%) LHL (40%)
2	ਤਰਾਹ /tərá/	0.39	0.32	0.36	196	216	206	188	521	355	LH (80%) NT (20%)
3	ਵਸਾਹ /vəsá/	0.40	0.29	0.35	209	244	227	212	485	349	LH (80%) LHL (20%)
4	ਵਿਆਹ /vɪá/	0.43	0.35	0.39	194	293	244	233	329	281	LH (80%) LHL (20%)
5	ਵਿਦਰੋਹ /vɪdəró/	0.40	0.29	0.35	219	223	221	185	442	314	LH (40%) LHL (40%) NT (20%)

Table 3/29: Contour of Independent Tone in Di/Tri-syllabic Words (with consonant /h/ as coda in final syllable)

In the trisyllabic word ਵਿਦਰੋਹ /vɪdəró/ rebellion, allotone LHL is observed in 40% of the speakers, whereas LH is seen in 40% of the speakers and 20% of the speakers have pronounced the consonant /h/.

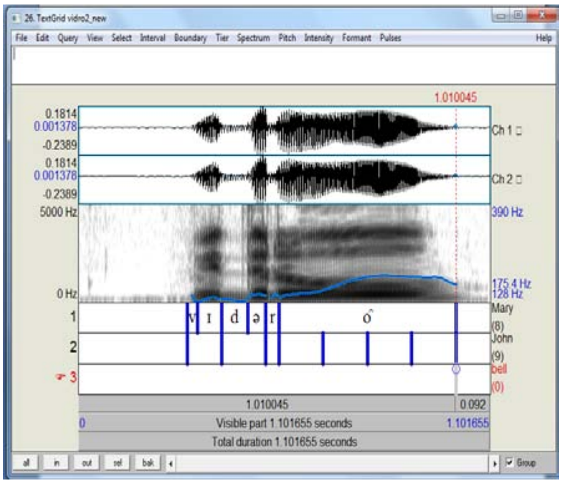


Fig 3/24: Male Sample - LHL

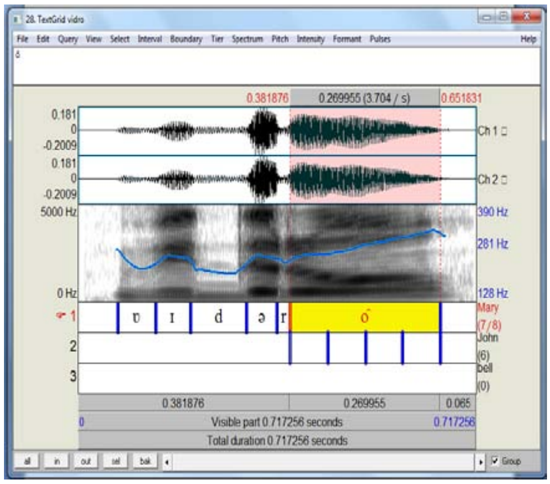


Fig 3/25: Female Sample - LH

Discussion

Rising tone was observed in 70% of the speakers and rising-falling in 20% speakers. A trend of loss of these tones has been observed.

S. No.	Acoustic environment	Tone observed	Allotones
1	Di-syllabic / Tri-syllabic with consonant /h/ as coda in final syllable	Rising	Rising-falling

Table 3/30: Tone Rules (refer Data Table: 3/29)

3.3.1.4 Independent Tone Rules Associated with Consonant /h/

Based on the above discussions, the tone rules are summed up below:

S. No.	Independent Tone	Corroboration of tone	Acoustic environment	Observations on tone variations / Allotone
1	Consonant /h/	LH	Monosyllabic with consonant /h/ as coda	LHL (50%)
			• Fricative onset	HLH (70%) LHL (30%)
			• Composite word with consonant /h/ in initial syllable	HLH (60%) NT (40%)
			Di-syllabic with consonant /h/ as coda in initial syllable	-
			Di / Tri-syllabic with consonant /h/ as coda in final syllable	LHL (20%)
2		NA	Monosyllabic with consonant /h/ as coda and toneme as onset	HLH (75%) HL (25%)

Table 3/31: Independent Tone Rules associated with Consonant /h/ and Allotone Variations

3.3.2 Tone Variations Associated with Conjuncts of /ɦ/

3.3.2.1 Monosyllabic Words

S. No.	Word Text & IPA	Duration			F_0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
1	ਗੋਲ੍ਹ /gól/	0.29	0.31	0.30	207	288	248	241	210	226	LH (100%)

Table 3/32: Contour of Tone in Mono-syllabic Words

Discussion

Rising tone is observed based on the single word examined as such words are infrequently used in the language.

3.3.2.2 Tri / Poly-syllabic words Conjunct containing /ɦ/ in Medial Syllable

S. No.	Word Text & IPA	Duration			F_0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
1	ਖਮ੍ਹਣੀ /kʰəmə́ɳi/	0.07	0.06	0.07	238	300	269	284	489	387	LH (100%)
2	ਖਰ੍ਹਵਾ /kʰərə́va/	0.06	0.06	0.06	184	286	235	326	270	298	LH (100%)
3	ਖੁਲ੍ਹਣਾ /kʰʊlə́ɳa/	0.08	0.08	0.08	236	312	274	168	306	237	LH (100%)
4	ਖੁੱਲ੍ਹਵਾਂ /kʰʊllə́vã/	0.05	0.06	0.06	224	315	270	286	326	324	LH (100%)
5	ਸਿੰਨ੍ਹਣਾ /sĩnə́ɳa/	0.08	0.08	0.08	230	311	271	201	257	229	LH (50%) LHL (50%)
6	ਗੜ੍ਹਕਣਾ /gəɽə́kəɳa/	0.02	0.02	0.02	205	298	252	836	733	785	LH (30%) LHL (70%)
7	ਸਲ੍ਹਾਬਾ /səlàba/	0.13	0.13	0.13	219	295	257	333	417	375	HL (100%)
8	ਤਮ੍ਹਾਤੜ /təmàtəɽ/	0.13	0.12	0.13	224	291	258	318	364	341	HL (100%)
9	ਪੜ੍ਹਾਉਣਾ /pəɽàʊɳa/	0.23	0.23	0.23	247	294	271	195	263	229	HL (100%)
10	ਖਲ੍ਹਾਰਨਾ /kʰəlàrna/	0.19	0.20	0.20	194	264	229	123	215	169	HL (100%)

Table 3/33: Contour of tone associated with Conjunct of /ɦ/ in Medial Syllable in Tri / Poly-syllabic Words

It is observed from the above table:

- The medial syllable containing short vowel and conjunct of /ɦ/ results in rising tone e.g. ਖਮ੍ਹਣੀ /kʰəmə́ɳi/ Multicoloured yarn

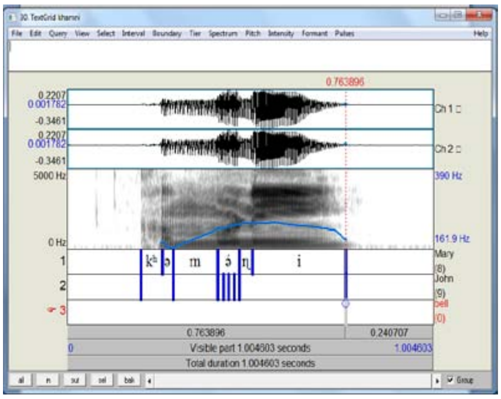


Fig 3/26: Male Sample - LH

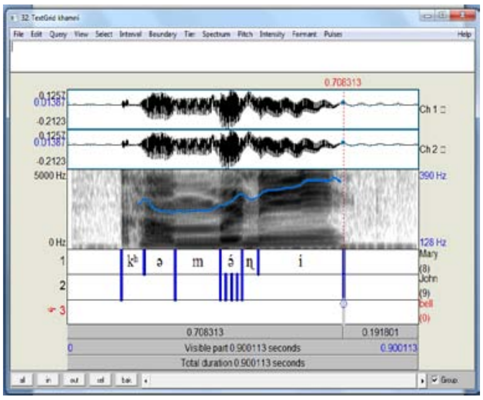


Fig 3/27: Female Sample - LH

- The medial syllable containing long vowel and conjunct of /ɦ/ results in falling tone e.g. ਸਲ੍ਹਾਬਾ /səlàba/ Seepage

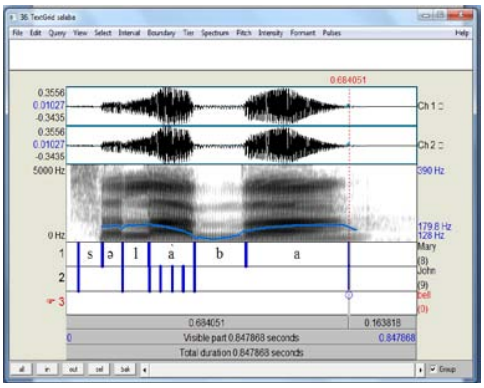


Fig 3/28: Male Sample - HL

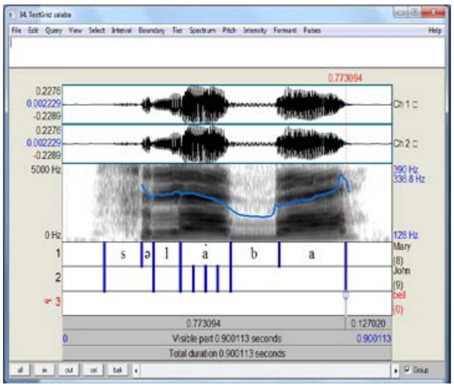


Fig 3/29: Female Sample - HL

Discussion

The rising / falling tone is observed incase conjunct of /ɦ/ in medial syllable depending on whether the TBU is short / long vowel as in the case of tonemes in the same acoustic environment as discussed in section 3.1.3. Rising-falling allotone is observed in case of short vowel being TBU due to flap and nasal onset.

The observations are summed up below:

S. No.	Acoustic environment	Tone observed	Allotones
1	Tri / Poly-syllabic with conjunct of /ɦ/ in medial syllable and short vowel as TBU	Rising	Rising-falling
2	Tri / Poly-syllabic with conjunct of /ɦ/ in medial syllable and long vowel as TBU or dipthong (long + short)	Falling	-

Table 3/34: Tone Rules (refer Data Table: 3/33)

3.3.2.3 Di-syllabic Words Containing Conjunct of /ɦ/ in Final Syllable

S. No.	Word Text & IPA	Duration			F_0			Slope			Contour of tone
		M avg	F avg	Avg	M avg	F avg	Avg	M avg	F avg	Avg	M & F
1	ਗਾਲ੍ਹੜ /galə́ɽ/	0.10	0.13	0.12	233	320	277	169	325	247	LH (60%) LHL (40%)
2	ਗੁੰਮ੍ਹੜ gũmə́ɽ/	0.11	0.13	0.12	235	324	280	208	264	236	LH (70%) LHL (30%)
3	ਜਿਲ੍ਹਣ /dʒɪlə́ɳ/	0.11	0.12	0.12	236	315	276	161	210	186	LH (50%) LHL (50%)
4	ਠੁਲ੍ਹਾ /ʈʰʊlá/	0.22	0.20	0.21	206	322	264	123	182	153	LH (50%) LHL (50%)
5	ਪੜ੍ਹਿਆ /pəɽía/	0.38	0.32	0.35	224	308	266	181	286	234	LH (50%) LHL (50%)
6	ਪੜ੍ਹਾਈ /pəɽăi/	0.47	0.41	0.44	198	295	247	158	299	229	HLH (100%)

Table 3/35: Contour of Tone in Di-syllabic Words containing Conjunct of /ɦ/ in Final Syllable

- LH is observed in words having final syllable in 50% of the speakers and LHL is observed in rest 50% e.g. ਗਾਲ੍ਹੜ /galə́ɽ/ Squirrel

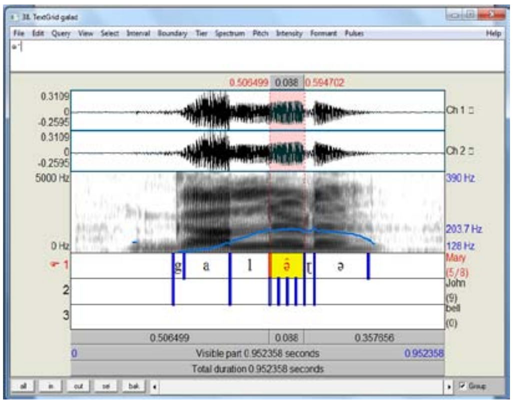


Fig 3/30: Male Sample - LHL

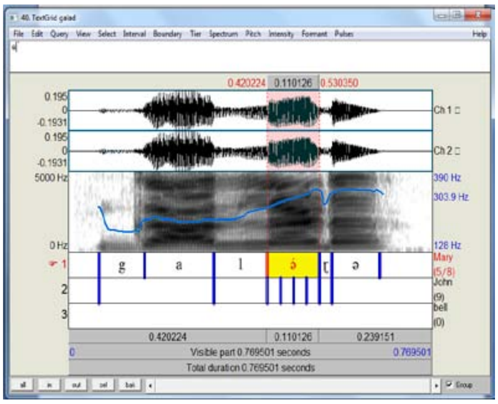


Fig 3/31: Female Sample - LH

Discussion

Rising tone is observed in 50% cases and allotone rising-falling in rest 50%. In case of dipthong (long vowel + long vowel), falling-rising tone is observed.

The observations are summed up below:

S. No.	Acoustic environment	Tone observed	Allotones
1	Di-syllabic with conjunct containing /ɦ/ in final syllable or dipthong (short + long vowel)	Rising	Rising-falling
2	Di-syllabic with conjunct containing /ɦ/ in final syllable followed by dipthong (long + long vowel)	Falling-rising	-

Table 3/36: Tone Rules (refer Data Table: 3/35)

3.3.2.4 Independent Tone Rules Associated with Conjunct of /ɦ/

Based on the above discussions, the tone rules are summed up below:

S. No.	Independent Tone	Corroboration of tone	Acoustic environment	Observations on tone variations / Allotone
1	Conjunct of /ɦ/	LH	Monosyllabic with conjuncts of /ɦ/ in final position	-
			Di-syllabic with conjuncts of /ɦ/ in final syllable or dipthong (short + long)	LHL (50%)
			Open syllable with dipthong (long + long)	HLH (100%)
			Tri / Poly-syllabic with conjuncts of /ɦ/ in medial syllable containing short vowel	-
			Flap / nasal onset	LHL (60%)
2		HL	Tri / Poly-syllabic with conjuncts of /ɦ/ in medial syllable containing long vowel or dipthong (long + short vowel)	-

Table 3/37: Tone Rules associated with Conjunct of /ɦ/ and Allotone Variations

3.3.3 Non-Tonal (NT) Occurrences of Consonant /h/

In section 3 discussed that /h/ in initial position is non-tonal Sangha (2014). The following data was analysed to verify it.

S. No.	Word	IPA transcription	Meaning	S. No	Word	IPA transcription	Meaning
1	ਹਉਕਾ	/hɔka/	Sigh	1	ਹਸਬ	/həsəb/	law
2	ਹਗਾਰ	/həgar/	Excreta of houseflies	2	ਹਜ਼ਮ	/həzəm/	Digested
3	ਹਿਸਾਬ	/hɪsab/	calculation	3	ਹਿਕਾਇਤੀ	/hɪkaɪti/	Apologal
4	ਹਿਮਾਚਲ	/hɪmatʃl/	Himachal Pradesh	4	ਹੁਨਰ	/hʊnər/	Art, skill,
5	ਹੁਲਾਰਾ	/hʊlara/	Swing	5	ਹਾਕਮ	/hakəm/	Ruler
6	ਹਾਜਰ	/hadʒər/	Present	6	ਹੀਆ	/hia/	courage
7	ਹੀਟਰ	/hiʈər/	Heater	7	ਹੂਕਣਾ	/hukəɳa/	To raise
8	ਹੂਰਾ	/hura/	buffet	8	ਹੈਸੀਅਤ	/hɛsiət/	Status
9	ਹੈਵਾਨ	/hɛvan/	uncivilized person	9	ਹੋਛਾ	/hotʃʰa/	Mean
10	ਹੋਰ	/hor/	More, else	10	ਹੌਸਲਾਮੰਦ	/hɔslamə̃d/	Patience
11	ਹੌਜ	/hɔdʒ/	Water tank	11	ਅਹੰਕਾਰ	/əhə̃kar/	Pride
12	ਅਹਾਰ	/əhar/	Food, diet	12	ਅਹਿੰਸਕ	/əhĩsək/	Peaceful
13	ਅਹਿੰਸਾਵਾਦ	/əhĩsavad/	Doctrine	13	ਇਸ਼ਤਿਹਾਰ	/ɪʃtehar/	Poster
14	ਇਤਿਹਾਸ	/ɪtehas/	History	14	ਸਾਹਿਤ	/sahɪt/	Literature
15	ਸਾਹਿਬ	/saheb/	Master	15	ਸੁਹਿਰਦ	/sʊhɪrd/	kind, gentle
16	ਸੁਹੇਲਾ	/sʊhela/	Soothing	16	ਸ਼ਹਾਦਤ	/ʃəhadət/	Martyrdo m
17	ਸ਼ਹੀਦ	/ʃəhid/	Martyr	17	ਔਹਰ	/ɔhər/	Diseases
18	ਅਹਿਦ	/ɛhəd/	Resolve	18	ਅਹਿਦਨਾਮਾ	/ɛhədnama/	Treaty
19	ਆਹਰ	/ahər/	Impulse	19	ਆਹਲਾ	/ála/	Superior
20	ਇਹਨਾਂ	/énã/	These	20	ਇਮਤਿਹਾਨ	/ɪmtehan /	Test
21	ਸਹਿਸੁਭਾ	/sèsubà/	Naturally	21	ਸਾਹਸ	/sahəs/	Courage
22	ਸਿ ਹਤਮੰਦ	/sehətəmə̃d/	Healthy	22	ਸਿਹਰਾ	/sehəra/	Honour
23	ਸੁਹਜ	/sʊhədʒ/	Grace	23	ਸੁਹਣਾ	/sohəɳa/	Good looking
24	ਸੁਹਾਗਾ	/sʊhaga/	Borax	24	ਸ਼ਹਿਤੂਤ	/ʃɛhətut/	Mulburry

S. No.	Word	IPA transcription	Meaning	S. No	Word	IPA transcription	Meaning
25	ਸ਼ਹਿਰ	/ʃɛhər/	City, town	25	ਸ਼ਾਹਦੀ	/ʃahədi/	Testimon y
26	ਸ਼ੌਹਰ	/ʃɔhər/	Husband	26	ਸਹਾਇਕ	/səhaɪk/	Assistant
27	ਸਹਾਇਤਾ	/səhaɪta/	support	27	ਸਹਾਈ	/səhai/	Who provides help
28	ਸਹਾਰਨਾ	/səharna/	Bear	28	ਸਹਾਰਾ	/səhara/	Support
29	ਸਹਿਜ	/sɛhədʒ/	Easy				

Table 3/38: Words with Non-Tonal Consonant /h/

Discussion

The acoustic environment in which /h/ is non-tonal i.e. mono/ di/ tri/ poly-syllabic having consonant /h/ as onset in associated syllable. Some sample graphs are given below:

Monosyllabic ਹੋਰ /hor/ More

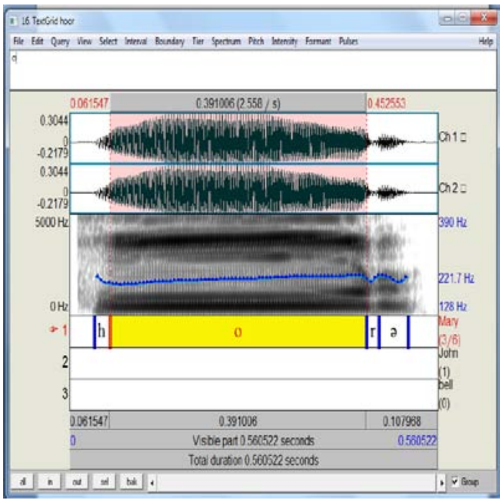


Fig 3/32: Male Sample - NT

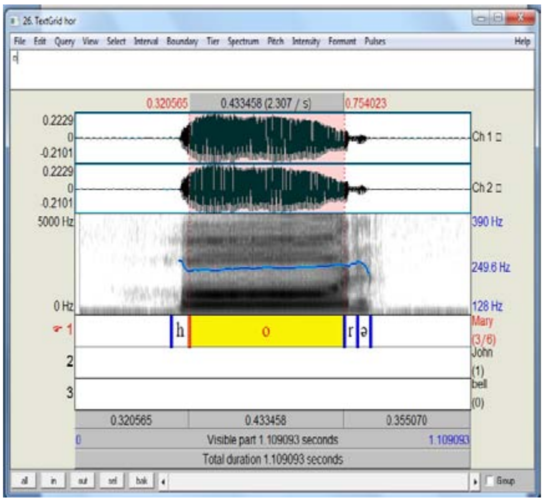
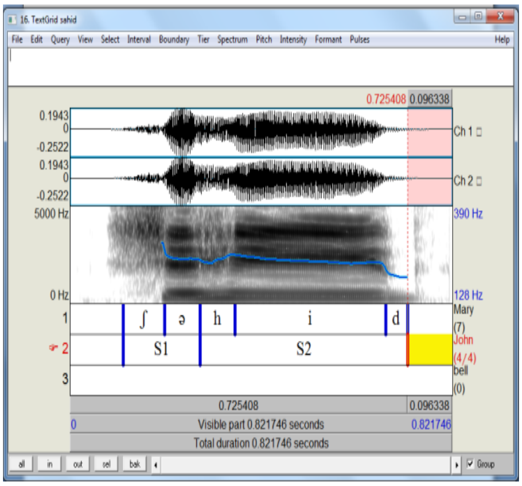


Fig 3/33: Female Sample - NT

Disyllabic ਸ਼ਹੀਦ /ʃəhid/ Martyr



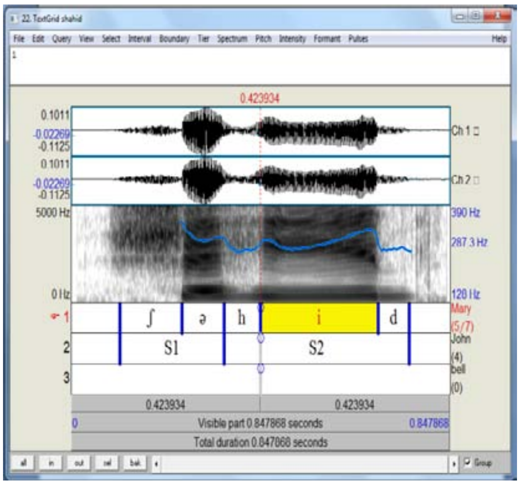
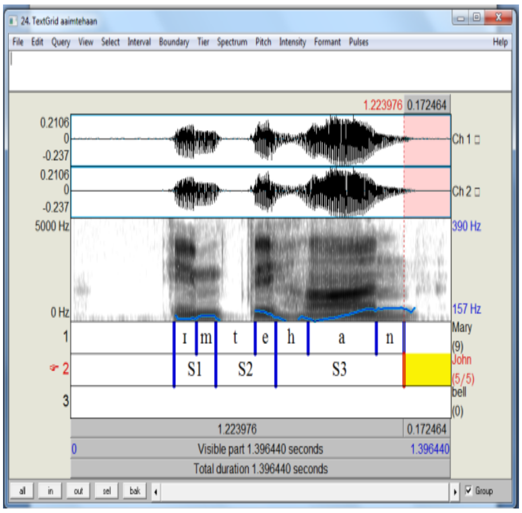


Fig 3/34: Male Sample - NT

Fig 3/35: Female Sample - NT

Trisyllabic ਇਮਤਿਹਾਨ /ɪmtehan/ Examination



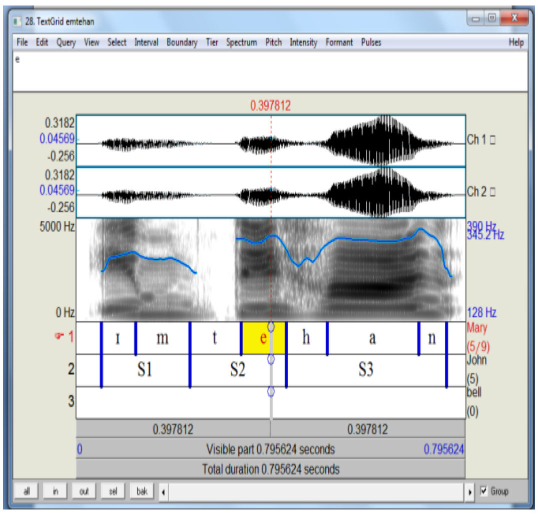


Fig 3/36: Male Sample - NT

Fig 3/37: Female Sample - NT

Polysyllabic ਅਹਿੰਸਾਵਾਦ /əhĩsavad/ Doctrine

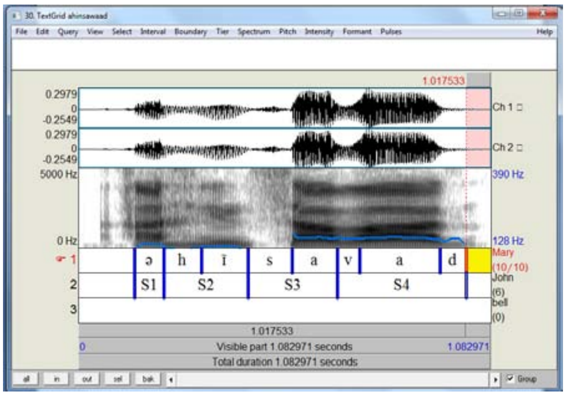


Fig 3/38: Male Sample - NT

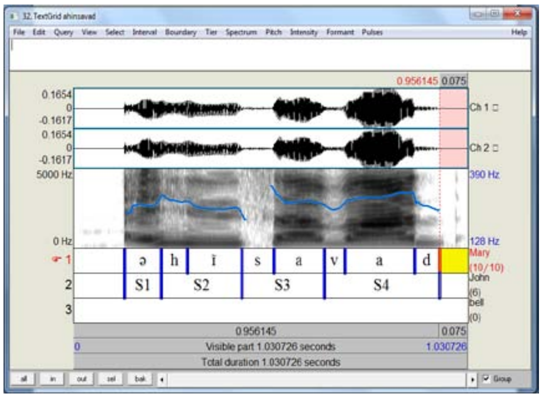


Fig 3/39: Female Sample - NT

3.3.4 Research Findings on Independent Tones

The rising (LH) & falling (HL) tone as discussed in the literature survey (refer section 3 Independent Tone) has been corroborated by and large other than some specific acoustic environments as discussed below:

- The allotone rising-falling (LHL) has been observed in 50% of the speakers in monosyllabic words having consonant /h/ as coda, di-syllabic words having conjuncts of /ɦ/ in final syllable and tri / poly-syllabic words having conjuncts of /ɦ/ in medial syllable with flap / geminated nasal onset.
- The allotone falling-rising (HLH) have been observed in following acoustic environments:
  a) Toneme / fricative onset in monosyllabic words having consonant /h/ as coda.
  b) Dipthong (long + long vowel) in open final syllable containing conjuncts of /ɦ/.
  c) Composite word having first syllable having consonant /h/ as coda.

- The Mono/ Di/ Tri/ Poly-syllabic words having consonant /h/ as onset in the initial syllable are found non-tonal.

Occurrence of Consonant /h/ in	**Acoustic environment**	**Tonal variations**
Initial syllable	Monosyllabic with consonant /h/ and conjunct containing /ɦ/ as coda • Fricative onset • Toneme as onset and /h/ as coda • Composite word (initial syllable with /h/ as coda)	LH (50%), LHL (50%) HLH (70%), LHL (30%) HL (25%), HLH (75%) HLH (60%), NT (40%)
	Di-syllabic with consonant /h/ as coda in initial syllable	LH (100%)
Medial syllable	Tri-syllabic with conjunct containing /ɦ/ and short vowel • Flap / nasal onset	LH (100%) LH (40%), LHL (60%)
	Tri-syllabic with conjunct containing /ɦ/ and long vowel or dipthong (long + short vowel)	HL (100%)
Final syllable	Di /Tri-syllabic with consonant /h/, conjunct containing /ɦ/ as coda • Open syllable with dipthong (long + long)	LH (70%), LHL (30%) HLH (100%)

Table 3/39: Independent Tone Rules

3.4 Summary

- The historical origin of tone in Punjabi has been discussed in the Introduction section. The rules for contextual substitution of Tonemes orthographically by their voiced / voiceless unaspirated counter parts belonging to same group of consonants and the tone associated marking rules have also been discussed for Tones arising from Supra-Laryngeal Consonants. The nature of tones associated with consonant /h/ and conjuncts of /ɦ/ has been deliberated under the Independent Tone section and rules have been summed up including non-tonal exceptions.
- The objective of experimental work carried out in this chapter was to corroborate the tone rules of Punjabi as collated through the literature survey. These rules have been experimentally verified and are applicable by and large. The detailed analysis has been presented in the chapter based on experimental observations which lead to discovery of allotones and findings on tone variations due to various co-articulatory factors.
- The presence of rising and falling tone as discussed in literature survey is attested as seen from the table below. The major research findings are the presence of allotones viz LHL, HLH for example:

  a) LHL (100%) : ਦੁਧੀਆ /dʊdîa/ Milky white

  b) LH (70%); LHL (30%) : ਗਾਲ੍ਹੜ /galə́ɽ/ Squirrel

  c) LH (50%); LHL (50%) : ਵਾਹ /vá/ Wonderful

  d) LH (100%) , Tone shifts to nucleus of prior syllable : ਨਿੱਘਾ /nígga/ Warm

  e) HLH (100%), Dipthong monosyllabic open vowel : ਢਾਈ /ʈăi/ Two and a Half

  f) HLH (100%), Dipthong disyllabic final closed vowel : ਪ੍ਰਧਾਨ /prədăn/ Chief

  g) HLH (100%), Dipthong trisyllabic final open vowel : ਪੜ੍ਹਾਈ /pəɽăi/ Education

  h) HL (50%); HLH (50%) : ਧਿਆਨ /tìan/ Attention

  i) HL (60%), HLH (40%) : ਧਨਾਢ /tə̀na ɖ/ Rich Person

Tone on vowel of syllable under consideration	Category of words (syllable under consideration)	Co-articulation parameters in a syllable	Tone variations (percentage of speakers)
LH	Monosyllabic	Consonant /h/ as coda	LH (50%); LHL (50%)
	Mono/di/ tri/poly-syllabic (initial syllable)	Toneme or conjunct containing conjuncts of /ɦ/ as coda	LH (100%)
	Di/tri/poly-syllabic (medial syllable with short vowel as nucleus)	Toneme or conjunct containing /ɦ/ as onset	LH (100%)
	Di/ tri/poly-syllabic (final open syllable)	Toneme as onset	LH (100%) Tone shifts to nucleus of prior syllable
	Tri/-syllabic (final open syllable)	Dipthong (long + long)	LHL (100%)
	Di/ tri-syllabic (final closed syllable)	Consonant /h/ or conjunct containing /ɦ/ as coda	LH (70%); LHL (30%)
HL	Monosyllabic (closed syllable)	Toneme as onset Consonant /h/ as coda Any other consonant as coda	 HL (100%) HL (50%); HLH (50%)
	Monosyllabic (open syllable)	Dipthong	HLH (100%)
	Di/ tri/poly-syllabic (initial syllable)	Toneme as onset.	HL (100%)
	Tri/poly-syllabic (medial open syllable and long vowel as nucleus)	Toneme or conjunct containing /ɦ/ in the onset Dipthong (long + short vowel)	HL (100%)
	Di-syllabic (final closed syllable)	Toneme as onset Toneme as coda Dipthong (short + long) and (long + long) and flap / fricative / nasal coda	HL (100%) HL (60%), HLH (40%) HLH (100%)
	Tri-syllabic (final open syllable)	Consonant /h/ or conjunct containing /ɦ/ as coda with dipthong (long + long)	HLH (100%)

Table 3/40: **Tone Marking Rules for Punjabi Language**

The sample data sheets and few reference graphs have been given at Appendix B & C

Chapter 4

Experimental Study of Lexical Stress

4. Introduction

Stress is a large topic which has been extensively studied for a very long time and still has many areas of disagreement. However, it is true that in all languages some syllables are in some sense stronger than other syllables. The difference between strong and weak syllables is of linguistic importance and in every language strong and weak syllables do not occur at random. It is observed that in all languages the words get distinguished by the position of strong syllable alone are comparatively few in number. Thus stress alone, without the accompaniment of some other distinguishing feature does not constitute a very effective means of differentiating words. The effort of pronouncing syllables with strong stress is clearly felt by the speaker but the resulting prominence is not always easily perceived by hearers Jones (1967-146).

4.1 Syllabification

How are syllable structures assigned to words? There are two main types of principles that determine syllabification in words in languages- one, *universal syllabification principles* and two, *language-specifc syllabification principles*.

In most languages, syllabication in words follows the following generalizations:

i. Each vowel is assigned to a syllable:
   E.g. mæ. tɪ. ni: ‘matinee’ go:. ɪŋ ‘going’

ii. A consonant between two vowels goes with the following syllable.
   E.g. mæ. t̲ɪ. n̲i: ‘matinee’ i:. t̲ɪŋ ‘eating’

iii. A final consonant goes with the preceding vowel.

   E.g. i:. tɪŋ̲ ‘eating’

iv. Between two consonants, there is a syllable division.

E.g. lɐn̲.d̲ən ‘London’

v. Languages differ with regard to restrictions on syllable structures.

a) Universal Syllabification Principles

The two most important universal principles influencing syllabification are: Maximal Onset Principle (MOP) and Sonority Sequencing Principle (SSP).

The Maximal Onset Principle (MOP) the syllabification of a sequence of consonants requires that they occur as onsets not as codas. Thus when there is a single consonant it is syllabified with the following vowel not with the preceding vowel in a majority of languages, for example, [mæ.tɪ.ni:] ‘matinee’ not *[mæt.ɪn.i:].

The Sonority Sequencing Principle (SSP) requires that the sonority of a syllable increases from the centre to the edge of a syllable. The sonority scale is given below.

Vowels or syllabic consonants- Glides- Liquids – Fricatives –Stops – Geminate stops

The sonority scale could also be given with the least sonorous first and the most sonorous last.

Thus a look at the sonority in the following English words- *tend, great, swat*, etc. In all these words, the sonority of the consonants increases towards the centre of the syllable. There are also violations of SSP. For example, in the word “pest” the SSP is working at the end, but not at the beginning in stop. The fricative /s/, which is more sonorous than /t/ is towards the edge of the word.

b) Language-specific syllabification constraints

A language-specific constraint on syllabification in English is the following:

There is no syllable division between s+C, C+r/l/w/j and s+C+r/l/w/j

Followng this constraint, the syllabification in the following English words is as follows:

deprive: dɪ.praɪv *replay*: rɪ.pleɪ *equate*: ɪ.kwaeɪt *inspect*: ɪn.spekt

The following syllabifications are unacceptable: * dɪp.raɪv, *rɪp.lei, *ɪk.weɪt, *ɪns.pekt.

Consonant Clusters in Punjabi:

Two consonant clusters:

Initial: 1) p/k/g/t/ʈ + r; 2) s+l; 3) p/t/k/k^h +j; 4) k/g +w

Final: General

Medial: General

Three consonant clusters:

Initial: Nil

Final: Nil

Medial: N + S + ʈ / ɭ / r

4.2 Linguistic Theories of Syllabic Structure

4.2.1 Metrical Phonology

The structure of the syllable as proposed in Selkirk (1982) is binary branching:

σ >Onset-Rime; Rime >Nucleus-Coda

This structural representation allows the syllable to represent quantity, by separating the Onset from the Rime. Rime carries the weight of a syllable in languages in which weight plays an important role in word-stress. The structure is exemplified below:

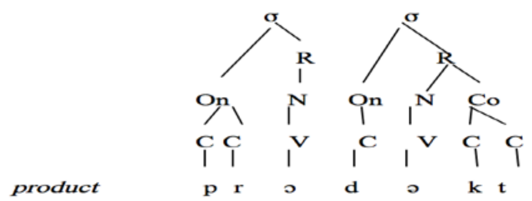


Fig 4/1: Structure- Metric Phonology

In this representation a binary branching Rime represents a Heavy syllable; a non-branching Rime represents a Light syllable.

4.2.2 Moraic Theory

Hyman (1985), Hayes (1989) The binary branching structure can be alternatively represented in terms of a mora (μ), which only shows the weight of the syllable, as below:

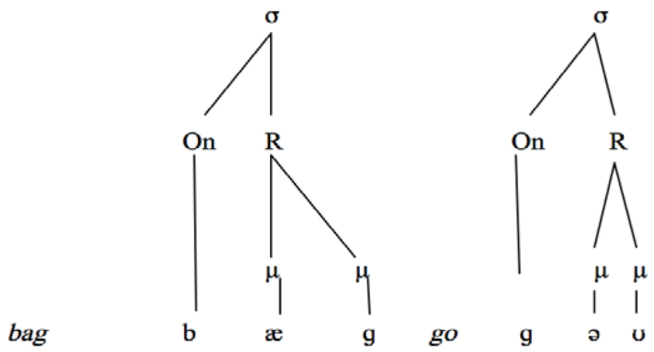


Fig 4/2: Structure- Moraic

The phenomenon of word-stress in many languages, including Punjabi, involves the weight of the syllable, as we will see below. For Punjabi, as also for Hindi see Kelkar (1968), Pandey (1989), a three-degree classification is crucial: Light (a short vowel-V), Heavy (a long vowel (VV) or a short vowel followed by a consonant (VC) and Superheavy (a long vowel followed by a consonant (VVC) or a short vowel followed by two consonants (VCC))

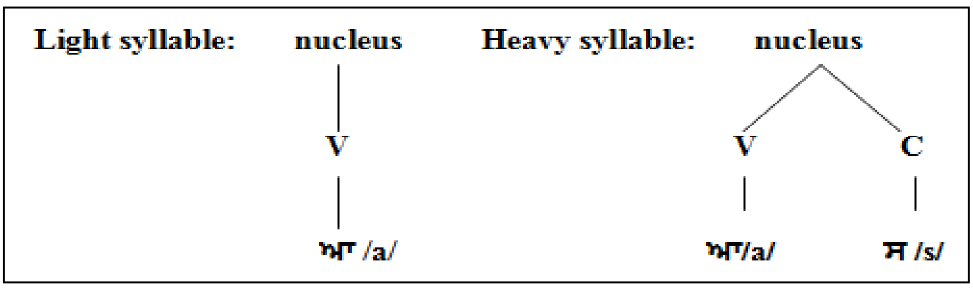


Fig 4/3: Weight of Syllables

The above definition doesn't characterise the consonant clusters occurring as onset / coda or dipthongs. Which result in three –tier syllables.

For example:

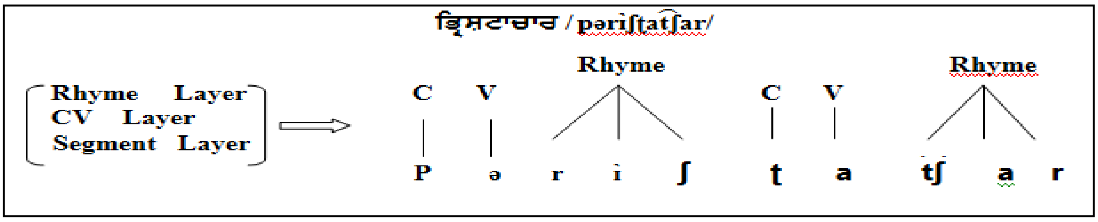


Fig 4/4: Syllable Definition

Based on the syllable definition as discussed above & also in section 1.5.1, word categories in Punjabi based on the number of syllables in a word as discussed by Singh (1991) as given below:

Monosyllabic Words: The words containing only one syllable.

V : ਆ /a/, ਏ /e/, ਓ /o/

VC: ਇੱਕ /ɪkk/, ਅੱਜ /ədʒdʒ/, ਉੱਡ /ʊɖɖ/, ਔੜ /ɔɽ/

CV : ਪੀ /pi/, ਦੇ /de/, ਸੌ /sɔ/

CVC: ਕਰ /kər/, ਪੈਰ /pɛr/, ਨਾਲ /nal/

Di-syllabic Words: The words containing two syllables

VCV: ਏਦਾਂ /edã/, ਉਰੇ /ʊre/, ਓਥੋਂ /otʰõ/

CVCV: ਸਾਰਾ /sara/, ਮੋਟਾ /moʈa/, ਕੀਤਾ /kita/

VCVC: ਉਤਾਰ /ʊtar/, ਓਦਣ /odəɳ/, ਅਜਾਣ /ədʒaɳ/

CVV: ਲਾਇਆ /laɪa/, ਹੋਇਆ /hoɪa/

CVCV: ਚੁਆਤੀ /tʃʊati/, ਗੁਆਚਾ /gʊatʃa/, ਕਿਆਰੀ /kɪari/

CVV: ਲਿਆਈ /lɪai/, ਖੁਆਈ /kʰʊai/, ਖੁਆਉ /kʰʊao/

Tri-syllabic Words: The words containing three syllables

VCVCV: ਅਗਾੜੀ /əgaɽi/, ਉਸਾਰੀ /ʊsari/, ਇਲਾਵਾ /ɪlava/

CVCVCV: ਸਵਾਰੀ /səʋari/, ਮੁਟਾਪਾ /mʊʈapa/, ਕੁੱਚਜੀ /kʊtʃədʒdʒi/

CVCVCVC: ਸੜੇਹਾਣ /səɽehaɳ/, ਕੁੜੀਮਾਰ /kʊɽimar/, ਤਾੜੇਬਾਜ /təɽebadʒ/

The frequency of disyllabic words is maximum and there are loan words borrowed from other Indo-Aryan languages. The vocabulary is mainly composed of “tadbhavas”, however the percentage of “tatsama” words is also on the rise. The vocabulary logs words in the domain of politics, science and technology. The morphological forms in Punjabi can’t be directly related to the parts-of- speech. New word forms are constructed by using pre-fixes and suffixes however no. of prefixes is much less than suffixes. Prefixes are mainly used in formation of adjectives. Compound words are also quite frequently used and there is reduplication also in their use. Some of the notable features of Punjabi are:

1) Punjabi has abundance of masculine words.
2) It is known as /a/ ending language as most of the nouns and many verbs and adjectives also follow this pattern.
3) The gemination is a special feature of Punjabi among Indo-Aryan languages.
4) It has lexically significant constractive tone.
5) Nasalization is phonemic.

4.3 Word-Stress

4.3.1 Phonetics of Word-Stress

The phonetic definition of stress is one of the most difficult topics.

According to Hayes (1995:5) says, *"The definition of stress is one of the perennially debated and unsolved problems of phonetics"*.

Trask (1996.336) *"Stress is invariably associated with greater loudness, higher pitch and greater duration, any of which may be more important in a given case, and sometimes also with vowel quality. Earlier attempts to identify stress with greater intensity of sound are now discredited, and current thinking holds that stress is primarily a matter of greater muscular efforts by the speaker and that hearers take advantage of several types of information to identify that effort"*.

Thus, phonetically it may be realized by any or a combination of any of the following features: extra breath force, vowel lengthening, loudness and pitch change. An example of stress realized as extra breathforce is the pronunciation of the word *potato* as [pəˈtʰeɪtəʊ]. The stressed syllable with an onset /t/ is aspirated, but the unaspirated syllable with an onset /t/ is unstressed. Stressed syllables are realized in most languages with the vowel longer. For example, in the word /a:ka:ʃ/ the stressed second /a:/ is longer than the unstressed first /a:/. As we will see vowel lengthening of the stressed syllable and the complementary feature of vowel shortening in unstressed syllable is a prominent feature of stress in Punjabi. Stressed syllables are found to be louder than the unstressed syllables in most languages. Stressed syllables are perceived to bear change of pitch from Low to High in Hindi.

The production of stress is generally believed to depend on the speaker using more muscular energy than is used for unstressed syllables.

Measuring muscular effort is difficult, but it seems possible, according to experimental studies, that when we produce stressed syllables, the muscles that we use to expel air from the lungs are more active, producing higher sub glottal pressure. It seems probable that similar things happen with muscles in other parts of our speech apparatus. Phonetically, stress is also employed to express emphasis. The phonetic correlate of stress is a combination of length and pitch. Unstressed syllables lack length and a high pitch.

4.3.2 Phonology of Word-Stress

The phonological account of word-stress has passed through several stages-Structuralist (e.g.), Generative Phonology by Chomsky & Halle (1968) and Metrical Phonology by Selkirk (1980), Hayes (1981) being the most prominent. Metrical Phonology (refer section 4.2.1) later came to be subsumed by Prosodic Phonology Selkirk (1984), Nespor & Vogel (1986). Our main concern here is with the metrical phonological approach to the study of stress. It would not be out of place to briefly discuss to the theory of Prosodic Phonology

Prosodic Phonology proposes that the phonological structure consists of the hierarchical units as given below:

Utterance (U)
|
Intonational Phrase (Ip)
|
Phonological Phrase (φ)
|
Phonological Word (ω)
|
Metrical Foot (Σ)
|
Syllable (σ)

Fig 4/6: Stages of Phonological Stress

An Intonational Phrase has at least one nuclear tone. A Phonological Phrase has at least one phrasal accent, a word has at least one stress Foot, and a Foot has at least one Syllable.

The theory of Prosodic Phonology claims that a unit at a certain level consists of the unit at the immediately lower level. Thus a word consists of at least one Foot, and a Foot consists of at least one Syllable. Given a word such as *examination* [ɪgˌzæmiˈneiʃən], it has the following prosodic/ metrical structure:

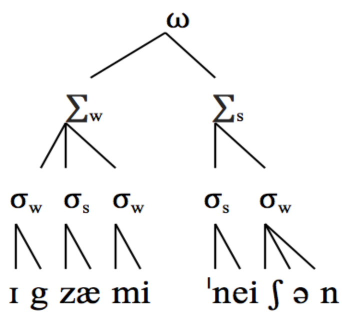


Fig 4/7: Metrical Structure

Metrical Tree Theory of Word-stress Hayes (1981) proposes that word-stress in languages can be represented in terms of relative prominence on the labelled tree structure. All branches are labeled either strong (s) or weak (w), where strength is the formalization of stress as shown below for the words *differ* and *defer:*

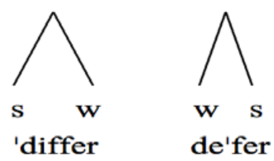


Fig 4/8: Labelled Tree Structure

This not only presents stress as relative prominence, but also explicates secondary and other level of stress.

Extrametricality: In the theory of metrical phonology, the notion of ‘extrametricality’ plays a crucial role in the assignment of stress in words.

In languages, a syllable, mora, vowel or consonant may not be counted at the periphery, i.e. at the beginning or the end of the word. Hayes (1995) discusses the notion in full. The extrametrical constituent is shown with an angled bracket (<>), as in the representations of the words in Hindi below.

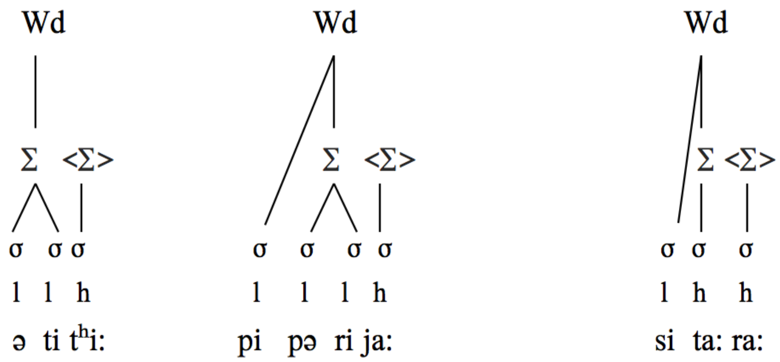


Fig 4/9: Notion of Extrametrical

It is important to note here that in Punjabi, the final foot is extrametrical.

4.4 Parameters of Stress

Hayes (1981 & 1995) proposes the following parameters along which stress systems in world languages vary:

Quantity-sensitivity:	Quantity-sensitive (QS) vs. Quantity-insensitive (QI)
Boundedness:	Bounded vs. unbounded
Dominance:	Left- dominant (LD) vs. Right-dominant (RD)
Directionality:	Left-to-Right (LR) vs. Right-to-Left (RL)

These parameters are further illustrated by Gussenhoven and Jacobs (2001):

Quantity-sensitivity: It refers to the difference in the quantity of syllables affecting stress. For example, in Hindi, the words [ˈməhila:] ‘lady’ and [məˈhi:na:] ‘month’ have identical syllable structure, with the difference in the middle syllables. The difference causes the stress pattern to differ in the two words.

Boundedness: It refers to the difference in stress systems allowing a single stress at the edges in words of any length (undbounded) or words having stress within a number of syllables (bounded). In Punjabi, for instance, word-stress must be placed maximally until the ante-penultimate syllable.

Dominance: It refers to languages allowing either the left branch or the right branch to be strong. For instance, in Adi, a language spoken in Arunachal Pradesh, the right branch has stress, whereas in Punjabi, it is the opposite. This difference can be illustrated with the help of the pronunciations of the English word “city” by an Adi speaker and a Punjabi speaker: [siˈti:] (Adi English), [ˈsiti] (Punjabi English). Adi is Right dominant (or RD) and Punjabi is Left-dominant (or LD).

Directionality: It refers to the stress assignment going from one of the two directions- Left-to-Right (lr) or Right-to-Left (rl). For instance, in Tamil, the first syllable of the word is stressed. The stress assignment in Tamil starts at the left. In Malayalam, however, stress begins at the right: Leaving out the final long vowel, the first long vowel from the right is stressed; e.g. [mɒləˈja:ləm]; if there is no long vowel, then the first vowel is stressed [ˈkəmələm] ‘lotus’.

4.5 Rules for Assignment of Stress

The rules for stress assignment are presented at two levels- at level of the Foot (containing a single stress) and the Word level (containing one or more stresses)

The following rule applies for English Hayes (1995)

Foot level: Raise LD, QS, bounded tree from right to left (LR)

Word level: Raise a LD word-tree

The word-tree gives us the primary and secondary stress in the presence of more than a foot in multi-syllabic word eg: ˈdevaˌstate.

The rules yield the correct output in a majority of English words, subject to morphological structure of words.

4.6 Review of Studies on Stress in World Languages

Language in which meaning depends in any degree upon types of stress or upon the location of strong stress in sequences of syllables is termed as "stress languages." They fall into three categories:

(i) Those in which the the location of strong stress in words of more than one syllable is an integral part of the pronunciation of words.

(ii) Those in which the use of special types of stress is an integral part of the pronunciation of words.

(iii) Those in which strong stress is used in sentences but do not have fixed positions in particular words known as intonation and isn't discussed here as it is outside the scope of defined research problem.

Stress languages of the first category are numerous. Among them are English, German, Russian, Spanish, Danish, Hungarian, Icelandic, Welsh, Greek, etc. In these languages a given word always, or generally, has strong stress on a particular syllable. Some of these words of more than one syllable may be differentiated by the position of the strongest stress. Stress is accentuations of syllables within words and this type of stress is known as lexical stress and fits into second category. The Indo-Aryan language falls into this category.

Stress functions only to point out the existence, at some point in the utterance, of a significant unit carrying the amount of information which is expected from a lexical unit. In lexical- stress languages, the syllables of any polysyllabic word are not created equal. Some syllables may serve as the focus of accentual prominence; others may not. Perceptually, this results in a distinction between the syllables within a word.

According to M. Ohala (1977) “Stress involves morpho-syntactically conditioned intonational difference rather than lexically marked accentual differences”, Languages may differ as to the place of stress in a word.

Proto-Indo-European (PIE) is the linguistic reconstruction of the hypothetical common ancestor of the Indo-European languages, the most widely spoken language family in the world.

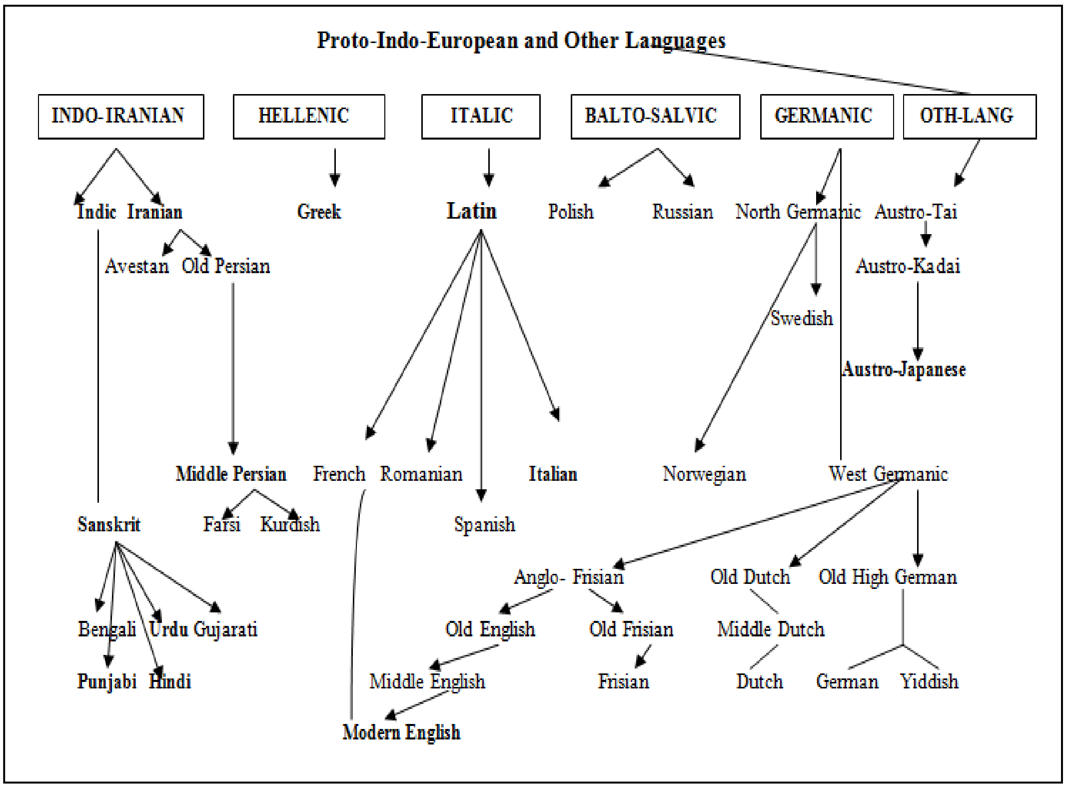


Fig 4/10: Proto-Indo-European Languages Representation

4.6.1 European Languages

The ancient Greeks studied no language but their own; they took it for granted that the structure of their language embodied the universal forms of human thought or, perhaps, of the cosmic order. Accordingly, they made grammatical observations, but confined these to one language and stated them in philosophical form. They discovered the part of speech of their language, its syntactic constructions, such as, especially, that of subject and predicate, and its chief inflectional categories: genders, numbers, cases, persons, tenses and modes. They defined these not in terms of recognizable linguistic forms, but in abstract terms which were to tell the meaning of the linguistic class. These teachings appear most fully in the grammar of dyscolus Thrax (Second Century B.C) and of Apollonius Dyscolus (Second Century A.D).

Greek is a language with lexical stress that marks stress orthographically with a special diacritic. Thus, the orthography and the lexicon constitute potential sources of stress assignment information in addition to any possible general default metrical pattern. In Greek spelling, contemporary rules dictate that every word with more than one syllable must bear a stress diacritic on the vowel of its stressed syllable Petrounias (2002). Greek words with two or more syllables written without a stress diacritic are thus considered misspelled, even though stress assignment can usually be guessed successfully from the phoneme sequence Protopapas (2006). Extending and complementing previous studies in Italian and Spanish, Greek allows investigation of stress assignment free from the structural (Phonological) constraints that interact with default placement in those languages.

Phonological changes concern the segmental and supra-segmental characteristics. Changes in both aspects are bounded through production and perception. Expending more muscular energy in the articulatory movements for making a syllable more prominent influences timing which may possibly result in different vocal tract configurations in stressed versus unstressed vowels. This may cause more or less perceptible changes in time, leading eventually to a different set of syllables depending on position in the word.

When an unstressed syllable is emphasised, jaw lowers and the short vowels tend to be perceived and perceived as more open (short i>e; short u>o; short e> ɛ, short o> O, etc.).
Classical Latin is considered to have a melodic accent on the penultimate or the ante-penultimate Roudet (1910). The prosodic anchor point for the pitch-accent was the penultimate syllable, if the penultimate was a heavy syllable, i.e. a closed syllable ("syllable entravée"), ending by a consonant (mam), ending by a consonant (amantem > amant[amA$] 'loving') or had a long vowel (farina > farine '[faÂin] 'flour' , amatus > aimé [Eme]'loved'), and on the ante-penultimate on the other cases ('asinus > asne> âne[An]'donkey', fragile > frêle [frEl] 'frail'). French descends from Vulgar latin, e.g. the Latin spoken by the soldiers, the merchants, the immigrants after the roman conquest.
Stress can be on the first or penultimate or final syllable as in Czech, polish and French respectively. Similarly there can even be complicated stress on penultimate syllable if it is long and on the third syllable from the end if the penultimate syllable is short in classic Latin. In French the distribution of stress serves only as a kind of gesture: ordinarily the end of a phrase is louder than the rest; sometimes, in emphatic speech, some other syllable is especially loud; often enough one hears a long succession of syllables with very little fluctuation of stress. In languages such as Italian, Spanish, the selvic languages etc. the stress characterizes combination of linguistic forms; the typical case is the use of one high stress on each word in the phrase, with certain unstressed or low stressed words as exceptions. Thus there are differences in the manner of applying stress among stress using languages.
In English, the prominence results from the pitch movement and gives the strongest type of stress. The stress in English is either primaryˈ/ or secondary /ˌ/ . Primary stress is stronger than secondary stress and there may be some syllables which are unstressed e.g: Photographic- /ˌfəʊt̪əˈgræfik/. Stress placement in a word in some cases divides its function as a noun/verb hence it is called functional stress e.g. in word delegate

[ˈdɛləˌget] verb; [ˈdɛləgət] noun

In order to decide on stress placement, it is necessary to make use of some or all of the following information:

1. Whether the word morphology is simple, or whether it is complex as a result of either containing one or more affixes (that is, prefixes or suffixes) or of being a compound word.
2. The grammatical category to which the word belongs (noun, verb, adjective, etc.).
3. The number of syllables in the word.
4. The phonological structure of those syllables.

4.6.2 Indo-Iranian Languages

The rapid initial expansion of Islam in the seventh century brought Arabic as the sacred language of the Quran to all the vast territories of the Caliphate, but as a spoken language only to the Middle East and North Africa. In the eastern lands of Iran and Central Asia, Persian continued to be spoken and soon evolved as a literary language also. This classical Persian, the most prominent representative of the Iranian languages which are quite closely related to Indo-Aryan retained its Indo-European structure and basic vocabulary but incorporated a huge number of loan-words from Arabic and was written in the Arabic script. Persian language was also known as "Farsi" an Arabic adaptation of the word "Parsi".

Chodzko (1852), was the first person to discuss stress in Persian. He identified the basic rule that stress is word final in simple, derived & compound nouns and adjectives, and nominal verbs. As to verbal stress, he has different rules for different tenses. Another researcher Mahootian (1997), explained stress point of Persian language: stress is word-final in simple nouns, derived nouns, compound nouns, simple adjectives, derived adjectives, infinitives, and the comparative and superlative forms of adjectives as well as in nouns with plural suffixes, and mentions verbal stress as one of the exceptions to this rule.

Vahid Sadeghi (2011), discussed the Persian stress pattern by examining the acoustic correlates i.e. duration & intensity and concluded that the majority of lexical words in Persian are stressed on final syllable. Word-final, stress pattern applies to nouns, adjectives, most adverbs & simple verbs.

The phonological literature typically describes Arabic stress as predictably falling on a particular location in the word, depending on the internal structure of the syllables making up the word. The pattern of stress location varies considerably in colloquial and modern renditions of classical Arabic Jong & Zawaydeh (1998). The general pattern of stress placement in Arabic is that the last heavy syllable is typically stressed. Here heavy is a term grouping syllables which are closed and open syllables which contain a long vowel. If there are no heavy syllables in a word, then stress falls in some other predictable location.

4.6.3 Lexical Stress due to Gemination in Japanese and Italian

Gemination of consonants as a distinctive feature occurs in some languages however it is subject to various phonological constraints depending on the language. Languages such as English and Spanish do not have geminates. Japanese and Italian geminates are exemplified by the minimal pairs as given:

1. Japanese geminate contrast (Tsujimura 2007)
   a. [saka] 'hill'
   b. [sakka] 'author'
2. Italian geminate contrast
   a. [fato] 'fate'
   b. [fatto] 'fact'

Leben (1980), posited an autosegmental representation of geminates in which a single phoneme is linked to two slots on a skeletal tier that encodes the prosody of the word. This skeletal tier is also referred to as a CV-tier, an X-tier, or a length tier depending on the specific conception of the researcher.

Important earlier works that incorporate a CV-tier include McCarthy (1979 & 1981), Halle and Vergnaud (1980), Clements and Keyser (1983) and Hayes (1986). Geminate representation on this view is exemplified by the geminate [kk] of the Japenese word in (1b).

. **CV –tier representation**

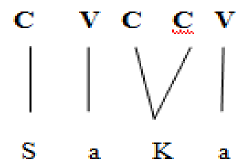


Fig 4/11: Skeletal Tier (CV -tier representation) – [sakka]

Languages with geminates vary considerably with respect to the durational difference between the geminate and its singleton counterparts. The Ratio may vary from 3:1 (in Japanese to 1.8:1 ratio for Italian) Idemaru and Guion (2008). Thus geminate consonants are transcribed by a sequence of two identical letters in orthographic representation. The phenomenon of pronouncing geminated consonants leads to stress.

4.7 Lexical Stress in Indo-Aryan Languages

The history of the easternmost branch of the Indo-European language family, known as Indo-Aryan, dated back at least three thousand years to the earliest hymns of the Rigveda, the most ancient of the sacred texts of Hinduism. When the natural processes of linguistics change threatened to corrupt the sacred vedic texts and thereby sap their ritual power, the world's first linguists emerged from the ranks of the Brahmins to codify and thereby artificially preserve their language. This process reached its culmination in the grammar of Panini (4thc.B.C.), which fixed Old Indo-Aryan in the stage of 'Classical Sanskrit'.

4.7.1 Hindi – Urdu Languages

Thus Hindi and Urdu can be described as being ultimately descended from Sanskrit, near relatives of such contemporary New Indo-Aryan languages as Panjabi or Bengali, quite closely related to the next languages of the vast Indo-European family (refer Fig 4/10), such as Persian and still more distantly connected to languages such as English and Portuguese belonging to remoter branches. Such relationships can be objectively demonstrated by reference to shared grammatical structures or to etymologically shared vocabulary e.g. Hindi-Urdu /mã/, Sanskrit /mãtər/, Persian /mãdər/, English /mothər/.

Husain (1997) discussed that stress falls on the right most heavy syllable in the word. If there is no heavy syllable, stress falls on penultimate syllable. Word final segments are extrametrical (invisible to the stress rules).

Halpern (2009) presents five stress rules which govern word-level stress patterns in Modern Standard Arabic. First, stress always falls on the ultimate syllable, should the ultimate syllable be superheavy e.g. in the word /ʤa.di:d´/ meaning 'new', the stress falls on the final syllable as it is superheavy. This rule takes precedent over all others. Second, in monosyllabic words, stress always falls on the ultimate syllable. Though this seems obvious, it is necessary to remember that words which contain proclitics are considered monosyllabic, and thus the ultimate syllable must be stressed. This is important because in a disyllabic word with a proclitic, if the proclitic was considered in applying stress, the stress rules would dictate that the stress be penultimate instead of ultimate. For example, the word /bi.kám/ meaning 'how much', contains the proclitic /bi/ and thus the ultimate syllable is stressed rather than the penultimate. Third, the stress in disyllabic words falls on the pentultimate syllable, regardless of syllable weight, should the word be lacking a superheavy syllable. This pattern can be seen in the word /kta: ɪb/ meaning 'writer', in which the stress falls on the penultimate syllable because the final syllable is not superheavy. Fourth, stress falls on the pentultimate syllable in polysyllabic words if that syllable is heavy.

The word /ħu.ku:ˊ.ma/ meaning ‘government’, has stress on the penultimate syllable because it is a heavy syllable. Finally, if the penultimate syllable is light in a polysyllabic word, then the stress falls on the antepenultimate syllable. The verb /kaˊ.ta.ba/ meaning ‘write’ demonstrates this pattern, with stress falling on the antepenultimate syllable because the following penultimate syllable is light Erica Lauren Shifflet (2011). Halpern (2009) mentions a few points which are necessary in understanding how to apply these stress rules. As previously stated, though words with proclitics are technically disyllabic or more, the proclitic is ignored when applying stress. As a result, words with proclitics that are disyllabic are treated as monosyllabic and polysyllabic words with three syllables are treated as disyllabic, with regards to the stress pattern rules. Examining how a word is actually pronounced is also important with Modern Standard Arabic (MSA) because in formal situations words are pronounced with case endings. When these case endings are excluded and not pronounced, the stress pattern of the world will change, as will the number of syllables in the word. For example, the word /ʤa.di:dˊ/ meaning ‘new’ has final stress as mentioned above. However, with a formal marking of case, the stress moves to the penultimate syllable because a new syllable is added to the end of the original word. Therefore the word becomes /ʤa.di:ˊ.dun/ with stress on the heavy penultimate syllable, which follows the rule for polysyllabic words.

4.7.2 Punjabi Language

Assignment of stress in Punjabi is entirely predictable, yet it patterns differently in disyllabic and trisyllabic words. Optimality Theory provides a unified system in which both disyllabic and trisyllabic words can be handled under a single ranking using typologically attested constraints. Dhillon (2007) presented Optimality Theoretic analysis of Punjabi stress as well as a brief exploration of Hindi, Sindhi, and Urban Hijazi Arabic- three languages with stress systems similar to that of Punjabi. Punjabi exhibits a three-way distinction in syllable weight with monomoraic light syllables, bimoraic heavy syllables and trimoraic superheavy syllables.

Secondary stress is not found in Punjabi and main stress is not contrastive except for few minimal word pairs. Stress is also not affected by morphology. In the verb forms, the addition of a suffix to the verb stem does not alter stress placement nor does the addition of the plural suffix alter stress placement for the nominal forms. Stress in Punjabi is distributed solely according to a pattern based on the syllables present in a word, the same phenomenon is evident in Hindi Hayes (1995), Pandy (1989), Kelkar (1968) and Sindhi Walker (1997)- two Indo-Aryan Languages closely related to Punjabi. Sangha (2014) discussed although Punjabi is not a stress language like English however in many words the change in stress position is lexically significant and sometimes may result in change of POS category. Stress is a multidimensional suprasegmental feature of Punjabi.

Nara (2016) carried out study of 85 words on stress and tone analysis for Doabi dialect of Punjabi using mixed effects model of stress. He also reported only primary stress. The stress analysis by him is briefly given here:

- The syllable with longest rhyme is stressed e.g.

  ਕਿਤਾਬ /kɪˈt̪ab/ viz book

  ਬੁਨਿਆਦ/bʊˈnɪad/ viz foundation

- If there is no long rhyme then the penultimate syllable is stressed e.g.

  ਉਨੰਜਾ /ʊˈnə̃dʒa/ viz forty nine

- Singleton coda consonants do not contribute to the weight of the rhyme e.g.

  ਫਿਕਰ /ˈpʰɪkər/viz. worry

  ਕਿਰਨ /ˈkɪrən/ viz. ray

- Homorganic Nasal stops and geminate consonants do contribute to the weight of the rhyme:

ਅਨੰਦ /əˈnə̃d/ “happiness”

ਪਸੰਦ /pˈsə̃d/ “Preference”

ਪਵਿੱਤਰਤਾ /pəˈvɪttərta/ “Purity”

ਪ੍ਰਤੱਖ /pərˈtəkkʰ/ “Obvious”

Pitch starts out low on the stressed syllable and rises through the syllable boundary so that it is the syllable following the stressed syllable that has the highest pitch. A phonemically long vowel may become a phonemically short vowel when the syllable within which it occurs loses its stress e.g. ba'taa (To tell) viz.' baat (utterance). Thus stress falls on highest sonority syllable.

Stress placement in Punjabi is determined by syllable structure and morphology similar to Hindi - Urdu stress placement. The stress bearing syllable carries high tone.

4.8 Stress Patterns of Punjabi

Stress is not a prominent feature of Punjabi, however it is utilized in di-syllabic words to distinguish between grammatical categories, known as functional stress. In the noun category stress falls on the initial syllable and in the verb category stress falls on the final syllable. In gemination, stress falls on the geminated consonant and it additionally co-occurs with tone in tonal words. The acoustic characterization of the properties can help in identifying the stressed syllable from other unstressed syllables in a word.

4.8.1 Functional Stress

Stress can be used to establish a distinction in meaning between two words, where the only difference is with regards to the placement of stress. Such stress is known as functional stress. English has functional stress. Punjabi also exhibits functional stress in a very small set of words.

Stress placement in these words divides their function as noun / verb / adjective etc i.e. the POS changes with the change in the position of stress e.g.

Sr No	Noun	Verb
1.	ਹਰਾ /ˈhə ra/ (Green colour)	ਹਰਾ /həˈra:/ (Defeat)
2.	ਭਰਾ /ˈpəra/ (Brother)	ਭਰਾ /pəˈra:/ (Filling)
3.	ਸਫ਼ਾ /ˈsə pha/ (Page of book)	ਸਫ਼ਾ /sə ˈpha:/ (Clean)
4.	ਗਲਾ /ˈgəla/ (Throat)	ਗਲਾ /gəˈla:/ (Cause to melt)
5.	ਤਲਾ /ˈtəla/ (Sole)	ਤਲਾ /təˈla:/ (Cause to fry)

Table 4/1: Pairs of Functional Words

It is noted that there is also an alternation of vowel quality depending on the position of stress. The last vowel gets elongated when second syllable is stressed, it is also referred as prolative vowel.

4.8.2 Stress due to Gemination

Gemination in Punjabi is phonemic. The minimal pairs (non- nasal and nasal) are given below:

Non –Geminate			Geminate		
Word	**IPA**	**Meaning**	**Word**	**IPA**	**Meaning**
ਪਤ	pət	Honour	ਪੱਤ	pətt	Leaf
ਸਤ	sət	Essence	ਸੱਤ	sətt	Seven
ਜਿਨ	dʒɪn	Who	ਜਿੰਨ	dʒĩn	Devil

Table 4/2: Minimal Pairs (non- nasal and nasal)

Orthographically gemination is represented by double consonants and such consonants occur in medial & final position only. These are preceded by short vowels **/ə, ɪ, ʊ/**.

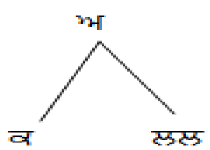
For example, the geminate clusters are written by the sign ਅੱ known as /**əddək**/. The consonantal segments **/ɳ /, /ɭ /, /r /, / ɽ /, /h/ and /j/** do not occur as geminates.

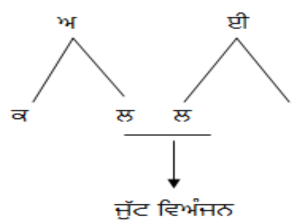
Geminates of /ਫ **/pʰ/, ਥ /tʰ/, ਠ /ʈʰ/, ਛ /tʃʰ/, ਖ /kʰ/** aspirate only at the final release in a geminated word. They are phonetically similar to a cluster of an unaspirated stop and homorganic aspirate. There is, however, no structural reason to consider such geminates as different from others. S.S.Sangha (2014)

Word	IPA
ਜੱਫਾ	/dʒəppʰa/
ਹੱਥੀ	/həttʰi/
ਕੱਠੀ	/kəʈʈʰi/
ਵੱਛੀ	/wətʃtʃʰi/
ਖੱਖਾ	/kʰəkkʰa/

Table 4/3: Examples- Geminate Aspirates

The geminate cluster can be within the same cluster e.g. ਕੱਲ /kəll/ or can go across the syllable e.g. ਕੱਲੀ /kəlli/ as illustrated below:





ਕੱਲ /kəll/ ਕੱਲੀ/kəlli/

Phonetically, the duration of double consonant becomes 1.5 to 2 times longer than the non-geminate consonant, thus leading to the increased duration of the syllable of which geminate consonant is the part. Such syllable becomes stressed as compared to other syllables in a word.

Phonotactics

(i) Diphthongs do not occur in word initial position.

(ii) Short vowels don’t occur in word final position.

(iii) Short vowels /I/ & /U/ generally occur in word initial position.

(iv) The vowels /ɛ/ & /ɔ/ generally do not occur in word final position except for some monosyllabic words.

(v) Words don’t begin with these consonants /ਙ, ਞ, ਣ, ੜ, ਲ਼/- /ŋ, ɲ, ɳ, ɽ, ɭ/

(vi) There is abundance in use of vowel diphthongs in the end of the words including three or more than three vowels.

The generalization about where stress occurs, can only be made in reference to syllable types for the study of stress patterns. These types are usually described in terms of weight of syllables categorized into types such as light, heavy or super heavy. The following syllable definitions have been followed for the purpose carrying out the experimental study of intra-syllabic stress the definitions of light (L), heavy (H) and super- heavy (SH) syllable have been evolved by Slata et al (2015).

Light Syllable (L)
(i) Open syllable containing a class I vowel i.e. **V_1 or CV_1**
Heavy Syllable (H)
(i) Open syllable containing a class II vowel or a diphthong viz. **V_2 , CV_2, V_d, CV_d**
(ii) Any syllable having class I vowel with a coda or onset & coda viz. **V_1C (C), CV_1C**
Super Heavy Syllable (SH)
(i) Class II vowel or a dipthong followed by one or more consonants viz. **$V_2C(C)$, $V_dC(C)$** (ii) Class II vowel or a dipthong having onset as well as coda viz. **CV_2C, $(C)CV_2C$, CV_dC, $(C)CV_dC$**
(ii) Class I vowel followed by two or more consonants viz. **CV_1CC**

Table 4/4: Syllable Definitions for Experimental Work

4.9 Experimental Study

4.9.1 Articulatory Features for Determining Syllabic Stress

Co-articulation is a phenomenon in which the articulatory movements required for a syllable are often anticipated (anticipatory Co-articulation) or carried over (carry over Co- articulation) during the production of an adjacent syllable. Stress plays an important role in this. It depends on: quality of syllable peak, openness or closeness of the syllable, type of syllable margin, position of the syllable in the word under consideration, presence of germination/tone etc.

Syllable peaks and syllable margins show considerable reduction of quantity, quality, and intensity and pitch when occurring in weak position of a syllable whereas there is an all around rise in a stronger syllable. Reduction in quality of the initial syllable in disyllabic words is a common feature. Sharma (1971) discusses syllabic structure of Punjabi in detail with reference to the variations in quality of syllable peaks, vowel reduction, schwa deletion etc. as is evident from following examples:

S. No.	Description	Example word	IPA	Meaning
1.	Preference for class I syllable peaks	ਅੱਗ	/əgg/	Fire
		ਫੁੱਲ	/p^{h}ʊll/	Flower
		ਤਿੱਖਾ	/tɪkk^{h}a/	Sharp
2.	Reduction / centralization of first syllable to neutral schwa when second syllable is heavy and closed	ਬਾਜ਼ਾਰ → ਬਜ਼ਾਰ	/bazar/ → /bəzar/	Market
3.	Reduction of class II (phonemically shorter duration of vowel) syllable peak in the final syllable of di/ploy-syllabic words	ਕਵੀ	/kəvi·/	Poet
		ਕਿਰਪਾਲੂ	/kɪrpalu·/	Kind
	Contd..			

S. No.	Description	Example word	IPA	Meaning
4.	Occurrence of class I syllable peak in final open syllable only in mono-syllabic function words	ਕਿ	/kɪ/	That
		ਕੁ	/kʊ/	Approximately
5.	Preference for nasalization with long and open syllable peaks	ਮੀਂਹ	/mĩ́/	Rain
		ਤੂੰ	/tũ/	You
6.	Regressive nasalization of syllable peak	ਕੁੜੀਆਂ	/kʊɖĩã/	Girls
		ਲਾਵਾਂ	/lãvã/	May take
7.	Schwa deletion	ਸੜਕਾਂ	/səɽkã/	Roads
		ਕਾਗਜ਼ਾਂ	/kagzã/	Papers

Table 4/5: Variations in Quality of Syllable Peaks & Vowel Reduction in Punjabi

Crystal (1997) further describes syllables by their position within the word e.g. in a tri-syllabic word, final syllable is referred to as the ultimate syllable, while the second to the last syllable is the penultimate syllable and the third to final syllable is the antepenultimate syllable. All of these placements are determined beginning from the rightmost edge of the word, which would be the ultimate syllable.

Lexical Stress in terms of Intra-syllabic stress needs to be examined to aid the prosodic PLS development in Punjabi.

4.9.2 Empirical Research

"Empirical" means "based on observation or experience," according to the Merriam-Webster Dictionary. Empirical research is a research using empirical evidence. It is a way of gaining knowledge by means of direct or indirect observation or experience. Empirical evidence can be analyzed quantitatively or qualitatively.

Empirical analysis is an evidence-based approach to the study and interpretation of information. Empirical analysis is integral to the scientific method and is the usual approach used to study subjects for a probable answer through quantified observations of empirical evidence.

Scientific method begins with scientists forming hypotheses and then acquiring the knowledge through observations and experiments to either support or disprove a specific theory. The scientific method often involves lab experiments and these experiments result in quantitative data in the form of numbers and statistics. The role of empirical study is to develop a general hypotheses which relies upon the capacity to characterize computational models as far as sets of features that can be utilized to make and evaluate predictions about what influences the conduct under investigation Cohen (1995), Sparck-Jones and Galliers (1996), Walker (1996).

4.9.3 Acoustic Parameters

The stress measurement parameters as discussed in section 4.3.1 viz. Pitch (P), Duration (D) and Intensity (I) of the syllables in a word form the hypothesis for determining the Intra-syllabic stress experimentally. As per literature study, intensity, fundamental frequency (Pitch) and duration of vowels is greater within stressed syllables. Though data is still lacking to establish definite correlates, however Erica Lauren Shifflett (2011) says fundamental frequency, intensity and duration can be used as phonetic correlate measurements to determine the stress pattern of a language. Thus a systematic approach needs to be taken to measure these parameters of Punjabi word samples. Di-syllabic words have highest frequency of occurrence in Punjabi. The frequency analysis also reveals presence of 10-15% tonal words. Therefore the empirical study is based on this premise and to start with, non-tonal words will be taken as basis for determining the inter-relationship of these parameters in the context of stress.

4.10 Methodology

4.10.1 Data Selection, Recording and Annotation

The phonologically rich words in various combinations of syllables as per definition given in Table: 4/4 are being considered for analysis for 10 speakers (4 Male & 6 Female).

The distribution of data across various catogries of words is given in the table below:

S. No.	Word category	Total words
1.	Di-syllabic	185
2.	Tri-syllabic	86
3.	Poly-syllabic	12
	Total	283

Table 4/6: Data Samples for Study of Lexical Stress

Recording of data done as per specifications as discussed in section 1.8.2. Data annotation using PRAAT tool was done at the phoneme level as per procedure discussed in section 3.1.2. The syllables in each word were also marked. A sample annotation is depicted below:

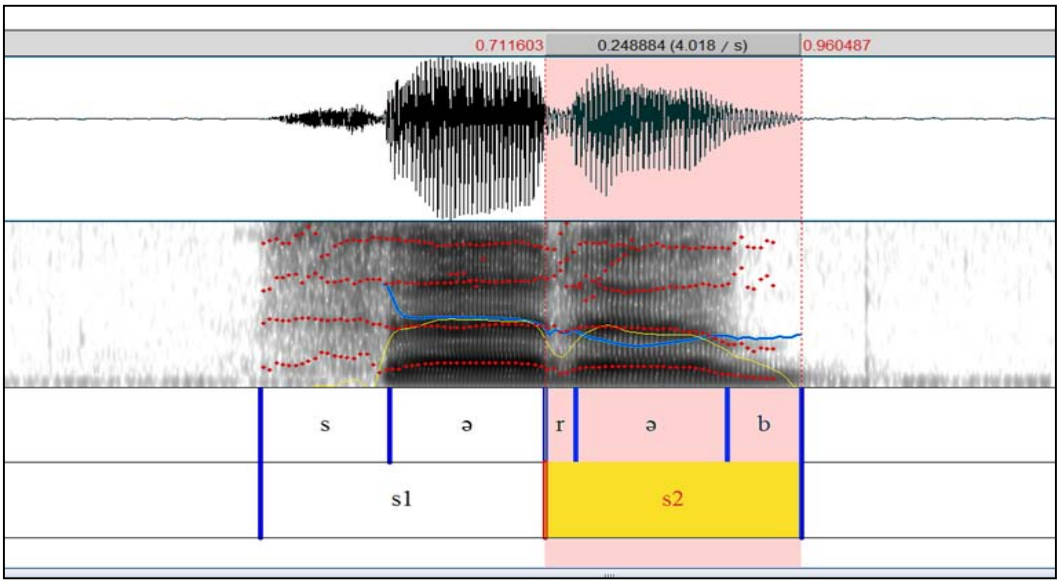


Fig 4/12: Sample Annotation (syllable & phoneme level)

4.10.2 Recording of Data Sheets

The syllable level annotated data of above samples was used for recording various acoustic parameters as discussed in section 4.9.3. A sample data sheet is given below:

ਸਰਬ /sərəb/						
Speakers	**Syb1**			**Syb2**		
	D	P	I	D	P	I
M1 (S8)	0.13	135	71	0.18	165	70
M2(S13)	0.2	200	71	0.21	192	66
M3 (S5)	0.29	188	63	0.22	186	65
M4 (S7)	0.2	171	65	0.16	176	67
F1 (S1)	0.27	241	67	0.25	205	64
F2 (S2)	0.23	241	63	0.24	248	62
F3 (S3)	0.4	239	63	0.22	227	65
F4 (S11)	0.27	305	70	0.31	357	71
F5 (S6)	0.26	241	62	0.23	248	62
F6 (S9)	0.32	246	72	0.25	261	72
Average	**0.26**	**220.70**	**66.70**	**0.23**	**226.50**	**66.40**

Table 4/7: Sample of Syllable Level Data of different Acoustic Features

4.10.3 Linear Regression Analysis

Linear regression is a linear approach to modelling the relationship between a scalar response (or dependent variable) and one or more explanatory variables (or independent variables). Linear regression is a basic and commonly used type of predictive analysis.

These regression estimates are used to explain the relationship between one dependent variable and one or more independent variables. Linear regression is very extensible and can be used to capture non-linear effects. There are typically a small number of coefficients. If we have a small number of features that are important, it predicts future data quite well in a lot of cases, despite its simplicity.

The standard deviation (represented by the Greek letter sigma σ) is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A low standard deviation indicates that the data points tend to be close to the mean of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values. In statistics, a confidence interval (CI) is a type of interval estimate, computed from the statistics of the observed data. The confidence level represents the frequency (i.e. the proportion) of possible confidence intervals that contain the true value of the unknown population parameter. In other words, if confidence intervals are constructed using a given confidence level from an infinite number of independent sample statistics, the proportion of those intervals that contain the true value of the parameter will be equal to the confidence level. Most commonly the 95% confidence level is used. However, other confidence levels can be used in the range of 90% - 99%.

In two-dimensional linear regression, the general form for a model is a distribution concentrated along a line. A line is determined by two parameters – its slope and it y-intercept – and we want to find the parameters that determine the best fit line for a given set of points. We know that the data points probably won't all fall right on any one line, so there will always be some error. For any given line, we can define a distribution that is equal to one along the line and decreases as we move away from the line. In particular, the probability will be defined by the Gaussian function $\mathbf{e}^{-d\hat{}2(x,y)\ /\ 2\ \sigma\hat{}2}$ where d is the distance, so that as we move away from the line, the probability will follow a bell curve.

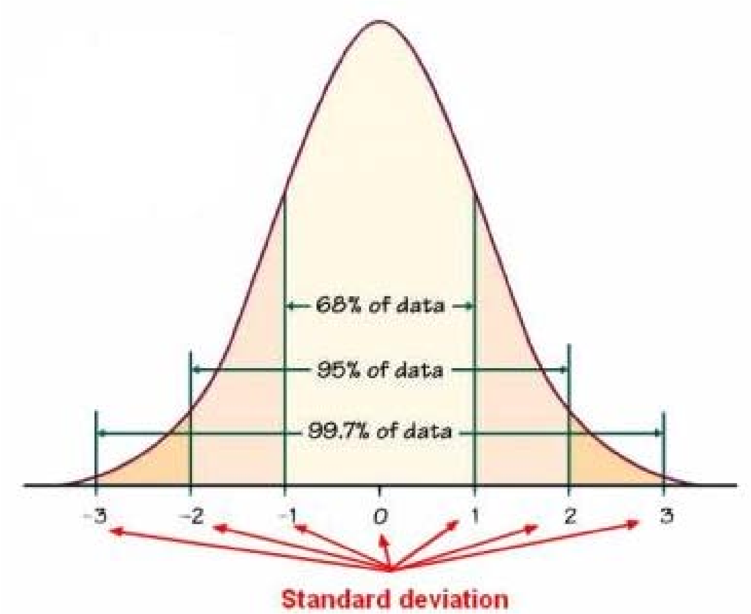


Fig 4/13: Graph of the Distribution Function

The properties of a normal distribution are:

- The mean is at the middle (50% of the data are above and 50% of the data are below)
- 68% of the data fall between -1 and 1 standard deviation
- 95% of the data fall between -2 and 2 standard deviation
- 99.7% of the data fall between -3 and 3 standard deviation

The acoustic parameters as discussed in section 4.9.3 will be modelled using Linear Regression for relational analysis. Linear regression is a standard mathematical technique which has been used to predict the intra-syllabic stress in percentage i.e. the heaviest syllable will be identified for marking the stress. The duration, pitch and intensity of both the syllables in a word averaged across 10 speakers for 95 words was tabulated in a spreadsheet and was plotted using Curve Expert Professional, a cross-platform solution for curve fitting.

A sample spreadsheet and graph-plot for duration of first syllable of all sample words is given below. Similar plots were made for Pitch and Intensity for both the syllables in each word.

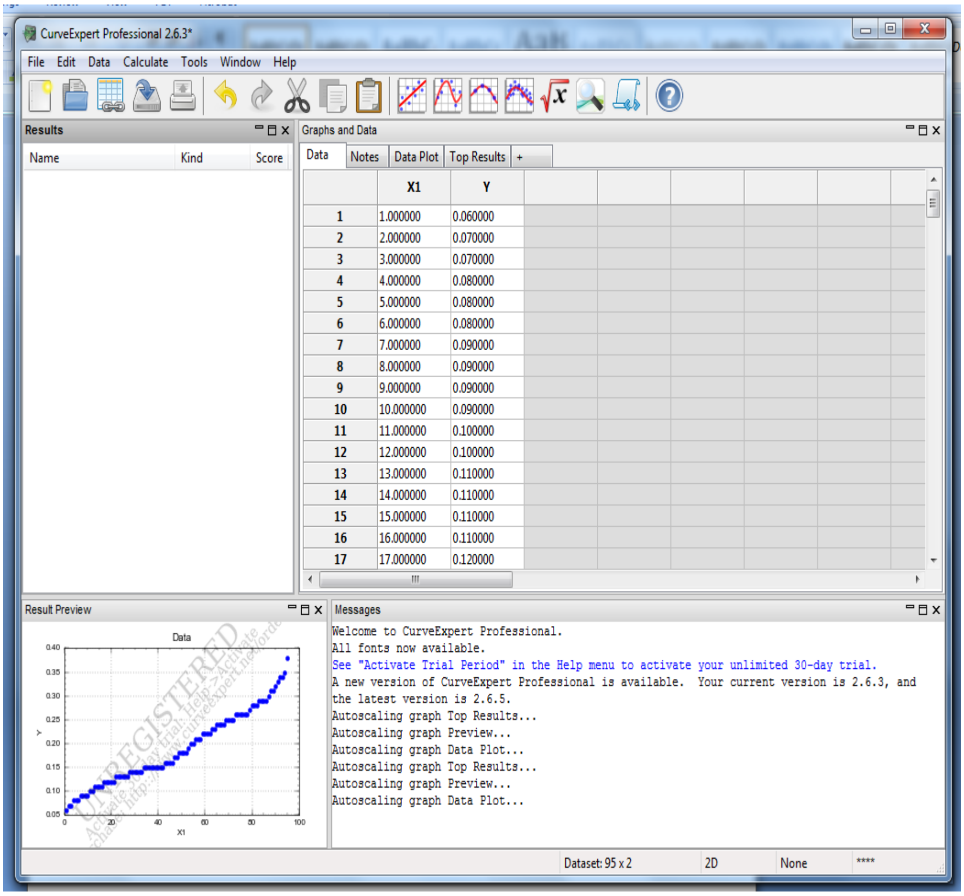


Fig 4/14: Plot for Duration

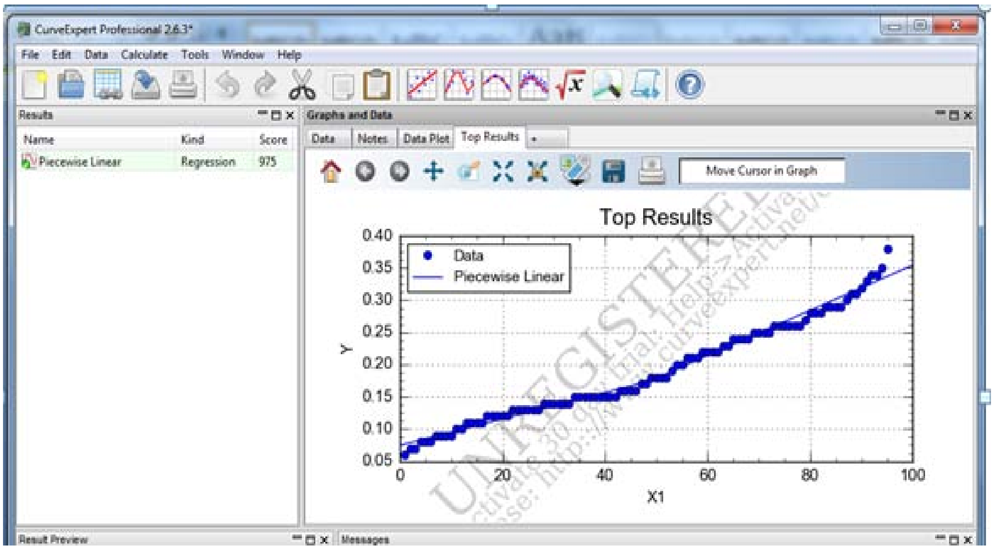


Fig 4/15: Piecewise Linear Curve Fitting

The process of finding the best fit piecewise linear curve was automated using this tool. Linear regression attempts to model the relationship between two variables by fitting a linear equation to observed data. A linear regression line has an equation of the form Y = ax + b, where X is the explanatory variable and Y is the dependent variable. Using Nonlinear model, the piecewise linear curve fitting equations: ax+b | cx+d (ax+b<50 ; cx+d>=50) were obtained from this tool for all the three parameters for both the syllables.

Duration(D)	**Syllable 1**	**Syllable 2**
	2.04 d + 7.48 n<50 3.50 d + 3.84 n>50	2.73 d + 2.51 n<50 3.74 d + 1.72 n>50
Linear Curve Equation (1)	5.54 d + 11.32	6.47 d + 4.23
Pitch(P)	6.21 p + 2 n<50 1.32 p + 1.48 n>50	4.95 p + 2.20 n<50 5.91 p + 2.12 n>50
Linear Curve Equation (2)	7.53 p + 3.48	10.86 p + 4.32
Intensity(I)	6.61 i + 6.58 n<50 8.27 i + 6.51 n>50	8.06 i + 6.43 n<50 4.88 i + 6.64 n>50
Linear Curve Equation (3)	14.87 i +13.09	12.94 i + 13.07

Table 4/8: Piecewise Linear Curve Fitting Equations of Acoustic Parameters

Averaging over two syllables, the linear equations of all the three acoustic parameters which influence the lexical stress are:

$f(d) = 6.00d + 7.77$

$f(p)= 9.19p + 3.90$

$f(i) = 13.90i + 13.08$

The normal distribution curve for all the three acoustic parameters is as below using Standard Deviation and mean of the data averaged over two syllables.

Analyzing the above functions derived from the stress patterns of the recorded samples, the corresponding weightage factors of the acoustic parameters have been calculated. Thus the empirical stress function (s_t) can be defined as

$\mathbf{s_t = 0.49d + 0.16p + 0.35i}$ where

d is the duration (ms)

p is the pitch measured in terms of frequency (hz)

i is the intensity (db)

This reveals that duration and intensity have higher importance in determining lexical stress as compared to pitch.

The syllabic weight of all the syllables using above stress function will be calculated and the heaviest syllable needs to be identified for determining the strongest syllable in a word.

4.11 Data Analysis

Statistics and Probability are interrelated but separate academic disciplines. Statistical analysis often uses probability distribution.

When a frequency distribution is normally distributed, we can find out the probability of a score occurring by standardizing the scores, known as standard scores (or z scores).

The standard normal distribution simply converts the group of data in our frequency distribution. Z-scores are expressed in terms of standard deviations from their means. The absolute value of z represents the distance between the raw score and the mean value in units of the standard deviation. z is negative when the raw score is below the mean, positive when above. Thus z-scores are a way to compare results.

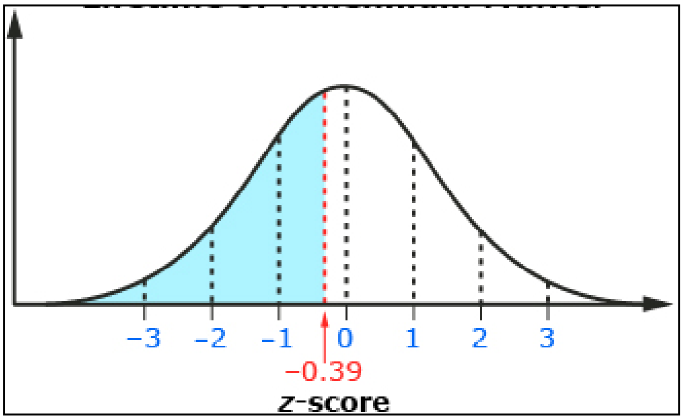


Fig 4/16: Normal Distribution of z-score

The formula for calculating the standard score is given below:

$$\textbf{z-score} = (\mathbf{x} - \boldsymbol{\mu}) / \boldsymbol{\sigma}$$

Where:

μ is the mean of the data

σ is the standard deviation

Applying this definition on the stress data:

$$\text{z-score} = (s_t - \bar{s}_t)/ \sigma$$

where

s_t is reference value taken as 0 to get the point to the left of which intra-syllabic stress is negative

$\bar{s}_t$ is the mean of the intra-syllabic stress (in %)

σ is the standard deviation

The z-score gives the percentage that scored lower than the reference value.

A standard normal table (Z Score Table) gives the values of the cumulative distribution function (Φ) of the normal distribution. Using this value of z-score, a value will be obtained from the online Z Score Table. This value gives the probability of the score lower than the defined reference value that gives the lexical stress pattern for the given range of the data.

The heuristic is an approach to problem solving, learning or discovery that employs a practical method, not guaranteed to be optimal, perfect, logical, or rational, but instead sufficient for reaching an immediate goal. Thus taking a clue from 80-20 rule, the stress rules will be evolved based on minimum 80% probability of occurrence of that rule in the given data being analysed using above defined heuristic approach.

4.11.1 Di-syllabic Words

Di-syllabic words have highest frequency of occurrence in Punjabi hence lexical stress will be experimentally examined for these words and findings will be extrapolated. The frequency of tonal words is only 10-15%, therefore the basis will be evolved first for di-syllabic non-tonal words and then will be validated for tonal words.

a) Di-syllabic Non-Tonal Words

Ninety five phonetically annotated words are being analysed. The stress of syllable 1 and syllable 2 of each word was calculated using the empirical stress function (s_t). The intra-syllabic stress was calculated using the formula $s_{ti} = ((s_{t2} - s_{t1}) / s_{t1}) * 100$ and s_{ti} is tabulated as at Annexure I in Appendix D, where i varies from 1 to 95.

Mean of s_{ti} for 95 words ($\overline{s}_t$) = 4.50

$$\text{Standard Deviation } (\sigma) = \text{sqrt}\left[(1/n\sum_{i=0}^{n} (s_{ti} - \overline{s}_t)^h)\right] \qquad \text{-------------------- eq (1)}$$

Where n=95; h=2

Using this formula, $\sigma = 3.11$

The range is $-3.65 \leq s_t \leq 11.51$

The normal distribution curve is:

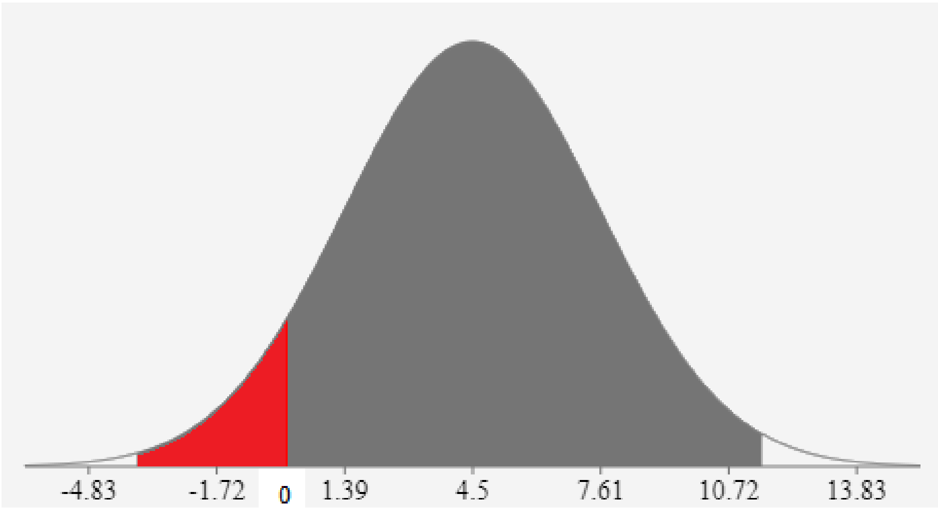


Fig 4/17: Graph of the Distribution of Lexical Stress Data of Non-Tonal Di-syllabic Words

It is observed that majority of data is positive which reflects that the stress lies on the second syllable. The probability (P_r) of words having intra-syllabic stress less than 0 can be calculated using z score.

$z = (0-4.50) / 3.11 = -1.44$

The corresponding value of Φ against this z-score is calculated given below:

$P_r (x < 0) = P_r (z < -1.44) = 0.075$ i.e. 7.5 % (marked red in fig)

Therefore there is 92.5% probability of lexical stress being present on second syllable (ultimate syllable).

S. No.	Word category	Rule	Probability of occurrence	Exception
1.	Di-syllabic non-tonal words	Stress on syllable 2 (R1)	0.93	-

Table 4/9: Lexical Stress Rules for Di-syllabic Non-Tonal Words

Rule 1: Stress falls on ultimate syllable

b) Di-syllabic Toneme Words

Sixty six phonetically annotated words have been analysed out of which 33 words contain toneme in initial syllable and balance 33 having toneme in final syllable. The stress of syllable 1 and syllable 2 of each word was calculated using the empirical stress function (s_t). The intra-syllabic stress was calculated and s_i is tabulated as at Annexure II in Appendix D, where i varies from 1 to 66.

Mean of s_{ti} for 66 words ($\overline{s}_t$) = 0.99

Using eq (1), Standard Deviation (σ) = 7.86
Where n=66; h=2

The range is $-14.36 \leq s_t \leq 20.45$
The normal distribution curve is:
z = (0-.99)/.7.86= -.12
P_r (x < 0) = P_r (z < -.12) = 0.45 i.e. 45 %

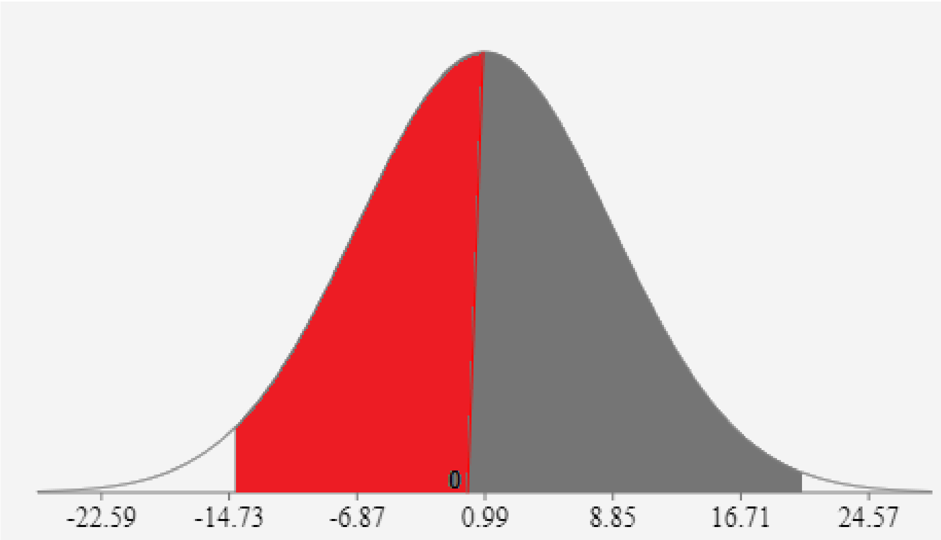


Fig 4/18: Graph of the Distribution of Lexical Stress Data of Di-syllabic Toneme Words

The Rule 1 (R1) is largly applicable for tonal di-syllabic words also however it is noted from the above figure that words towards the left side of the mean do not carry any lexical stress as these contain toneme in the initial syllable due to which the syllable 1 also becomes emphasised and counter balances the stress which is generally observed on syllable 2 in such words.

Rule 2: No Stress

Hence the Rule Table can be represented as:

S. No.	Word category	Position of toneme	Rule
1.	Di-syllabic Toneme words	Final syllable	Stress on syllable 2 (R1)
		Initial syllable	No Stress (R2)

Table 4/10: Lexical Stress Rules for Di-syllabic Toneme Words

c) Di-syllabic Words (consisting of cosonant /h/ or conjuncts of /ɦ/)

Twenty four words containing cosonant /h/ and conjuncts of /ɦ/ were examined. The stress of syllable 1 and syllable 2 of each word was calculated using the empirical stress function (s_t). The intra-syllabic stress of was calculated and s_i is tabulated as at Annexure III in Appendix D, where i varies from 1 to 24.

Mean of s_{ti} for 24 words ($\overline{s}_t$) = 4.82

Using eq (1), Standard Deviation (σ) = 5.40

Where n=24; h=2

The range is $-3.07 \leq s_t \leq 14.8$

The normal distribution curve is:

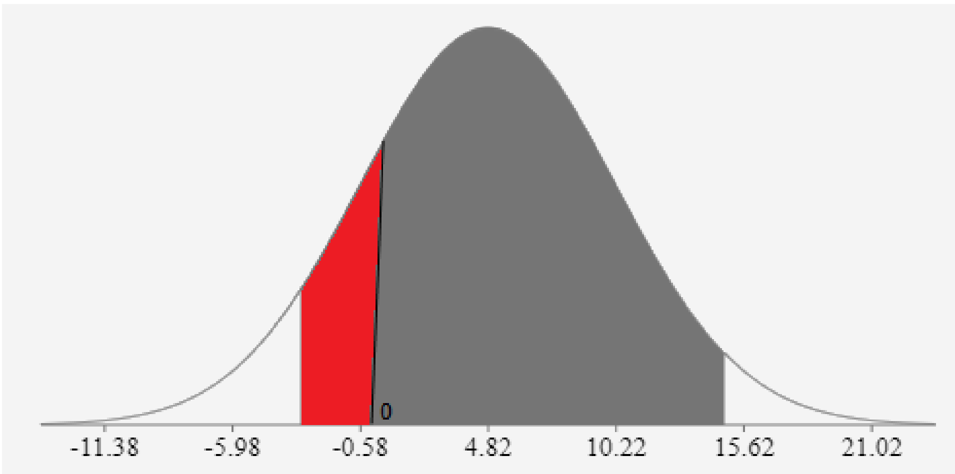


Fig 4/19: Graph of the Distribution of Lexical Stress Data of Di-syllabic Words (consisting of cosonant /h/ or conjuncts of /ɦ/)

It is observed that majority of data is positive which reflects that the stress lies on the second syllable. The percentage of words having intra-syllabic stress less than 0 can be calculated using z score.

$z = (0-4.82)/5.40 = -0.892$

$P_r (x < 0) = P_r (z < -0.892) = 0.186$ i.e. 18.6 % (marked red in fig)

Therefore there is 81% probability of lexical stress being present on second syllable. The Rule 1 (R1) is largely applicable for this category of words however it is noted from the above figure that three words marked in the red region do not carry any lexical stress. Hence the rule table can be represented as:

S. No.	Word category	Rule	Probability of occurrence	Exception
1.	Di-syllabic Words (consisting of cosonant /h/ or conjuncts of /ɦ/)	Stress on syllable 2 (R1)	0.81	-

Table 4/11: Lexical Stress Rules for Di-syllabic Words (consisting of cosonant /h/ or conjuncts of /ɦ/)

4.11.2 Tri-syllabic Words

In tri-syllabic words, the stress may fall on final syllable or penultimate syllable in case of European languages as discussed in section 4.6.1. This needs to be examined in the context of Punjabi. The experimental data of second and third syllable will be compared and stress will be reported along with exceptions if any.

a) Tri-syllabic Non-Tonal Words

Thirty phonetically annotated words have been analysed out of which three words contain toneme in initial syllable. The stress of all three syllables of each word was calculated using the empirical stress function (s_t). The intra-syllabic stress of was calculated using the formula $s_i = ((s_{t3}-s_{t2})/s_{t2})* 100$ and s_{ti} is tabulated as at Annexure IV in Appendix D, where i varies from 1 to 30.

Mean of s_{ti} for 30 words ($\overline{s}_t$) = 4.5

Using eq (1), Standard Deviation (σ) = 3.25

Where n=30; h=2

The range is $-1.48 \leq s_t \leq 10.85$

The normal distribution curve is:

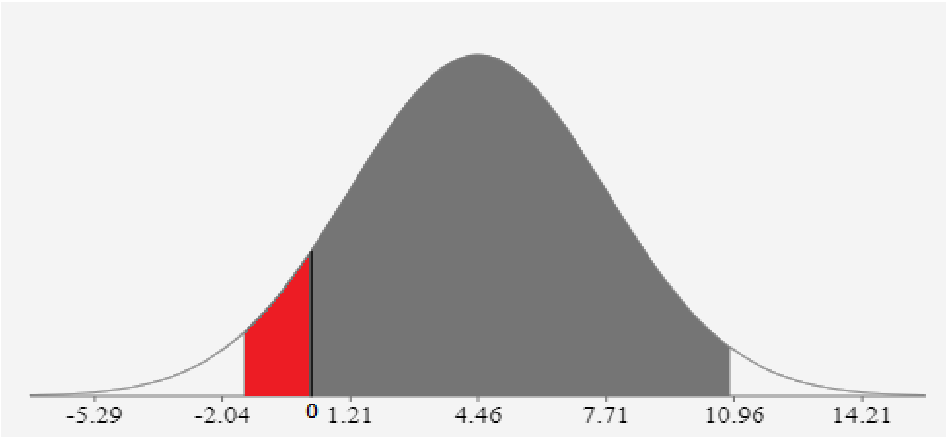


Fig 4/20: Graph of the Distribution of Lexical Stress Data of Tri-syllabic Non-Tonal Words

It is observed that majority of data is positive which reflects that the stress lies on the third syllable. The percentage of words having intra-syllabic stress less than 0 can be calculated using z score.

$z = (0\text{-}4.5)/3.25 = -1.38$

$P_r (x < 0) = P_r (z < -1.38) = 0.083$ i.e. 8 % (marked red in fig)

Therefore there is 92% probability of lexical stress being present on third syllable.

The Rule 1 (R1) is largely applicable for this category of words and stress falls on the third syllable. However, it is observed from the data that syllable 1 is stronger in case of occurance of toneme in initial syllable hence the stress gets counter balanced and there is no need to mark stress.

Hence the rule table can be represented as:

S. No.	Word category	Rule	Probability of occurrence	Exception
1.	Tri-syllabic non-tonal words	Stress on syllable 3 (R1)	0.92	-

Table 4/12: Lexical Stress Rules for Tri-syllabic Non-Tonal Words

b) Tri-syllabic Toneme Words

Twenty eight phonetically annotated words have been analysed out of which 7 words contain toneme in initial syllable. The stress of all three syllables of each word was calculated using the empirical stress function (s_t). The intra-syllabic stress of 28 words was calculated using the formula $s_{ti} = ((s_{t3}-s_{t2})/s_{t2})* 100$ and s_{ti} is tabulated as at Annexure V in Appendix D, where i varies from 1 to 28.

Mean of s_{ti} for 28 words ($\overline{s}_t$) = 4.85

Using eq (1), Standard Deviation (σ) = 5.92

Where n=28; h=2

The range is $-4.54 \leq s_t \leq 16.49$

The normal distribution curve is:

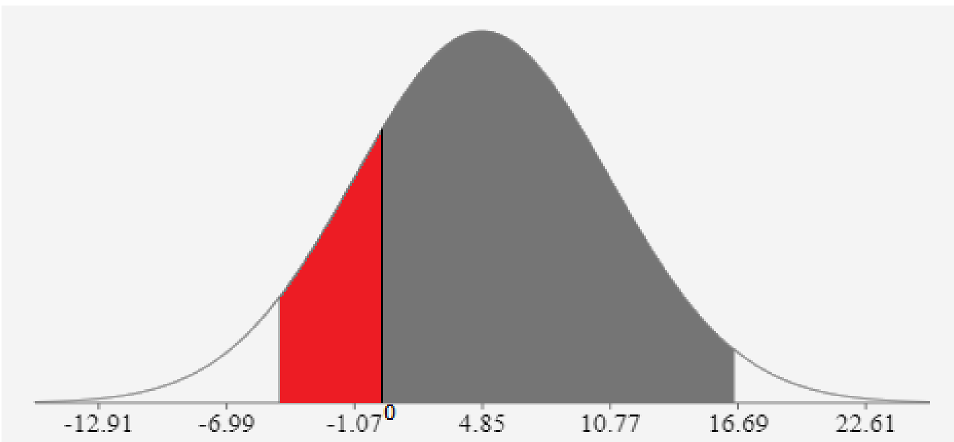


Fig 4/21: Graph of the Distribution of Lexical Stress Data of Tri-syllabic Toneme Words

It is observed that majority of data is positive which reflects that the stress lies on the third syllable. The percentage of words having intra-syllabic stress less than 0 can be calculated using z score.

$z = (0-4.85) / 5.92 = -0.81$

$P_r (x < 0) = P_r (z < -0.81) = 0.20$ i.e. 20 % (marked red in fig)

Therefore there is 80% probability of lexical stress being present on third syllable. It is observed that seven words (* marked) containing toneme as onset in the initial syllable have s_{t1} as the heaviest syllable and thus stress falls on the syllable 1 in these cases for example:

ਭਸੂੜੀ /pə̀suɽi/ (refer Annexure V in Appendix D)

The Rule 1 (R1) is largely applicable for this category of words and stress falls on the third syllable however observing from the data, it is noted that syllable s_{t1} is stronger if it contains toneme in the initial syllable. In this case the stress which generally falls on the ultimate syllable gets counter balanced. Hence the rule table can be represented as:

S. No.	Word category	Position of toneme	Rule
1.	Tri-syllabic Toneme words	Medial / Final syllable	Stress on syllable 3 (R1)
		Initial syllable	No Stress (R2)

Table 4/13: Lexical Stress Rules for Tri-syllabic Toneme Words

c) Tri-syllabic Words (consisting of cosonant /h/ or conjuncts of /ɦ/)

Twenty eight words containing consonant /h/ and conjuncts of /ɦ/ were examined. The stress of syllable 1, syllable 2 & syllable 3 of each word was calculated using the empirical stress function (s_t).

The intra-syllabic stress of was calculated using the formula $s_{ti} = ((s_{t3}-s_{t2})/s_{t2})* 100$ and s_{ti} is tabulated as at Annexure V1 in Appendix D, where i varies from 1 to 28.

Mean of s_{ti} for 28 words ($\overline{s}_t$) = 3.82

Using eq (1), Standard Deviation (σ) = 4.5

Where n=28; h=2

The range is $-8.03 \leq s_t \leq 17.6$

The normal distribution curve is:

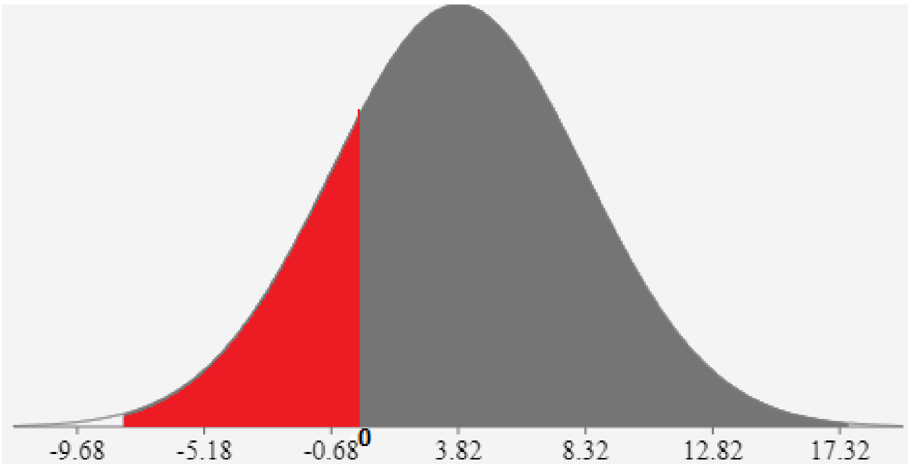


Fig 4/22: Graph of the Distribution of Lexical Stress Data of Tri-syllabic Words (consisting of cosonant /h/ or conjuncts of /ɦ/)

It is observed that majority of data is positive which reflects that the stress lies on the third syllable. The percentage of words having intra-syllabic stress less than 0 can be calculated using z score.

z = (0-3.82)/4.5= - 0.85

P_r (x < 0) = P_r (z < -0.85) =0.19 i.e. 19 % (marked red in fig)

Therefore there is 81% probability of lexical stress being present on third syllable.

The Rule 1 (R1) is largely applicable for this category of words however it is noted from the above figure that three words marked in the red region do not carry any lexical stress. Hence the rule table can be represented as:

S. No.	Word category	Rule	Probability of occurrence	Exception
1.	Tri-syllabic Words (consisting of cosonant /h/ or conjuncts of /ɦ/)	Stress on syllable 3 (R1)	0.81	-

Table 4/14: Lexical Stress Rules for Tri-syllabic Words (consisting of cosonant /h/ or conjuncts of /ɦ/)

4.11.3 Poly-syllabic Words

Twelve poly-syllabic (8 quadri-syllabic & 4 penta-syllabic) annotated words have been analysed. The syllabic weights of all the syllables of each word were calculated and have been tabulated as at Annexure VII in Appendix D.

S. No.	Word category	Rule	Exception
1.	Poly-syllabic words	Stress on ultimate syllable (R1)	Noted in 50% of the words
		Stress on penultimate syllable (R3)	Noted in 50% of the words
		No Stress (R2)	Toneme in initial syllable

Table 4/15: Lexical Stress Rules for Poly-syllabic Words

4.12 Findings and Discussion

<table>
<tr><th>S. No.</th><th colspan="2">Word category</th><th>Rule</th></tr>
<tr><td>1.</td><td colspan="2">Di / Tri-syllabic non-tonal words</td><td>Stress on ultimate syllable</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">Di /Tri-syllabic Supra-Laryngeal tonal words</td><td>Toneme in medial or final syllable</td><td>Stress on ultimate syllable</td></tr>
<tr><td>Toneme in initial syllable</td><td>No Stress</td></tr>
<tr><td>3.</td><td colspan="2">Di /Tri-syllabic words (consisting of cosonant /h/ or conjuncts of /ɦ/)</td><td>Stress on ultimate syllable</td></tr>
<tr><td rowspan="3">4.</td><td rowspan="3">Poly-syllabic words</td><td>Noted in 50% of the words</td><td>Stress on ultimate syllable</td></tr>
<tr><td>Noted in 50% of the words</td><td>Stress on penultimate syllable</td></tr>
<tr><td>Toneme in initial syllable</td><td>No Stress</td></tr>
</table>

Table 4/16: **Lexical Stress Marking Rules**

The difference between strong and weak syllables is of linguistic importance as discussed in section 4. In this context few examples of words having functional stress which is phonemic has been discussed in section 4.8.1. The experimental work carried above has focused on identifying the strongest syllable in a word so that stress can be marked on this syllable based on which prosody modeling can be done for text to speech system development.

Chapter 5

Acoustic Variability of Schwa

5. Introduction

Speech science is the study of all the factors involved in producing, transmitting, perceiving and comprehending speech, including all relevant aspects of anatomy, physiology, neurology and acoustics, as well as phonetics. Speech analysis began in 1940 in the United States of America. The study of speech production from an acoustical point of view provides the means for looking at a very complex process in a simple way. The source of sound with which we are most concerned is the human voice. Here fluctuations in air pressure are caused by a variety of means. The most important of these is the rapid opening and closing of the vocal cords. Each time the vocal folds are closed pressure is built up, which is suddenly released when they are opened. Consequently the rapid opening and closing of the folds causes a series of sharp variations in air pressure. The air in the vocal tract will vibrate in different ways when the vocal organs are in different positions.

Speech sounds in a language are generally classified in two broad categories, viz, segment and supra-segmental. Segmental sounds are further divided into vowels and consonants. Supra-segmental sounds are classified into stress, tone, nasalization etc. Vowels can be defined in terms of both phonetics and phonology. Phonetically, they are sounds articulated without a complete closure in the mouth or a degree of narrowing which would produce audible friction; the air escapes evenly over the centre of the tongue. If air escapes solely through the mouth, the vowels are said to be oral; if some air is simultaneously released through the nose, the vowels are nasal. It is very difficult to classify the vowels and this classification is usually carried out using acoustic or auditory criteria, supplemented by details of lips position. There are several systems for representing vowel position visually. From a phonological point of view, vowels are those units which function at the centre of syllables.

In some approaches, the term ‘vowel’ is reserved for the phonological level of analysis; vocoid is then used for the phonetic vowel which generally is called a semi-vowel also.

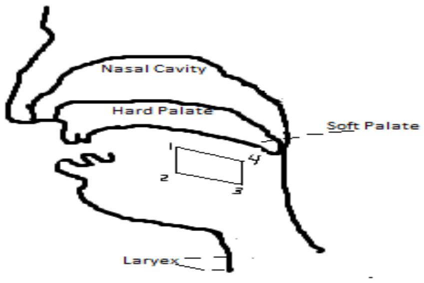


Fig 5/1: Tongue Positions in Production of Vowels

In the production of vowels, air stream coming from the lungs passes through the oral cavity without any obstruction. While producing vowels, different parts of the tongue move to different heights within the oral cavity, the shape of the lips is modified. In the production of vowels, vocal cords may vibrate to produce voiced vowels. The nasal passage remains closed when the non-nasal oral vowels are produced and it remains open allowing the air stream to pass through the nasal cavity thus producing nasalized vowels. Point 1 in the above Figure indicates the height to which the front of the tongue can be raised in the production of vowel sound. Points 1 & 4 represent the front close and the back close position respectively. Point 3 represents back open unrounded vowel i.e. /a/. Point 2 represents front unrounded vowel between half-open and open position i.e. vowel /œ/.

Vowel systems vary greatly in their complexity from language to language. English happens to be relatively rich in vowel contrasts, with the added complexity that the vowel system is by no means uniform across the English-speaking world. Lindblom (1986), provides a brief but useful survey of ‘some facts’ about vowel systems as well as discussion of how languages exploit the ‘vowel space’. His paper includes references to both classic and recent work on universal aspects of vowel systems.

At the end of the nineteenth century, scholars began to feel the need for a standardized and internationally acceptable, system of phonetic transcription. Although there was and still is much to be said for non-alphabetic system of representation, it is the International Phonetic Alphabet (IPA) developed and promulgated by the International Phonetic Association since 1888 which with or without minor modification is now most widely used by linguists. The basic principle upon which the IPA is constructed is that of having a different letter for each distinguishable speech-sound.

Primary & Secondary Cardinal Vowels

A reference system of vowel pronunciation in terms of the vowel sounds that is independent of any given language has been devised. A famous example of such a system is the Cardinal Vowels. Daniel Jones (1976) postulated the vowel quadrilateral and the cardinal vowels, a Primary set and a secondary set of cardinal vowels. Each set comprising eight vowels, the choice of 8 vowels in the primary cardinal vowel system was probably strongly influenced by the vowel system of late 19th/early 20th century. A given cardinal vowel is described by its articulation in terms of three dimensions: tongue height, front-back position of the tongue and degree of rounding.

	Primary Cardinal Vowels		**Secondary Cardinal Vowels**	
	Front	**Back**	**Front**	**Back**
Close	i	U	y	ɯ
Close-mid	e	O	ø	ɤ
Open-mid	ɛ	ɔ	œ	ʌ
Open	a	ɑ	ɶ	ɒ

Table 5/1: Cardinal Vowels (i)

The primary and secondary cardinal vowel categories provide a suitable framework for comparison for many languages.

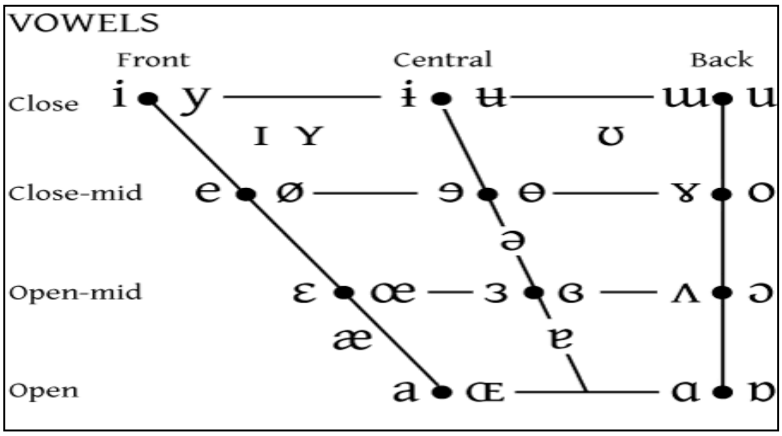


Fig 5/2: Cardinal Vowels (ii)

The neutral Schwa vowel sound is produced without tightening the throat and vocal cords, which is not the case for the other vowel sounds. Recasens (1991), claims that Schwa is the vowel with the highest degree of variability; hence it is important to discuss this in detail.

Quality of Schwa

Schwa is an important part of the vowel space but is considered as a weak vowel as compared to other vowels. The pitch of the neutral Schwa vowel sound is low and it is barely audible. It goes by so fast when someone is speaking that you may not even notice it's there. Thus orthographically also it is not written in some cases. To produce the neutral Schwa vowel sound, the throat must be relaxed and the air passage must remain open. The mouth will remain open slightly as well in order to produce this sound. Schwa is often taken to be a mid-central vowel, in accordance with the denotation of the Schwa symbol [ə] in the International Phonetic Alphabet. The three phonological processes of vowels are well known viz. Initial Vowel Truncation, Vowel Reduction and Vowel Deletion.

Initial Vowel Truncation

Vowel Schwa when used in initial position of the word sometimes gets truncated in pronunciation. This phenomenon may vary from language to language and is also speaker dependent. This variation may also be found in various dialects of a language.

Vowel Reduction

Phonetic reduction most often involves a centralization of the vowel that is, amount of movement of the tongue in pronouncing the vowel is reduced, as with the characteristic change of many unstressed vowels at the end of English words to something approaching Schwa. A well-researched type of reduction is that of the neutralization of acoustic distinctions in unstressed vowels, which occurs in many languages. Vowel reduction is a phenomenon that happens around the world, according to different rules for each language. The most common reduced vowel is Schwa which is particularly vulnerable to the co-articulatory effects of adjacent consonants.

Vowel Deletion

An elision or deletion is the omission of one or more sounds (such as a vowel, a consonant, or a whole syllable) in a word or phrase. The word elision is frequently used in linguistic description of living languages, and deletion is often used in historical linguistics for a historical sound change. Many studies have confirmed that Schwa deletion is influenced by multiple factors such as lexical stress position, sonority, lexical frequency, word length, phonotactic environment and speech style.

The basis for the weakness of Schwa has been the subject of much research by phonological experts Van Oostendrop (2000), but much less attention has been devoted to the question of what the phonetic characteristics of Schwa vowel are, hence acoustic analysis of only Schwa vowel has been undertaken in this thesis.

5.1 Variations of Schwa in English

In linguistics, mainly phonetics and phonology, Schwa is the mid-central vowel sound amidst the vowel chart, indicates by the IPA sound /ə/. It was first utilized in English texts between 1890 and 1895. In Hebrew writing, “shva” /ְ **(two vertical dots) /** is a vowel diacritic that can be written under letters to indicate an ‘eh’ sound (which is not the same as our Schwa). The term was first used in linguistics by 19th century Germany philologists, which is why we use the German spelling, “Schwa”. Styler (2012), discussed the difference between Schwa /ə/ and wedge /ʌ/. The difference between /ə/ and /ʌ/, at a fundamental level, is that /ə/ is a reduced vowel, whereas /ʌ/ is a full vowel. The language-specific Variations of Schwa are being discussed in this section.

5.1.1 Schwa in British English

In English, there are 44 distinctive speech sounds 20 of these are vowels and the remaining 24 are consonants. /ə/ is a very frequently occurring vowel in English. It occurs only in unaccented syllables. The vowel is articulated with 2 different tongue-positions, depending upon whether it occurs finally in a word or elsewhere. During the articulation of non-final /ə/, the centre of the tongue is lifted towards the roof of the mouth to a height along with half-close and half-open. The lips are neutral. Non–final /ə/ is therefore a central unrounded vowel lies between half-close and half-open.

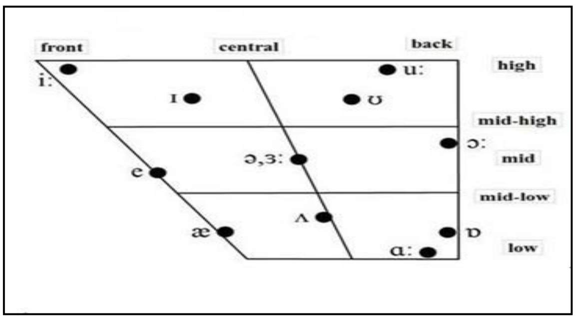


Fig 5/3: Cardinal Vowels (British English)

/ə/ occurs initially, medially and finally in a word.

Initial apˈpoint /əˈpɔɪnt/

Medial ˈexcellent /ˈeksələnt/

Final ˈdrama /ˈdramə/

English is a stress-timed language displaying phonological vowel reduction: weak vowels, such as Schwa [ə], are part of the phonological form of many words in the language. Schwa in English is mainly found in unstressed positions, but in some other languages it occurs more frequently as a stressed vowel. It is a particularly frequent vowel in English, as it is the one most commonly heard when a stressed vowel becomes unstressed, e.g. telegraph becoming telegraphy /ˈʈeləgraːf/ /ʈəˈlegrəfi/.

5.1.2 Schwa in American English

Vowel reduction is a prominent feature of American English, as well as other stress-timed languages. The vowel /ʌ/ is an unrounded mid-back morpheme, more or less lowered and fronted. It take places before all consonants excepting /h,z,j,w/ e.g supper /sʌpper/, cup /cʌp/, nut /nʌʈ/ etc. it can also precede clusters consisting of a resonant and a plosive e,g. hunt, bundle, punch etc or a plosive alone e.g. husk and lust. Schwa /ə/ is used only in unstressed syllable word initially medially and finally e.g. initial arise /ərise/, medial begin /bəˈgɪn/, final comma/ˈkɑmə/.

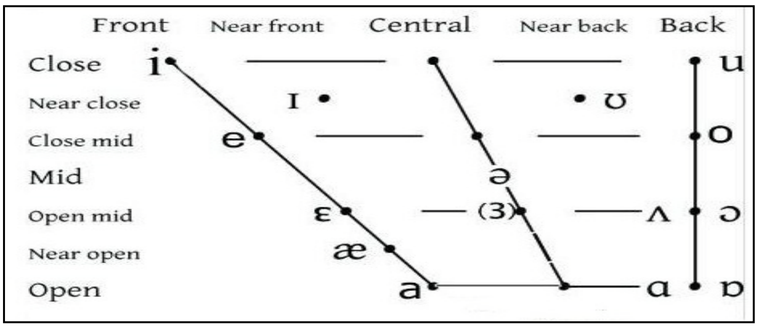


Fig 5/4: Cardinal Vowels (American English)

5.2 Schwa in Indo-Aryan Languages - Literature Survey

The Schwa sound in Greek, Latin, and Sanskrit (where it is called a *svarabhakti* vowel) and the notation of <ə> was used for Indo-European languages. The modern Indo-Aryan languages also prevalently use this notation. These languages are spoken in most of the north and centre of the Indian subcontinent, with outliers in Sri Lanka and the Maldives. Hindi-Urdu and Bengali are by far the largest; of the remainder, Marathi in south of the main area, Gujarati in south-west, Sindhi to the west, Punjabi in the north-west, Assamese in the east, Oriya in the south-east and Sinhalese in Sri Lanka all have a current literary standard and are linked to major political units. Others such as Bhojpuri or Maithili also have speakers in ten of millions. Across the main area, separate languages have arisen largely by division with a geographical continuum. The occurrence of vowel Schwa in these languages will be discussed in this section as deliberated by Pandey (2014) and many other linguists.

5.2.1 Assamese

Assamese has eight oral vowels. Vowel harmony is a distinguishing feature of the Assamese vowel system.

অ	a	ঋ	ri
আ	ā	এ	e
ই	i	ঐ	ai
ঈ	i	ও	o
উ	u	ঔ	au
ঊ	u		

Fig 5/5: Cardinal Vowels (Assamese)

Mahanta (2012), discussed the Vowel Triangle of Assamese. It is observed that there is no Schwa in Assamese.

5.2.2 Bengali

Schwa viz. /ɘ/ is open-mid central rounded vowel in Bengali. Vowel sequences of two and three occur e.g. /ɘe ɘo/, /ɘe̯o ɘe̯a/

	Front	Central	Back
Close	i		u
Close-mid	e		o
Open-mid	æ	ɞ	
Open		a	

Table 5/2: Cardinal Vowels (Bengali)

Schwa /ɘ/ in Bengali is a mid-low vowel and is realized as full vowel e.g.

/mɘl/ 'dirt' [ɘmol] 'pure',[ɘnek] 'many'.

5.2.3 Dogri

Dogri also uses mid-central open Schwa like Punjabi. In addition it has vowel allophone / ə̆/ i.e. extra short Schwa.

5.2.4 Gujarati

Murmur has been reported in Gujarati vowels which are attributed to loss of h in casual and rapid speech. Thus Schwa also gets breathy and is represented as /ə̤/ e.g.

/məhino/ [mə̤ jno] 'month'

/pəholũ/ [pɔ̤ lũ] 'broad'

There are two allophones of Schwa /ə/ viz [ɜ] [əː]

Example

/wəhelũ/ [vɛ̤ lũ] 'early'

5.2.5 Hindi

Schwa does not occur word finally.

Allophone [e] < /ə/ occurs when followed by /h/, e.g.

कहना /kæna/

लहर /lær/

5.2.6 Kashmiri

Kashmiri has in addition a long Schwa also. Both the Schwa do not occur word finally.

5.2.7 Konkani

In Konkani, Schwa is a close-mid central vowel. There are two allophones of Schwa viz. The raised, [ə̝] and [ə̞] lowered allophones occur before high and low vowels as dipthongs i.e. /əi əu/.

5.2.8 Maithili

Schwa is close-mid central vowel in Maithili and is instrumental in formation of geminates similar to Punjabi. Geminate consonants occur intervocalically. They are however in free variation with single consonants in this position.

/ pətta / [ˈpətta]

Schwa also is found as part of two and three-vowel clusters.

/ iəu iau əia əua uia /

5.2.9 Sindhi

Schwa occurs in the end of syllables unlike other Indian languages. Sindhi syllables in most of the cases end with vowels or semi-vowels and consonant can occur at initial, medial and final position of words Jatoi (1983)

For example:

S. No.	Vowel contrast		Sindhi in IPA	English	Sindhi in IPA	English
1	/ɑ/	/ ə/	sɑrə	Miss	sərə	reeds

Table 5/3: Occurrence of Schwa in end of Open Syllable in Sindhi

5.2.10 Urdu

In Urdu first alphabet alif (ا) is also used to represent Schwa /ə/. The behavior of alif in various contexts is described below:

Alif + jabar on top = /ə/ and is used as full vowel in the initial position of the word e.g.

(अल्हा) الحہٰ

Alif+ madd= /a/ in the initial position and is used as full vowel e.g.

(आम) آم

Alif in the medial and final position of a word is used as /a/ matra.

Alif + Zer below alif =/I/ and is used as full vowel in initial position e.g.

(इमली) الی

Schwa is also found as part of vowel consonant clusters:

Alif + vao = /ao/ which is a diphthong. e.g.

(आओ) اؤ

5.3 Phonetic Variations of Schwa in Punjabi

The Schwa has been the subject of much research by phonologists yet substantially less consideration has been dedicated to study of the phonetic attributes of Schwa vowel. Punjabi is a tonal language wherein Schwa is a short neutral vowel sounds like every single other vowel, its exact quality changes depending upon the adjacent consonants, which needs to be investigated.

5.3.1 Occurrence of Schwa in Isolated Words

(i) Word-initial Schwa or inherent Schwa in a consonant cluster (CC) and also Schwa as a tone bearing unit

e.g. ਅਸਾਨ (/əsan/), ਕਸਕ (/kəsək/), ਘਰ /kə̀r/

(ii) Nasalized Schwa

e.g. ਰੰਭਣਾ /rə̃bə́ɳa/, ਬਸੰਤ/bəsə̃t/

(iii) Schwa associated with Geminated Consonant as Onset

e.g. ਭਿੱਜਣਾ / pìdʒdʒəɳa/, ਬੁੱਝਣਾ/bʊdʒdʒə́ɳa/

(iv) Schwa as Release Vowel

Schwa doesn't occur in word-final position in Punjabi Panday Pramod (2014), however it is observed as consonantal release in words ending with closed syllable

e.g. ਝਾਂਜਰ /tʃã̀dʒər/, ਗੁਆਂਢਣ /gʊãɖ́ɳ/, ਢੱਕਣ /ʈə̀kkəɳ/

5.3.2 Schwa as Release Vowel in Sentences

The most psycholinguists have discussed the selection of lexical concepts and the generation of a syntactic structure of a sentence appropriate for conveying the speaker's intended meaning or "message".

Levelt (1989, 1992) argues that the unit of phonological encoding is the phonological word. He postulates a prosody generator that takes as input the rhythmic information about the selected words and combines them into phonological word frames. The phonological segments for each word are made available separately and then associated to the newly constructed phonological word frames in a left to right manner.

Short release vowel schwa is observed in following Punjabi sentence in some speakers:

(i) ਮੈਂ ਘਰ ਜਾਵਾਂਗਾ। /mɛ̃ kə̀r d͡ʒavãga/

(ii) ਮੈਂ ਘਰ ਜਾਵਾਂਗਾ। /mɛ̃ kə̀rˈə d͡ʒava/

This neutral Schwa vowel may sound like nothing or its something like a low volume, low pitch, very short grumble or grunt which ought to be verified experimentally. In this context, the phenomenon of Release Vowel as discussed in the context of Isolated Words needs to be examined in the context of a sentence and comparison needs to be drawn in both the acoustic contexts.

5.4 Experimental Study

5.4.1 Acoustic Parameters

The following parameters will be used to study the Schwa quality:

- Fundamental frequency (F_0)
- Formants (F1, F2)
- Acoustic space in terms of F1 and F2
- Intensity, Duration, slope
- Burst Energy (BE)

The acoustic space is calculated in order to determine the tongue position involved in articulation. The few examples of different categories of words will be recorded.

There can be more than one Schwa in a word occurring in different contexts as discussed in section 5.3. The Schwa in the words being analyzed will be highlighted in the word list. Burst energy i.e. (Intensity * Duration) of Schwa vowel will be calculated to determine the quality of a vowel viz lax/tense.

5.4.2 Methodology

5.4.2.1 Data Selection, Recording and Annotation

The list of phonetically balanced words was collated for this experimental analysis. The selection of the word will be prepared based on the criteria of occurrence of /ə/ in different contexts as discussed in the section 5.3.1 by using available published dictionary from authentic sources such as Punjabi-English Dictionary, Punjabi University (2011). Phoneme level annotation of the data was done based on auditory perception. The Release Vowel study is not limited to only Isolated Words and is being extended to sentence level containing that word. The Isolated Words containing tonemes and their occurrence in two different sentences were taken for two sentences containing these isolated words to examine the significance of release vowel in the Punjabi language. The informants were selected from region of Punjab where Malwai dialect is spoken. Each informant recorded the entire set of words thrice. Out of this, words containing toneme will also be recorded in sentences i.e. each word in two different sentences for study of release vowel in an isolated word viz-a-viz it's occurrence in a sentence. The sentence data was recorded only for 8 speakers (4 male & 4 female) and the corresponding Isolated Words were also recorded by these speakers for the study of release vowel.The recording and annotation of the data was carried out as per details discussed in section 1.8.2. The spectrographic analysis of all the male & female samples was carried out and phoneme level annotation was done and Release Vowel was marked in Isolated Words as well as sentences.

F_0, first two formants (F1 & F2), Intensity & duration of the schwa vowel under examination were recorded for each word by using PRAAT software for all the words being analyzed and also for the Release Vowel associated with Isolated Words as well as its occurrence in a sentence. Based on this data, the analysis of vowel quality will be carried out in various acoustic settings.

5.4.2.2 Recording of Data Sheets

The various acoustic parameters as discussed in section 5.3 were recorded and are given in the respective sections given below.

5.4.2.3 Analysis of Schwa Vowel in Isolated Words

Wilder (1975), Vowel height is inversely correlated with the frequency of the first formant: the higher the vowel (the higher the tongue position), the lower the F1. Vowel backness is reflected in the frequency of the second formant or more precisely, in the distance between the first and second formant frequencies. The frequency of the third formant does not change as much as that of F1 & F2. Formant frequencies higher that F3 are not considered important clues to the identity of the vowel. The production of nasalized vowel requires two resonators, the oral and nasal cavity. The difficult interface between these two resonators and the heavy damping of the nasal cavity give results in several differences between oral and nasalized vowels. In nasal vowel typically represent greater formants bandwidth, lower overall amplitude, a low frequency nasal formant. A traditional "vowel diagram" can be obtained by plotting the vowel formants in a graph where the horizontal axis is (F2-F1) and the vertical axis is inverse of F1. Burst energy i.e. (Intensity * Duration) of Release Vowel was recorded for Isolated Words vis-a-vis its burst energy in a sentence to identify the quality of a vowel viz lax/tense in both the contexts.

5.4.2.3.1 Oral Schwa Vowel

Schwa occurs in only word-initial and word-medial positions in Punjabi language.

The word-medial Schwa is usually used functionally to break the consonant clusters and is not represented orthographically but is phonetically realized.

Words	IPA	F1	F2	F2-F1
ਅਸਾਨ	/əsan/	625.1	1526.40	901.3
ਅਮੀਰ	/əmir/	634.22	1414.22	780
ਅਫ਼ੀਮ	/əpʰim/	649.33	1240.83	591.5
ਅਣਖ	/əɳəkʰ/	711.22	1526.78	815.56
ਅਭਿਆਸ	/əbĭas/	637	1306.90	669.9
ਅਕਾਲ	/əkal/	660	1484.00	824
ਅਨੰਦ	/ənə̃d/	665.1	1558.90	893.8
ਅੜੱਕ	/ətʃə̀kk/	603.8	1701.30	1097.5
ਅੜੱਕ	/ ətʃə̀kk /	751.8	1678.80	927
ਅੱਗੇ	/əgge/	620.8	1547.90	927.1
ਹਸਬ	/həsəb/	669.5	1505.50	836
ਹਸਬ	/həsəb/	606.1	1506.70	900.6
ਕਸਕ	/kəsək/	594.25	1380.75	786.5
ਕਸਕ	/kəsək/	590.75	1406.45	815.7
ਸਰਬ	/sərəb/	626.1	1565.20	939.1
ਸਰਬ	/sərəb/	599.5	1569.20	969.7
ਸੜਕ	/səɽək/	614	1609.90	995.9
ਸੜਕ	/səɽək/	610.50	1684.80	1074.3
ਸ਼ਗਨ	/ʃəgən/	573.4	1685.00	1111.6
ਸ਼ਗਨ	/ʃəgən/	577.7	1640.10	1062.4
ਸੰਕਟ	/sə̃kəʈ/	582.2	1633.20	1051
ਢੱਕਣ	/ʈə̀kkəɳ/	683.3	1665.80	982.5
ਲੱਭਣਾ	/ləbbə́ɳa/	655.3	1500.70	845.4
ਘੱਸਾ	/ kèssa /	592	1562.00	970
ਬਸੰਤ	/bəsə̃t/	492.5	1527.40	1034.9
ਦੁਰ ਲੱਭ	/dʊrlə́bb/	814.3	1472.19	657.89
ਝੱਗ	/tʃə̀gg/	748.1	1686.50	938.4
ਬੱਘੀ	/bə́ggi/	584.2	1457.87	873.67
ਘੱਲੂਘਾਰਾ	/kə̀llukàra/	654.6	1561.00	906.4
Average		635.40	1538.14	902.74

Table 5/4: F1 & F2 – Oral Schwa

5.4.2.3.2 Nasalized Schwa (ə̃)

Schwa before a nasal in the same syllable tends to be nasalized. The few examples of Schwa with nasalization are shown below:

Words	F1	F2	F2-F1
ਅਨੰਦ/ ənə̃d /	541.30	1498.20	956.90
ਬਸੰਤ/ bəsə̃t /	560.80	1505.90	945.10
ਸੰਕਟ/ sə̃kəʈ /	523.10	1427.20	904.10
ਅੰਗੂਰ / ə̃gur/	499.78	1274.40	774.63
ਧੰਦਾ/ tə̃̀da /	476.50	1557.20	1080.70
ਸੰਢਣਾ /sə̃ɖ̀ ɳa /	522.00	1653.70	1131.70
ਕੰਧੂਈ /kə̃dŭi /	453.67	1456.77	1003.10
ਗੰਧਲਾ /gə̃də́la /	475.80	1615.90	1140.10
ਬੰਧੂਆ /bə̃dŭa /	471.33	1359.33	888.00
ਰੰਭਣਾ /rə̃bə́ɳa/	585.10	1532.20	947.10
ਅੰਧੇਰਾ /ə̃dèra/	491.40	1594.90	1103.50
Average	534.99	1502.19	967.20

Table 5/5: F1 &F2 – Nasalized Schwa

5.4.2.3.3 Schwa Associated with Geminated Consonant as Onset ($ə_g$)

The effect of occurrence of geminated toneme as onset of the syllable containing Schwa ($ə_g$) needs to be examined to understand the variation of schwa in this context.

Words	F1	F2	F2-F1
ਬੁੱਝਣਾ /bʊˈdʒdʒə́$_g$ɳa/	510.90	1861.9	1351.00
ਰਿੱਝਣਾ /rɪˈdʒdʒə́$_g$ɳa/	504.70	1901.6	1396.90
ਭਿੱਜਣਾ /pìˈdʒdʒə$_g$ɳa/	493.10	1927.4	1434.30
ਲੱਭਣਾ /ləˈbbə́$_g$ɳa/	564	1498	934
ਇੱਧਰ /ɪˈddə́$_g$r/	624.40	1729	1104.60
Average	539.42	1783.58	1244.16

Table 5/6: F1 & F2 – Geminated Schwa

The analysis of above examples reveals that the tongue moves higher and forward in the phonetic realization of schwa in such cases.

5.4.2.3.4 Schwa as Release Vowel (ə$_r$)

Schwa doesn't occur in word-final position. In Panday (2014) however it is observed as consonantal release in words ending with closed syllable which is termed as Release Vowel (RV). The examples are shown below:

Words	IPA	F1	F2	F2-F1
ਧੜ	/tə̀ɽə$_r$/	554.08	1681.56	1127.48
ਅਣਘੜ	/ənkə̀ɽə$_r$/	565.48	1694.52	1129.04
ਅਝੱਕ	/ətʃə̀kkə$_r$/	518.2	1539.6	1021.4
ਮਾਘ	/màgə$_r$/	535.37	1545.62	1010.25
ਸਾਂਝ	/sã̀dʒə$_r$/	436.98	1766.85	1329.87
ਝਾਂਜਰ	/tʃàdʒərə$_r$/	539.99	1682.13	1142.14
ਢੱਕਣ	/ ʈə̀kkəɳə$_r$ /	556.94	1606.6	1049.66
ਘਰ	/kə̀rə$_r$/	523.42	1675.41	1151.99
ਝੱਗ	/tʃə̀ggə$_r$/	515.51	1586.65	1071.14
ਝੂਠ	/tʃùʈ^{h}ə$_r$/	549.13	1518.61	969.48
ਧੰਨ	/tə̀nə$_r$/	556.42	1598.79	1042.37
	Contd..			

Words	IPA	F1	F2	F2-F1
ਬੋਝ	/bòdʒə$_r$/	451.06	1687.67	1236.61
ਉਝਬੁਘ	/ʊ̀dʒəbʊ́gə$_r$/	471.43	1459.12	987.69
ਡਿੰਘ	/ɖɪ̃̀gə$_r$/	564.83	1602.56	1037.73
ਤਾਂਘ	/tã̀gə$_r$/	517.84	1568.88	1051.04
ਪੀਂਘ	/pɪ̃̀gə$_r$/	490.42	1588.66	1098.24
ਊਂਘ	/ʊ̃̀gə$_r$/	597.81	1477.94	880.13
Average		526.17	1604.775	1078.6

Table 5/7: F1 & F2 – Release Vowel in Isolated Words

5.4.2.3.5 Vowel Diagram of Schwa

Based on the above findings, the acoustic space is depicted in the below graph for various phonological settings plotting the average values of each category as discussed above:

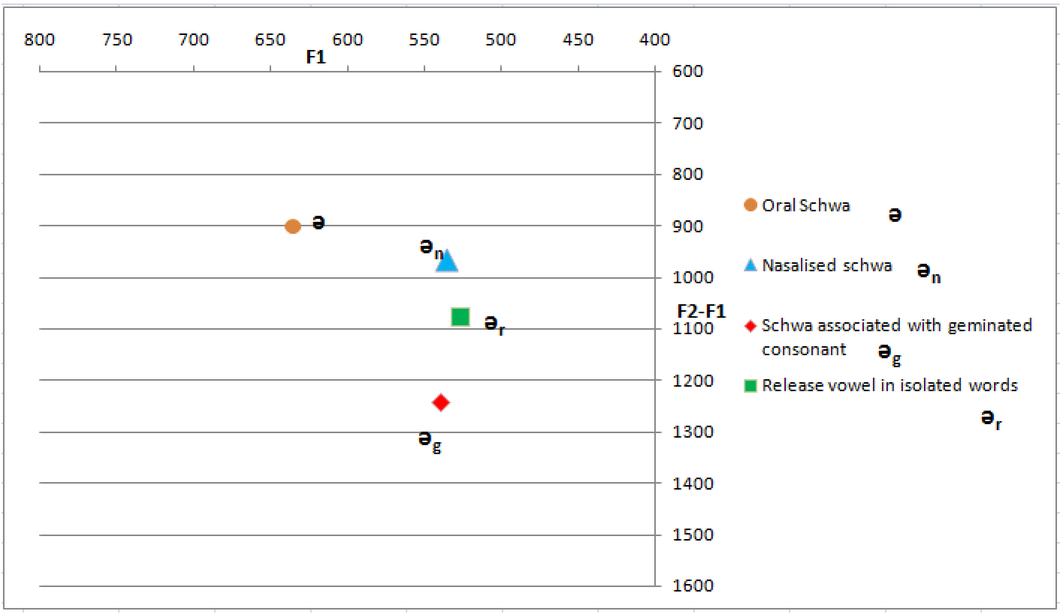


Fig 5/6: F1, F2–F1 Plot of Schwa in different Acoustic Contexts

The acoustic variations of Schwa can be observed from F1 & F2 plot given below:

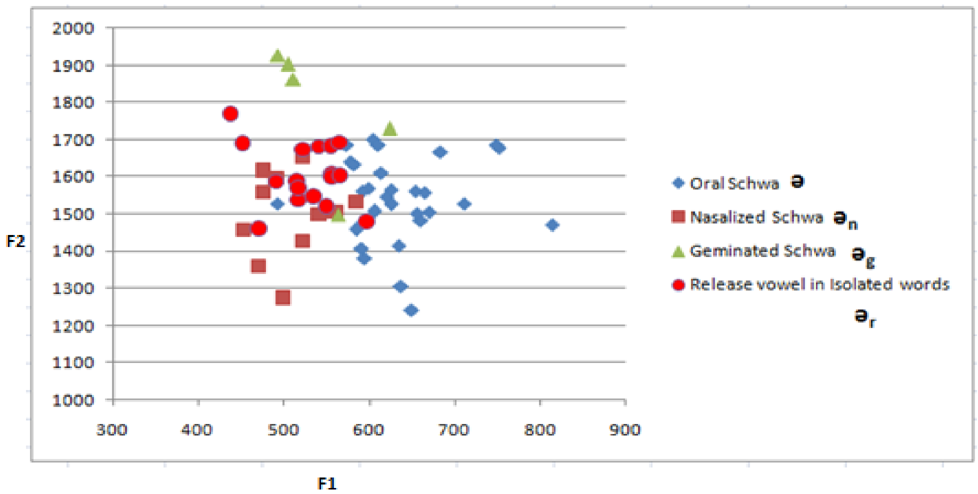


Fig 5/7: F1, F2 Scattered Graph of Schwa

The range of F1 &F2 of Schwa vowel in above acoustic contexts is tabulated below:

F1 Table

Categories	**F1 range**	**Vowel height**
ə	500-800	Mid
$ə_n$	450-600	Transition zone high
$ə_g$	500-650	
$ə_r$	450-600	

Table 5/8: F1 Range in different Acoustic Contexts

F2 Table

Categories	**F2 range**	**Articulatory zone**
ə	1200-1700	Central
$ə_n$		
$ə_g$	1500-1950	Transition zone front
$ə_r$	1450-1800	Transition zone front

Table 5/9: F2 Range in different Acoustic Contexts

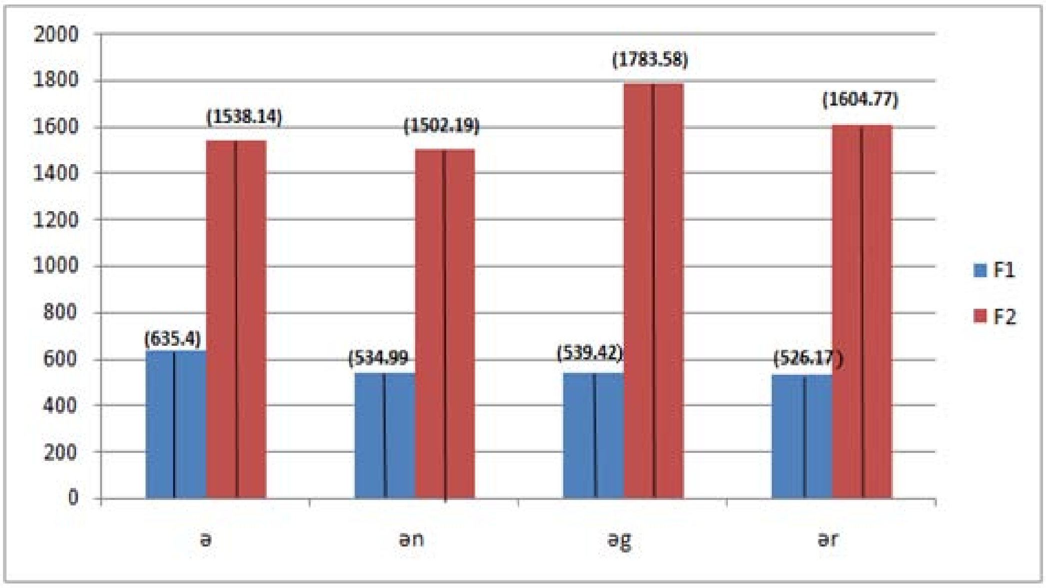


Fig 5/8: F1, F2 Average Values Bar Chart in different Acoustic Contexts

5.4.2.4 Comparison of Release Vowel (ə$_r$) in Isolated Words viz-a-viz Sentences

The average of burst energy of Release Vowel in Isolated Words viz-a-viz average of burst energy when the same word occurs in two sentences is tabulated below:

	Word with in a Sentence			**Isolated Words**		
Words	**F1**	**F2**	**Burst Energy (Duration * Intensity)**	**F1**	**F2**	**Burst Energy (Duration * Intensity)**
ਘਰ /kə̀rə$_r$/	443.25	1792	2.71	470.00	1725.00	9.03
ਢੱਕਣ /ʈə̀kkəɳə$_r$/	391	1498	0.78	567.00	1730.50	6.04
ਧੰਨ /tə̃̀nə$_r$/	409	1969.5	2.28	538.50	1686.00	9.23
ਧੜ /tə̀ɽə$_r$/	497.5	1650.5	3.23	506.50	1705.50	10.87
ਝੱਗ /t͡ʃə̀ggə$_r$/	387	2342	2.26	494.00	1612.00	10.15
ਝੂਠ /t͡ʃùʈ^{h}ə$_r$/	475.5	1921	2.21	442.00	1522.00	10.02
						Contd..

	Word with in a Sentence			Isolated Words		
Words	**F1**	**F2**	**Burst Energy (Duration * Intensity)**	**F1**	**F2**	**Burst Energy (Duration * Intensity)**
ਝਾਂਜਰ /t͡ʃȁd͡ʒərə$_r$/	408	1323.5	4.50	470.50	1724.50	8.72
ਚਿੰਘਾੜ /t͡ʃĩgàɽə$_r$/	502	1687.5	0.17	694.00	1876.00	5.18
ਅਣਘੜ /ənkə̀ɽə$_r$/	551.5	1695	2.53	499.00	1766.50	8.13
ਉਝਬੁਘ /ʊd͡ʒbʊ́gə$_r$/	556	1777.5	1.92	441.50	1471.50	9.19
ਸੀਂਢਲ /sĩɖ̤`lə$_r$/	446.5	1569.5	3.40	516.00	1477.00	11.38
ਅਝੱਕ /ət͡ʃə̀kkə$_r$/	514	1450	3.31	528.50	1584.50	8.05
ਡਿੰਘ /ɖ̤ĩ́gə$_r$/	546.5	1746.5	4.76	511.50	1625.00	9.66
ਤਾਂਘ /tã́gə$_r$/	426.5	1727.5	1.20	454.50	1567.00	8.48
ਪੀਂਘ /pĩ́gə$_r$/	624	1940	2.30	453.00	1655.00	6.58
ਊਂਘ /ṹgə$_r$/	417	1750	1.48	515.50	1471.00	9.60
ਮਾਘ /mágə$_r$/	503	1759.5	1.70	482.00	1601.50	7.12
ਸਾਂਝ /sã́d͡ʒə$_r$/	448	1799	1.16	402.50	1940.00	6.95
ਬੋਝ /bód͡ʒə$_r$/	435.5	1930	0.61	418.50	1992.50	8.37
Average	474.58	1771.17	2.24	495.00	1670.16	8.57

Table 5/10: F1 & F2 - Isolated Words viz-a-viz Sentence

Fundamental frequency (F_0) male & female speakers

	Male	**Female**
Isolated Words	190.11	263.33
Word occurrence in sentence	188.32	268.58

Table 5/11: F_0 - Isolated Words viz-a-viz Sentence

5.5 Results & Discussion

The variations as observed from above data analysis are reported below with reference to pure vowel /ə/ characteristics:

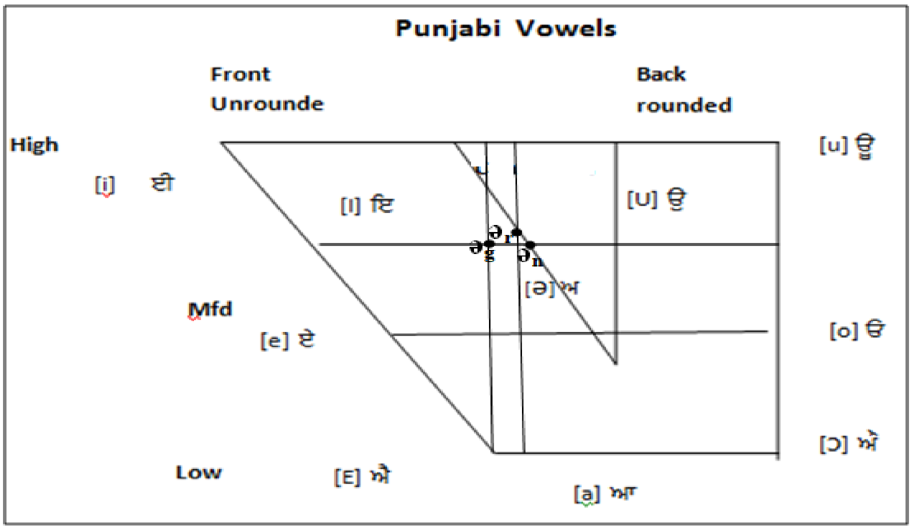


Fig 5/9: Cardinal Vowels (Punjabi)- Acoustic Variabiality of Schwa

The data analysis from the above tables and graphs reveals that there is variation in the quality of Schwa in Punjabi language. The Schwa in IPA is indicated as mid-central vowel as discussed in this chapter however the data analysis shows changes in the vowel height and degree of backness. The following is observed from the above tables and graphs:

- The values of F1 are decreasing for nasalized Schwa and also for Release Vowel associated with Isolated Words. Similar phenomenon is also observed in case the geminated toneme occurring as onset of the syllable containing Schwa. In these cases the vowel height is 20-25% higher.
- The F2-F1 value is maximum for geminated toneme as onset of the syllable containing Schwa ($ə_g$) and decreases in case of Release Vowel associated with Isolated Words having closed last syllable ($ə_r$) & nasalized Schwa ($ə_n$) as compared to mid-central Schwa i.e. there is a relative shift in the vowel position towards the front. This shift in case of $ə_n$ is negligible.

The Release Vowel in Isolated Words (ə_r) gets shifted towards the front by 20 % in articulation. The major change in the place of articulation happens in case of ə_g which can be considered in between the front and central in the vowel triangle.

- It is observed that Burst energy of Release Vowel in a sentence is much less (only 25 %) as compared to the Release Vowel associated with Isolated Words. Hence can be ignored. It is also noted that there is not much variations in fundamental frequency and the first two formants.
- Thus the Release Vowel in a sentence gets suppressed due to the continuation of speech in the sentence due to accompanying intonation features whereas the release energy in maximum in Isolated Words due to un-interrupted pronunciation. Hence the Release Vowel in a sentence is not phonologically significant. Thus mid-central Schwa /ə/ is a pertinent vowel in terms of acoustic variations as discussed above and can be represented in IPA as follows:

(i) All nasalized Schwa (ə_n) /ə̞/

(ii) Schwa associated with geminated consonant as onset (ə_g) /ə̞̟̟/

(iii) Schwa as Release Vowel (ə_r) /ə̞̞̟/

The above findings can assist TTS developers in realizing natural speech in Punjabi TTS.

Chapter 6
Correlation of Morpho-syntactic Features with Lexical Representation and its Co-articulation

6 Introduction

In spoken production, there is an intimate link between morphological and phonological processing. First and foremost, the output of morphological operations serves as the input to phonological processes. When morphological processes combine lexical representations (morphemes) to form a multi-morphemic word, the constituent sounds must also be combined in such a way that the resulting phonological representation is suitable for driving spoken production.

The PLS provides inter-operable specification of pronunciation information which can be used for speech technology development. W3C PLS 1.0 represents the requirements of Latin script based languages with few examples mentioned for Japanese and Chinese, thus keeping the specification very broad, however it currently does not cover morphological, syntactic and semantic information associated with pronunciations (such as word stems, inter-word semantic links, pronunciation statistics, prosody etc.). POS is an available source for feature extraction for building NLP & speech systems. PLS based on morphology with overriding phonological features such as stress, tone, gemination, nasalization etc covering phonological words that contain maximum inflection under each POS category can be a useful resource for training of speech systems. An initial work on Part of speech (POS) and morphological pronunciations in Pronunciation Lexicon Specification (PLS) – Bengali has been carried out as discussed in section 1.7.1. The paper proposed addition of POS feature in PLS XML structure either as an attribute or an element. This can be used to choose the proper pronunciation among multiple pronunciations of the same orthography of a word. This information can reduce the search time in a large vocabulary recognition and synthesis system. This needs to be further investigated for Punjabi language. Therefore there is a need to standardized the tags to be used for part-of-speech information to be encoded in PLS data.

6.1 Standard POS Tag Set

Parts of Speech tagging is one of the key building blocks for developing speech applications. A Part-Of-Speech Tagger (POS Tagger) is a piece of software that reads text in a language and assigns parts of speech tag to each word such as noun, verb, adjective etc. Punjabi has a rich base of POS based inflections e.g.

Word	IPA	POS	Gloss
ਉੱਕਰਵਾਂ	/ʊkkərʋã/	JJ,M,S	engraved, etched
ਉਕਰਵਾਉਣਾ	/ʊkərʋaʊɳa/	VM,M,S	to get engraved, inscribed
ਉਕਰਵਾਈ	/ʊkərʋai/	N,F,S	wages for

Table 6/1: Example of POS Based Inflections

The POS tag set for Punjabi language has been standardised as discussed in Paper "Standardization of POS Tag Set for Indian Languages based on XML Internationalization best practices guidelines" by Lata et al (2012), the same is enclosed at Annexure I of Appendix D. The prosodic features of Punjabi are discussed here with the help of examples transcribed in IPA using these standard POS Tags.

6.2 POS Inflections in Punjabi

Punjabi is highly inflectional language like most other Indo-Aryan Languages. POS is an important feature in Punjabi language. Main parts of speech (POS) in Punjabi are noun, pronoun, verb, adjective, adverb, preposition, conjunction and interjection etc. An affix is a morpheme that is attached to a word stem to form a new word. Affixes are divided depending on their position with reference to the stem as discussed below:

6.2.1 Prefix

A prefix is a morphological unit, for example 'un-' or 'multi-', which is added to the beginning of a word in order to form a different word. For example, the prefix 'un-' is added to 'happy' to form 'unhappy’. Use of prefixes is much lesser as compared to the use of suffixes in Punjabi. These are mostly used with Nouns, Adjectives. Its use with verbs is very rare. For example:

Word	IPA	POS	Gloss
ਪਹਿਲ	/pél/	N,F	first step/initiative
ਪਹਿਲਾ	/pél-a/	JJ,M	First
ਪਹਿਲੂ	/pél-u/	N,M	aspect/point of view
ਪਹਿਲੇ	/pél-e /	JJ,M	first/foremost
ਪਹਿਲਣ	/pél-əɳ/	JJ	calved for the first time
ਪਹਿਲਾਂ	/pél-ã/	RB	formerly/before hand

6.2.2 Suffix

A suffix is a morphological unit attached to the end of a word to form a new word or to change the grammatical function (or part of speech) of the original word. For example, the verb read is made into the noun reader by adding the suffix -er. Similarly, read is made into the adjective readable by adding the suffix -able. The addition of suffix may also lead to change in number, gender & person. The Punjabi examples related to these changes are covered in the following section.

6.2.2.1 Change in Grammatical Categories

Word	IPA	POS	Gloss
ਮੁੰਡਾ	/mũd-a/	N,M,S	boy
ਮੁੰਡੇ	/mũd-e/	N,M,P	boys
ਮੁੰਡਿਆਂ	/mũd-Iã/	N,M,P	boys
ਮੁੰਡਿਓ	/mũd-Io/	N,M,P	boys

6.2.2.2 Word Inflection for Number, Gender and Person

Inflection for Number change

Word	IPA	POS	Gloss
ਮੁੰਡਾ	/mũd-a/	N,M,S	boy
ਮੁੰਡੇ	/mũd-e/	N,M,Pl	boys
ਕੁੜੀ	/ kuɽ-i /	N,F,S	girl
ਕੁੜੀਆਂ	/ kuɽ-ia /	N,F,Pl	girls

Gender change

Word	IPA	POS	Gloss
ਬੁੱਢਾ	/ bʊ́d̪ d̪-a/	N,M	old man
ਬੁੱਢੀ	/ bʊ́d̪ d̪-i /	N,F,S	old woman
ਘੋੜਾ	/koɽ-a/	N,M	horse
ਘੋੜੀ	/koɽ-i/	N,F,S	mare

6.3 Distinctive Features of Morphology-Phonology Interface

The morphological structure of a complex word determines how the constituent morphemes of a word are realized phonetically. The phonological structure of a complex word reflects its morphological structure, but is not isomorphic to that structure. A native speaker understands that spoken words are made up of sequences of speech sounds and has the ability to hear and manoeuvre the sounds in spoken words. This ability is known as phonemic awareness. Phoneme is capable of distinguishing meanings of words. Phonemic awareness is a subset of phonological awareness in which listeners are able to hear, identify and manipulate phonemes, the smallest mental units of sound that helps to differentiate units of meaning (morphemes). Phonology plays a role in the selection of one from a set of competing affixes. The supra-segmental phonemes i.e. patterns of articulations due to presence of tone, stress, nasalisation, germination etc are phonemic. Hence the distinctive features of morphology-phonology interface of Punjabi language will be discussed in this section. These features are essential for the completeness of PLS and should necessarily be captured for complete phonological coverage of the language.

6.3.1 Tone

Tone in Punjabi language has been discussed in detail in chapter 2 & 3. The tonal minimal pairs based on three types of tone i.e. high-tone /ó/, low-tone /ò/ and mid-tone /ō/ have been discussed in this section. Level tone is also phonemic however it is customary not to mark it in the pronunciation lexicon. For example:

Word	IPA	POS	TONE	Gloss
ਸਨ	/sən/	V,Aux	Nil	were
ਸੰਨ	/sə̃n/	N,M	Nil	year
ਸੰਨ੍ਹ	/sə̃́n/	N,M	HighTone	hole made by thieves
ਭਾਰ	/pɑ̀r/	N, M	Low Tone	load
ਪਾਰ	/pɑr/	RB ,Both	NiL	beyond
ਬਾਹਰ	/bɑhər/	RB, Both	NiL	out

6.3.2 Nasalization

Nasalisation is phonemic in Punjabi. Tippi (ਘਂ) and Bindi (ਸੇਂ) are used to represent nasalisation. Functionally both are same however there are some rules in orthography with regard to use of tippi and bindi. Tippi is used only in conjunction with some vowels and matras i.e. [ਅ, ਇ, ਿ, ੁ, ੂ] /ə, I, I, U, u/ and rest of the vowels and matras use bindi. For example:

Word	IPA	POS	Gloss
ਘਟਾ	/kə̀ʈa/	N,F	to subtract/decrease
ਘੰਟਾ	/kə̃̀ʈa/	N,M	large bell
ਸੌ	/ sɔ /	N	hundred
ਸੌਂ	/ sɔ̃/	V	to sleep

6.3.3 Gemination

Punjabi has a large number of geminates. In Punjabi, gemination is phonemic and it results in unique words. For example:

Word	IPA	POS	Gloss
ਦਸ	/dəs/	JJ	digit ten
ਦੱਸ	/dəss/	V	to tell
ਦਿਲੀ	/dIli/	JJ	from heart
ਦਿੱਲੀ	/dIlli/	N	delhi

Word	IPA	POS	Gloss
ਸਤ	/sət/	N, M	strength
ਸੱਤ	/sətt/	QTC	seven
ਸਦਾ	/səda/	RB	always
ਸੱਦਾ	/sədda/	N, M	invite
ਘੁਟਣਾ	/ kʊ̀ʈɳɑ /	N	knee
ਘੁੱਟਣਾ	/kʊ̀ʈʈɳɑ/	V	to press

6.4 Word variants

6.4.1 Free variations

It is the phenomenon of two (or more) sounds or forms appearing in the same environment without a change in meaning. There is an alternative textual representation for the same word or phrase in Punjabi. For example:

Word	IPA	POS	Gloss
ਗੁਰਦੁਆਰਾ	/gʊrudʊɑrɑ/	N	place of worship
ਗੁਰਦਵਾਰਾ	/gʊrdəvɑrɑ /	N	place of worship
ਕੁਤਕੁਤਾਰੀ	/ kʊtkʊtɑri/	V	tickling
ਕੁਤਕੁਤੀ	/kʊtkʊti /	V	tickling
ਭੈ	/pὲ /	N	fear
ਭੌ	/ pɔ̀/	N	fear

6.4.2 Homonyms

Homonyms are words which sound alike, but have different meanings. There is abundance of homonyms in Punjabi.

Word	IPA	POS	Gloss
ਖਾਣ	/kʰɑɳ/	V	to eat
ਖਾਣ	/kʰɑɳ/	N	mine
ਡੰਡ	/ʤ̃ɖ/	N	push-up
ਡੰਡ	/ʤ̃ɖ/	N	punishment
ਡੰਡ	/ʤ̃ɖ/	N	noise

6.4.3 Homographs

Homographs are words with the same spelling (and sometimes different pronunciations), but different meanings. For example:

Word	IPA	POS	Gloss
ਭਰਾ	/pə̀ra/	N, M	brother
ਭਰਾ	/pə̀ra:/	V	to get filled
ਹਰਾ	/həra/	JJ	green colour
ਹਰਾ	/həra:/	V	to defeat

6.4.4 Homophones

Words with the same pronunciation but different meanings and different spellings. For example:

Word	IPA	POS	Gloss
ਕੜ	/kəɽ/	N	hard layer
ਕੜ੍ਹ	/kə′ɽ/	V	continuous boiling at low temperature
ਪਾੜਾ	/paɽa/	N	gap
ਪਾੜ੍ਹਾ	/páɽa/	N	learner

6.4.5 Borrowed Words

A loan word is a word borrowed from a donor language and incorporated into a recipient language. Borrowed words are adapted to the sound system and grammatical system of the language in which they are borrowed. Like when Punjabi borrows word from other languages it changes its gender or other categories according to its nature or behaviour. Punjabi language has borrowed extensively from Sanskrit, Hindi, Urdu, Persian and English. ਸ਼ /ʃ /, ਜ਼ /z/, ਫ਼ /f/, ਖ਼ /x/, ਗ਼ /ɣ/ used only for borrowed words from Perso-Arabic. Such borrowed words have been assimilated in Punjabi however some of the native speakers do not pronounce nukta hence both the variants are in use. For example:

Word in Urdu	Word variants in Punjabi	IPA
زمانہ	ਜ਼ਮਾਨਾ	/zəmɑnɑ/
	ਜਮਾਨਾ	/dʒəmana/

These words pose a challenge in building PLS for Punjabi language, in deciding which pronunciation should be kept in the database, either or both.

6.4.6 Acronyms / Abbreviations

An acronym is a word or name formed as an abbreviation from the initial components in a phrase or a word, usually individual letters and sometimes syllables. There are no universal standards for abbreviations and the orthographic styling. For some words and phrases pronunciation can be expressed quickly and conveniently as a sequence of other orthographies. Acronyms / Abbreviations as used in some Punjabi language terms is given below:

ਭਾਸ਼ਾ ਵਿਭਾਗ ਪੰਜਾਬ	---	ਭਾ. ਵਿ. ਪੰ.
/pàʃa/ /vɪbàg/ /pə̃d͡ʒab/		/pà./ /vɪ./ /pə̃./
ਸਰਦਾਰ ਕੇਸਰ ਸਿੰਘ	---	ਸ. ਕੇ. ਸਿੰ.
/sərdar/ /kesər/ /sɪ̃́g/		/s./ /ke./ /sĩ./
ਵਿੱਚੋਂ	-	’ਚੋਂ
/vɪt͡ʃt͡ʃõ/		/’t͡ʃõ/
/ਅਤੇ/	-	’ਤੇ
/əte		/’te/
ਉੱਤੋਂ	-	’ਤੋਂ
/ʊttõ/		/’tõ/

6.4.7 Multi-Word Expressions (MWEs)

Multiword expressions (MWEs) are expressions which are made up of at least 2 words and which can be syntactically and/or semantically idiosyncratic in nature. These act as a single unit for linguistic analysis e.g.

ਪੰਜਾਬੀ ਯੂਨੀਵਰਸਿਟੀ ਪਟਿਆਲਾ

/pə̃d͡ʒabi/ /junivərsʈi/ /pəʈɪala/

Such language specific data of all possible MWEs also needs to be encoded in PLS. The value of this attribute can be "NER" for encoding this type of data. The corresponding abbrevaiation can be encoded using <alias> element. These value can be defined suitabily for example "echo" or "duplicate" for encoding echo words and duplicate words. The examples will be covered in the next chapter.

6.5 Conclusion

The data covering the Morpho-syntactic features of Punjabi as elaborated in this chapter need to be encoded in the PLS to get prosodically rich PLS. The word list of unique words in Punjabi from major POS categories such as Noun, Verb, Adjective, Adverb and other granular features may be collated along with the variations for developing phonologically rich PLS data.

Chapter 7
Prosodic Lexical XML Database-PLS Framework, Rules and Sample Data

7. Introduction

Pronunciation Lexicons are of critical importance in the development of speech technology for a language. They represent the interface between the interpretation and analysis of speech.

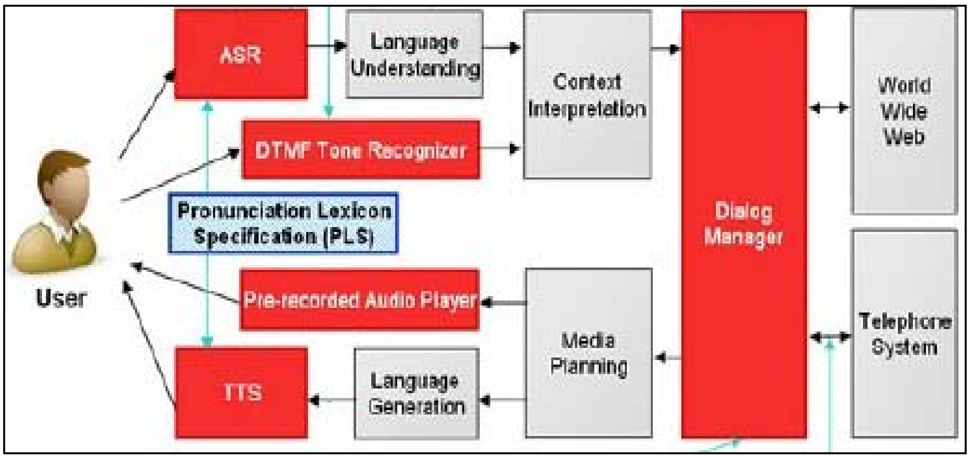


Fig 7/1: Interface between the Interpretation and Analysis of Speech

In text-to-speech (TTS) synthesis, for example, phonemic transcriptions of the pronunciations of words help determine the selection of the acoustic models for generating the targeted waveform. The Automatic Speech Recognition (ASR) engine developed based on Speech Recognition Grammar Specification (SRGS) uses PLS to leverage multiple pronunciations of words and phrases. PLS entries are also applied to the graphemes inside SRGS grammar rules to convert them into the phonemes to be recognized.

In Indian languages, Part of Speech (POS) plays an important role in pronunciation as discussed in chapter 6. The XML schema needs to be evolved which will help in capturing the language specific morphological features in PLS. The proposed XML design will also be targeted towards search optimization of PLS data.

7.1 Punjabi Lexicon

Punjabi lexicon is mainly composed of Tadbhavas and use of Tatsama words is very limited. The borrowed words pronunciation is adapted by the Punjabi speaker as discussed in section 6.4.5. Punjab being an agricultural state, the vocabulary is rich in this domain whereas vocabulary of science and technology is not so much developed. Punjabi has inflectional morphology as discussed in section 6.2. Punjabi singular nouns abundantly use ਆ /-a/ as suffix and this is indicative of the major use of masculine gender. It is also used in conjunction with singular form of verb and verb-adjective. The corresponding feminine suffix is ਈ /-i/.

The tone is phonemic and has been discussed in section 6.3.1. There is only single tone in a word and exhibits on the nucleus of the syllable containing toneme or consonant / h/ conjuncts of ਹ /ɦ/. The frequency of use of short vowels i.e. ਇ /ɪ/, ਉ /ʊ/ is very less. Among long vowels, use of ਐ /ɛ/ and ਔ /ɔ/ is less. Punjabi vocabulary contains monosyllabic and polysyllabic words however the frequency of disyllabic words is maximum. Many monosyllabic words end in long vowels. Use of dipthongs is frequently found in Punjabi. Four to five vowels can get aglutted to a verb and are commonly found in the language.

7.2 Current Framework for Pronunciation Lexicon Specification (PLS 1.0)

The current version of PLS may be referred as base line specification as it addresses the requirements of Latin script based languages.

The specification covers the multiple pronunciations and multiple orthography in the XML structure at the lexicon level thus providing the flexibility of creating language specific PLS documents.

Elements	Attributes	Description
<lexicon>	version xml:base xmlns xml:lang alphabet	root element for PLS
<meta>	name http-equiv content	element containing meta data
<metadata>		element containing meta data
<lexeme>	xml:id role	the container element for a single lexical entry
<grapheme>		contains orthographic information for a lexeme
<phoneme>	prefer alphabet	contains pronunciation information for a lexeme
<alias>	Prefer	contains acronym expansions and orthographic substitutions
<example>		contains an example of the usage for a lexeme

Table 7/1: Markup Language Definition of PLS 1.0

It only covers segmental features of the language. There is no provision to cover morphological, syntactic and semantic information associated with pronunciations (such as word stems, inter-word semantic links, prosody etc.), hence the research undertaken has addressed these additional language specific requirements in this context and proposed a new framework.

7.3 Proposed Framework for Pronunciation Lexicon Specification for Punjabi Language (PLS 2.0)

The main objective of the research undertaken has been:

- Adaptation of the W3C PLS 1.0 for evolving a framework for capturing Punjabi language phonological features.
- Corroboration of the major linguistic aspects through analytical study of recorded speech signals for Punjabi Language.
- Identification of the challenges for designing of web based Machine-Readable Pronunciation Lexicon Specification in XML.
- Design of new lexeme elements to incorporate identified features.

The supra-segmental features of Punjabi language have been experimentally examined using recorded speech samples and reported in the previous chapters. Based on these findings, W3C PLS 1.0 has been augmented as discussed here.

7.3.1 Addition of New XML Tags/Attributes

The co-rrelation of Morpho-Syntactic features with lexical representation and its co-articulation has been discussed in chapter 6. Based on these findings, new xml elements/attributes in yellow colour are proposed for addition in the existing PLS 1.0 as given in the table below:

Elements	Attributes	Description
<lexicon>	version xml:base xmlns xml:lang alphabet xml:script	root element for PLS
<meta>	name http-equiv content	element containing meta data
<metadata>		element containing meta data
<lexeme>	xml:id role	the container element for a single lexical entry

Elements	Attributes	Description
<rootword>		Container element for a rootword that contains nested derived root words with their prefixes and suffixes information
<stem>		Container elements for derivational words containing affixes of the root word
<grapheme>	Origin, pos, pre-fix, MWE , meaning	Contains orthographic information for a lexeme, its origin and it's Parts-of-speech label, Pre-fix and multi word expression viz MWE, meaning if any. Origin attribute will contain ISO 639-3 code of the language from which the word has been borrowed. The standard POS tagset will be referred as "BIS"
<suffix>		Element contains all the suffixes of the particular root word that may be nested
<inf>		Container contains all the inflections of a particular stem
<phoneme>	prefer alphabet	contains pronunciation information for a lexeme
<alias>	Prefer	contains acronym expansions and orthographic substitutions
<example>		contains an example of the usage for a lexeme

Table 7/2: **XML Structure of PLS 2.0 Framework**

"Script Attribute" of <lexicon>:

Punjabi is written in two scripts i.e. Gurmukhi script (used in Punjab, India) or Shahmukhi script, a Perso-arabic script (used in Punjab, Pakistan). Although the scope of the thesis is limited to Gurumukhi script yet it will be appropriate to add script attribute in the lexicon to cater to the users of both the scripts to keep the framework resilient. The script values for these languages can be encoded in the PLS lexicon, which is a four-letter code as per ISO: 15924 “Codes for the representation of names of scripts”. The code value for Gurmukhi is “Guru” and the code value for Shahmukhi is not yet assigned in the standard. The xml: lang tag is already provisioned in the PLS, code value of “Pan” will be encoded in the sample PLS data as per ISO: 639-3 “Codes for the representation of names of languages”.

Element <rootword>

It is a container element for a rootword and all other word inflections. The <rootword> element contains one <grapheme> element and corresponding <phoneme> element. The <rootword> element forms multiple orthographies and corresponding pronunciations using affixes.

Origin Attribute

There are many borrowed words as discussed in chapter 6. The origin attribute contains the information of the language from which the word has been borrowed and will be used only for borrowed words.

POS Attribute

It is important to encode POS information for each lexeme viz rootword and its inflected words. The Standrad POS labels will be used as per Annexure I (appendix D) of Chapter 6 to encode POS attribute for each lexeme and the tagset will be referred as “BIS”.

Prefix Attribute

The words generated from the root with addition of pre-fix will also be entered as lexemes within the rootword container however pre-fix attribute will be added with it’s <grapheme> and <phoneme> elements.

Suffix Element

The words generated from the root with addition of suffix will also be entered as lexemes within the rootword container and suffix element will be added.

Multi-Word Expression (MWE) Attribute

The combination of two or more words which conveys specific information needs to be encoded as use of such words is very common as discussed in section 6.4.7. This attribute will also be used for encoding echo words, duplicate words, idioms/ proverbs, compound words etc.

7.4 Sample PLS Data in Conformance with PLS 2.0 Framework

Punjabi morphology is highly inflectional as discussed in section 6.2. Verbs have maximum inflections. There are some words which are used both as native and borrowed. The linguistic variations as discussed in the previous chapters need to be captured in the PLS data for complete coverage of the language hence XML of representative examples is given in the following sections:

7.4.1 Verb/ Noun ਕਾਰ /kar/

As Tadbhava, it is native word of Punjabi and is used as a verb and as Tatsama, it is a word borrowed from English and used as a noun. Samples of lexicon xml are given below:

ਕਾਰ /kar/ - verb has 10 inflections viz 3 prefixes and 7 suffixes

```
<?xml version="1.0" encoding="UTF-8"?>
<lexicon version="1.0"
    xmlns="http://www.w3.org/2005/01/pronunciation-lexicon"
```

```
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.w3.org/2005/01/pronunciation-lexicon
      http://www.w3.org/TR/2007/CR-pronunciation-lexicon-20071212/pls.xsd"
    alphabet="ipa" xml:lang="pan">
<lexeme>
<rootword>          // native root word  /kar/ as verb starts here
<grapheme pos="BIS: V_VM"> ਕਾਰ </grapheme>
<phoneme> /kar/ </phoneme>
<stem>  // stems of the root word  /kar/ start here
<inf>               // inflections of native root word  /kar/ using prefix start here
<grapheme prefix="ਅ" pos="BIS: N_NN"> ਅਕਾਰ </grapheme>
<phoneme> /əˈkar/ </phoneme>
<grapheme prefix="ਅਧਿ" pos="BIS: N_NN"> ਅਧਿਕਾਰ </grapheme>
<phoneme> /ədìˈkar/ </phoneme>

<grapheme prefix="ਬੇ" pos="BIS: JJ"> ਬੇਕਾਰ</grapheme>
<phoneme> /beˈkar/ </phoneme>
</inf>              // inflections of native root word /kar/ using prefix end here
<suffix>            // suffixes of the native root word  /kar/ start here
```

<inf> // inflections of native root word /kar/ using suffixes starts here

<grapheme> ਕਾਰਗਰ </grapheme>

<phoneme> /karˈgər/ </phoneme>

<grapheme MWE="compound"> ਕਾਰ-ਆਮਦ </grapheme>

<phoneme> /kar-aˈməd/ </phoneme>

<grapheme MWE="compound"> ਕਾਰ-ਸੇਵਾ </grapheme>

<phoneme> /kar-seˈva/ </phoneme>

<grapheme MWE="compound"> ਕਾਰ-ਕਰਦਗੀ </grapheme>

<phoneme> /kar-kərdəˈgi/ </phoneme>

<grapheme MWE="compound"> ਕਾਰ-ਖ਼ਿਦਮਤ </grapheme>

<phoneme> /kar-xɪdəˈmət/ </phoneme>

<grapheme MWE="compound"> ਕਾਰ-ਮੁਖ਼ਤਿਆਰ </grapheme>

<phoneme> /kar-mʊxtɪˈar/ </phoneme>

<grapheme MWE="compound"> ਕਾਰ-ਵਿਹਾਰ </grapheme>

<phoneme> /kar-vɪˈhar/ </phoneme>

</inf> // inflections of native root word /kar/ ends here

</suffix> // suffixes of native root word /kar/ end here

</stem> // stems of native root word /kar/ end here

</rootword> // native root word /kar/ ends here

<lexicon>

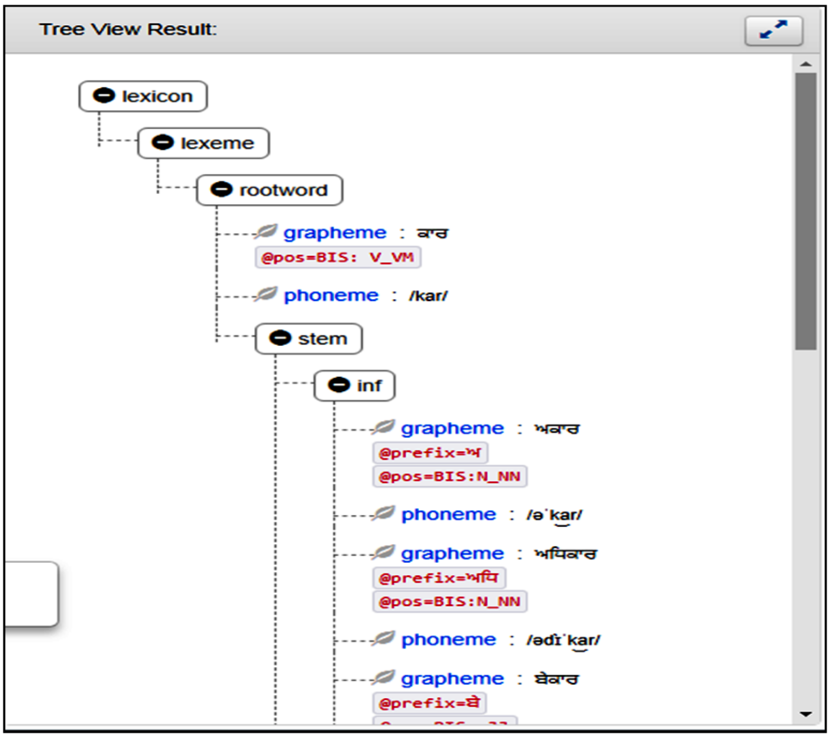


Fig 7/2: Tree view by XML Reader

A sample xml entry of lexicon for a rootword ਕਾਰ /kar/ as borrowed from English, used as noun in Punjabi language having 2 inflections viz suffixes

<lexeme>

<rootword> //Borrowed root word /kar/ starts here

<grapheme origin= “eng” pos=“BIS: N_NN”> ਕਾਰ </grapheme>

<phoneme> /kar/ </phoneme>

<stem> //stems of borrowed root word /kar/ start here

<suffix> //suffixes of Borrowed word /kar/ starts here

<inf> //inflections starts here

<grapheme> ਕਾਰੋਂ </grapheme>

<phoneme> /kaˈrõ/ </phoneme>

<grapheme> ਕਾਰਾਂ </grapheme>

<phoneme> /kaˈrã/ </phoneme>

</inf> //inflections borrowed root word /kar/ end here

</suffix> // suffixes of Borrowed word /kar/ viz car end here

</stem> //stems word of borrowed root word /kar/ end here

</rootword> // Borrowed root word /kar/ ends here

</lexeme>

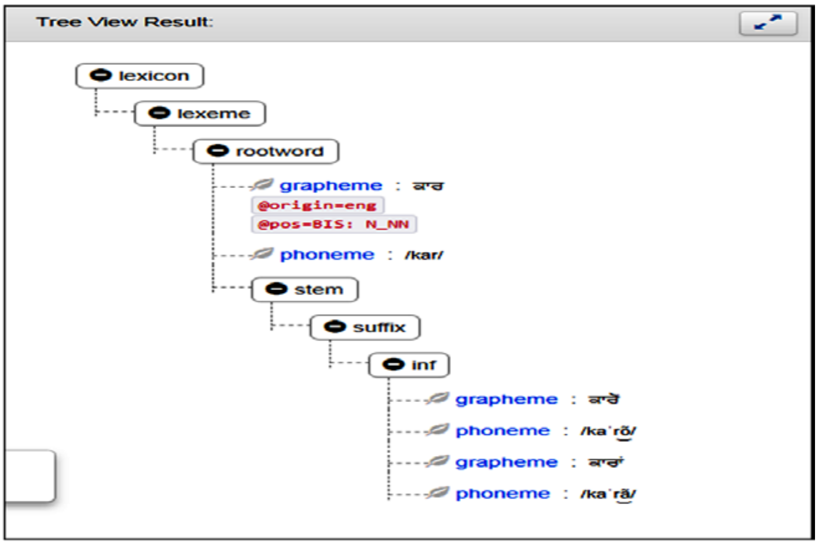


Fig 7/3: Tree view by XML Reader

7.4.2 Pronouns

The hierarchy of Pronouns (6 layers) as defined in the Standard POS Tag Set has been implemented in xml as given below:

<lexeme>

<grapheme pos="BIS: PR_PRP"> ਮੈਂ </grapheme>

<phoneme> /mɛ̃/ </phoneme>

<grapheme pos="BIS: PR_PRF"> ਆਪਣਾ </grapheme>

<phoneme> /apəˈɳa/ </phoneme>

<grapheme pos="BIS: PR_PRL"> ਜਿਸ </grapheme>

<phoneme> /dʒɪs/ </phoneme>

<grapheme pos="BIS: PR_PRC"> ਆਪਸ </grapheme>

<phoneme> /aˈpəs/ </phoneme>

<grapheme pos="BIS: PR_PRQ"> ਕਦੋਂ </grapheme>

<phoneme> /kəˈdõ/ </phoneme>

<grapheme pos="BIS: PR_PRI"> ਕੋਈ </grapheme>

<phoneme> /koi/ </phoneme>

</lexeme>

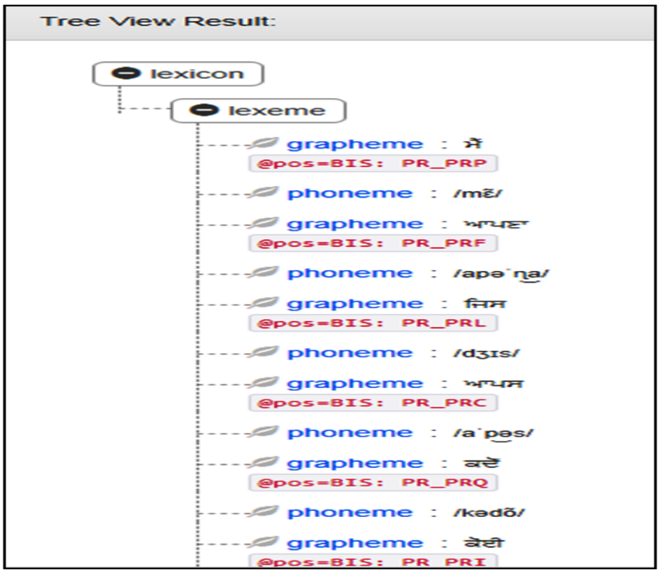


Fig 7/4: Tree view by XML Reader

7.4.3 Demonstrative Words

The hierarchy of Demonstrative words (4 layers) as defined in the Standard POS Tag Set has been implemented in xml as given below:

<lexeme><grapheme pos="BIS: DM_DMD"> ਇਹ </grapheme>

<phoneme> /í/ </phoneme>

<grapheme pos="BIS: DM_DMR"> ਜੋ </grapheme>

<phoneme> /dʒo/ </phoneme>

<grapheme pos="BIS: DM_DMQ"> ਕੌਣ </grapheme>

<phoneme> /kɔɳ/ </phoneme>

<grapheme pos="BIS: DM_DMI"> ਕਿਸ</grapheme>

<phoneme> /kɪs/ </phoneme>

</lexeme>

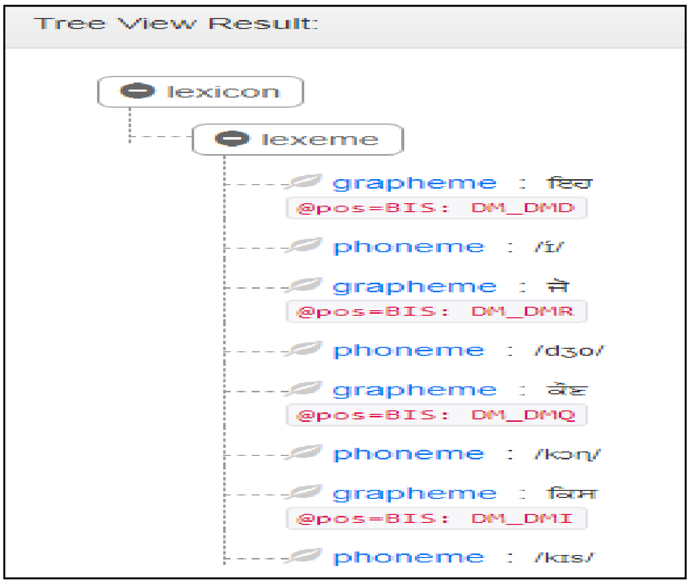


Fig 7/5: Tree view of Demonstrative Words by XML Reader

7.4.4 Verb ਘੜ /kə̀ɽ/

A sample xml entry of lexicon for a rootword ਘੜ /kə̀ɽ/, verb containing toneme ਘ /gʱ/ having nine stems, total 41 inflections out of which there are 4 prefixes. The causative form of ਘੜ /kə̀ɽ/ i.e. ਘੜਵਾ /'kə̀ɽva / has been encoded as a separate root word with 9 stems and total 37 inflections:

<lexeme>

<rootword>

<grapheme pos="BIS: V_VM"> ਘੜ </grapheme>

<phoneme> /kə̀ɽ/ </phoneme>

<stem>

<grapheme pos="BIS: V_VM"> ਘੜਿਆ </grapheme>

<phoneme> /kə̀ɽɪa/ </phoneme>

<inf>

<grapheme prefix="ਅਣ"> ਅਣਘੜਿਆ </grapheme>

<phoneme> /əɳkə̀ˈɽɪa/ </phoneme>

<grapheme prefix="ਅਣ">ਅਣਘੜਿਆਂ </grapheme> <phoneme> /əɳkə̀ˈɽĩã/ </phoneme>

<grapheme prefix="ਅਣ">ਅਣਘੜੀ </grapheme> <phoneme> /əɳkə̀ˈɽi/ </phoneme>

<grapheme prefix="ਅਣ">ਅਣਘੜੀਆਂ </grapheme> <phoneme> /əɳkə̀ˈɽĩã/ </phoneme>

</inf> </prefix>

<suffix>

<inf>

<grapheme> ਘੜੇ </grapheme> <phoneme> /kə̀ɽe/ </phoneme>

<grapheme> ਘੜੀ </grapheme> <phoneme> /kə̀ɽi/ </phoneme>

<grapheme> ਘੜੀਆਂ </grapheme> <phoneme> /kə̀ɽĩã/ </phoneme>

<grapheme> ਘੜਿਆਂ </grapheme> <phoneme> /kə̀ɽĩã/ </phoneme>

</inf> </suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਦਾ </grapheme>

<phoneme> /kə̀ɽəda/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜਦੇ </grapheme> <phoneme> /kə̀ɽəde/ </phoneme>

<grapheme> ਘੜਦੀ </grapheme> <phoneme> /kə̀ɽədi/ </phoneme>

<grapheme> ਘੜਦੀਆਂ </grapheme> <phoneme> /kə̀ɽədĩã/ </phoneme>

<grapheme> ਘੜਦਿਆਂ </grapheme> <phoneme> /kə̀ɽədĩã/ </phoneme>

</inf> </ suffix >

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਦੋਂ </grapheme>

<phoneme> /kə̀ɽədõ/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜਦੀਓਂ </grapheme> <phoneme> /kə̀ɽədĩõ/ </phoneme>

<grapheme> ਘੜਦਿਓ </grapheme> <phoneme> /kə̀ɽədɪo/ </phoneme>

<grapheme> ਘੜਦੀਓ </grapheme> <phoneme> /kə̀ɽədio/ </phoneme>

</inf> </suffix >

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਨਾ </grapheme>

<phoneme> /kə̀ɽəɳa/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜਨੇ </grapheme> <phoneme> /kə̀ɽəne/ </phoneme>

<grapheme> ਘੜਨੀ </grapheme> <phoneme> /kə̀ɽəni/ </phoneme>

<grapheme> ਘੜਨੀਆਂ </grapheme> <phoneme> /kə̀ɽənĩã/ </phoneme>

<grapheme> ਘੜਨ </grapheme> <phoneme> /kə̀ɽən/ </phoneme>

<grapheme> ਘੜਨੋਂ </grapheme> <phoneme> /kə̀ɽənõ/ </phoneme>

</inf> </ suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਾਂ </grapheme>

<phoneme> /kə̀ɽã/ </phoneme>

<inf>

<grapheme prefix="ਅਣ"> ਅਣਘੜੇ </grapheme>

<phoneme> /əɳˈkə̀ɽe/ </phoneme>

</inf>

<suffix>

<inf>

<grapheme> ਘੜੀਏ </grapheme> <phoneme> /kə̀ɽie/ </phoneme>

<grapheme> ਘੜੇਂ </grapheme> <phoneme> /kə̀ɽõ/ </phoneme>

<grapheme> ਘੜੋ </grapheme> <phoneme> /kə̀ɽo/ </phoneme>

<grapheme> ਘੜੋ </grapheme> <phoneme> /kə̀ɽe/ </phoneme>

<grapheme> ਘੜਨ </grapheme> <phoneme> /kə̀ɽən/ </phoneme>

</inf> </suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਾਂਗਾ </grapheme>

<phoneme> /kə̀ɽãga/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜਾਂਗੇ </grapheme> <phoneme> /kə̀ɽãge/ </phoneme>

<grapheme> ਘੜੇਂਗਾ </grapheme> <phoneme> /kə̀ɽẽga/ </phoneme>

<grapheme> ਘੜੋਗੇ </grapheme> <phoneme> /kə̀ɽoge/ </phoneme>

<grapheme> ਘੜੇਗਾ </grapheme> <phoneme> /kə̀ɽega/ </phoneme>

<grapheme> ਘੜਨਗੇ </grapheme> <phoneme> /kə̀ɽənge/ </phoneme>

</inf> </suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਾਂਗੀ </grapheme>

<phoneme> /kə̀ɽãgi/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜਾਂਗੀਆਂ </grapheme> <phoneme> /kə̀ɽãgĩã/ </phoneme>

<grapheme> ਘੜੇਂਗੀ </grapheme> <phoneme> /kə̀ɽẽgi/ </phoneme>

<grapheme> ਘੜੋਗੀਆਂ </grapheme> <phoneme> /kə̀ɽogĩã/ </phoneme>

<grapheme> ਘੜੇਗੀ </grapheme> <phoneme> /kə̀ɽegi/ </phoneme>

<grapheme> ਘੜਨਗੀਆਂ </grapheme> <phoneme> /kə̀ɽəngĩã/ </phoneme>

</inf> </suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜੀਦਾ </grapheme>

<phoneme> /kə̀ɽida/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜੀਦੇ </grapheme> <phoneme> /kə̀ɽide/ </phoneme>

<grapheme>ਘੜੀਦੀ</grapheme> <phoneme> /kə̀ɽidi/ </phoneme>

<grapheme>ਘੜੀਦੀਆਂ</grapheme> <phoneme> /kə̀ɽidĩã/ </phoneme>

</inf> </suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜੂੰ </grapheme>

<phoneme> /kə̀ɽũ/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜੀਂ </grapheme> <phoneme> /kə̀ ɽĩ/ </phoneme>

<grapheme> ਘੜਿਓ </grapheme> <phoneme> /kə̀ɽɪo/ </phoneme>

<grapheme> ਘੜੂ </grapheme> <phoneme> /kə̀ɽu/ </phoneme>

</inf> </suffix>

</stem>

</rootword>

<rootword>

<grapheme pos="BIS:V_VM"> ਘੜਵਾ </grapheme> //causative form of verb//

<phoneme> /kə̀ ɽəva/ </phoneme>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਵਾਉਣਾ </grapheme>

<phoneme> /kə̀ɽəvaʊɳa/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜਵਾਉਣੇ </grapheme> <phoneme> /kə̀ɽəvaʊɳe/ </phoneme>

<grapheme> ਘੜਵਾਉਣੀ </grapheme> <phoneme> /kə̀ɽəvaʊɳi/ </phoneme>

<grapheme> ਘੜਵਾਉਣੀਆਂ </grapheme> <phoneme> /kə̀ɽəvaʊɳĩã/ </phoneme>

<grapheme> ਘੜਵਾਉਣ </grapheme> <phoneme> /kə̀ɽəvaʊɳ/ </phoneme>

<grapheme> ਘੜਵਾਉਣੋਂ </grapheme> <phoneme> /kə̀ɽəvaʊɳõ/ </phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਵਾਉਂਦਾ </grapheme>

<phoneme> /kə̀ ɽəvãõda/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜਵਾਉਂਦੇ </grapheme> <phoneme> /kə̀ɽəvãõde/ </phoneme>

<grapheme> ਘੜਵਾਉਂਦੀ </grapheme> <phoneme> /kə̀ɽəvãõdi/ </phoneme>

<grapheme> ਘੜਵਾਉਂਦੀਆਂ </grapheme> <phoneme> /kə̀ɽəvãõdĩã/ </phoneme>

<grapheme> ਘੜਵਾਉਂਦਿਆਂ </grapheme> <phoneme> /kə̀ɽəvãõdĩã/ </phoneme>

</inf> </suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਵਾਉਂਦੋਂ </grapheme>

<phoneme> /kə̀ ɽəvãõdõ/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜਵਾਉਂਦੀਓਂ </grapheme> <phoneme> /kə̀ɽəvãõdĩõ/ </phoneme>

<grapheme> ਘੜਵਾਉਂਦਿਓ </grapheme> <phoneme> /kə̀ɽəvãõdɪo/ </phoneme>

<grapheme> ਘੜਵਾਉਂਦੀਓ </grapheme> <phoneme> /kə̀ɽəvãõdio/ </phoneme>

</inf> </suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਵਾਊਂ </grapheme>

<phoneme> /kə̀ɽəvãũ/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜਵਾਈਂ </grapheme> <phoneme> /kə̀ɽəvãĩ/ </phoneme>

<grapheme> ਘੜਵਾਇਓ </grapheme> <phoneme> /kə̀ɽəvaɪo/ </phoneme>

<grapheme> ਘੜਵਾਊ </grapheme> <phoneme> /kə̀ɽəvau/ </phoneme>

</inf> </suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਵਾਇਆ</grapheme>

<phoneme> /kə̀ɽəvaɪa/ </phoneme>

<suffix> <inf>

<grapheme> ਘੜਵਾਏ </grapheme> <phoneme> /kə̀ɽəvae/ </phoneme>

<grapheme> ਘੜਵਾਈ </grapheme> <phoneme> /kə̀ɽəvai/ </phoneme>

<grapheme> ਘੜਵਾਈਆਂ </grapheme> <phoneme> /kə̀ɽəvãĩã/ </phoneme>

<grapheme> ਘੜਵਾਇਆਂ </grapheme> <phoneme> /kə̀ɽəvãĩã/ </phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਵਾਈਦਾ </grapheme>

<phoneme> /kə̀ɽəvaida/ </phoneme>

<suffix> <inf>

<grapheme> ਘੜਵਾਈਦੇ </grapheme> <phoneme> /kə̀ɽəvaide/ </phoneme>

<grapheme> ਘੜਵਾਈਦੀ </grapheme> <phoneme> /kə̀ɽəvaidi/ </phoneme>

<grapheme> ਘੜਵਾਈਦੀਆਂ </grapheme> <phoneme> /kə̀ɽəvaidĩã/ </phoneme>

</inf> </suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਘੜਵਾਵਾਂ</grapheme>

<phoneme> /kə̀ ɽəvavã/ </phoneme>

<suffix>

<inf>

<grapheme> ਘੜਵਾਈਏ </grapheme> <phoneme> /kə̀ɽəvaie/ </phoneme>

<grapheme> ਘੜਵਾਏਂ </grapheme> <phoneme> /kə̀ɽəvaẽ/ </phoneme>

<grapheme> ਘੜਵਾਓ </grapheme> <phoneme> /kə̀ɽəvao/ </phoneme>

<grapheme> ਘੜਵਾਏ </grapheme> <phoneme> /kə̀ɽəvae/ </phoneme>

<grapheme> ਘੜਵਾਉਣ </grapheme> <phoneme> /kə̀ɽəvaʊɳ/

</phoneme>

</inf> </suffix>

</stem>

<stem >

<grapheme pos=“BIS:V_VM”> ਘੜਵਾਵਾਂਗਾ </grapheme>

<phoneme> /kə̀ɽəvavãga/ </phoneme>

<suffix> <inf>

<grapheme>ਘੜਵਾਵਾਂਗੇ</grapheme> <phoneme> /kə̀ɽəvavãge/

</phoneme>

<grapheme>ਘੜਵਾਏਂਗਾ</grapheme> <phoneme> /kə̀ɽəvãẽga/

</phoneme>

<grapheme>ਘੜਵਾਓਗੇ </grapheme> <phoneme> /kə̀ɽəvaoge/

</phoneme>

<grapheme>ਘੜਵਾਏਗਾ </grapheme> <phoneme> /kə̀ɽəvaega/

</phoneme>

<grapheme>ਘੜਵਾਉਣਗੇ </grapheme> <phoneme> /kə̀ɽəvaʊɳge/

</phoneme>

</inf> </suffix>

</stem>

< stem >

<grapheme pos="BIS:V_VM"> ਘੜਵਾਵਾਂਗੀ </grapheme>

<phoneme> /kə̀ɽəvavãgi/ </phoneme>

<suffix> <inf>

<grapheme> ਘੜਵਾਵਾਂਗੀਆਂ </grapheme> <phoneme>/kə̀ɽəvãvãgĩã/ </phoneme>

<grapheme> ਘੜਵਾਏਂਗੀ </grapheme> <phoneme> /kə̀ɽəvãẽgi/ </phoneme>

<grapheme> ਘੜਵਾਓਗੀਆਂ </grapheme> <phoneme> /kə̀ɽəvãõgĩã/ </phoneme>

<grapheme> ਘੜਵਾਏਗੀ </grapheme> <phoneme> /kə̀ɽəvaegi/ </phoneme>

<grapheme> ਘੜਵਾਉਣਗੀਆਂ </grapheme> <phoneme> /kə̀ɽəvaʊɳgĩã/ </phoneme>

</inf> </suffix>

</stem>

</rootword>

7.4.5 Adjective ਗਾੜ੍ਹਾ /gaɽá/

A sample xml entry of lexicon for a rootword ਗਾੜ੍ਹਾ /gaˈɽá/, adjective tonal word-conjunct of /ɦ/, is having 2 inflections of the root word and 1 inflection of the stem ਗਾੜ੍ਹੀ /gáˈɽi/.

<lexeme>

<rootword>

<grapheme pos="BIS:JJ"> ਗਾੜ੍ਹਾ</grapheme> <phoneme> /gaˈɽá/ </phoneme>

<suffix>

<inf>

<grapheme> ਗਾੜ੍ਹੇ </grapheme> <phoneme> /gaˈɽé/ </phoneme>

<grapheme> ਗਾੜ੍ਹਿਆਂ</grapheme> <phoneme>/gáˈɽíã/ </phoneme>

</inf>

</suffix>

<stem>

<grapheme pos="BIS:JJ"> ਗਾੜ੍ਹੀ </grapheme> <phoneme>/gaˈɽĩ/ </phoneme>

<suffix>

<inf>

<grapheme> ਗਾੜ੍ਹੀਆਂ </grapheme> <phoneme>/gaˈɽĩã/ </phoneme>

</inf>

</suffix>

</stem>

</rootword>

</lexeme>

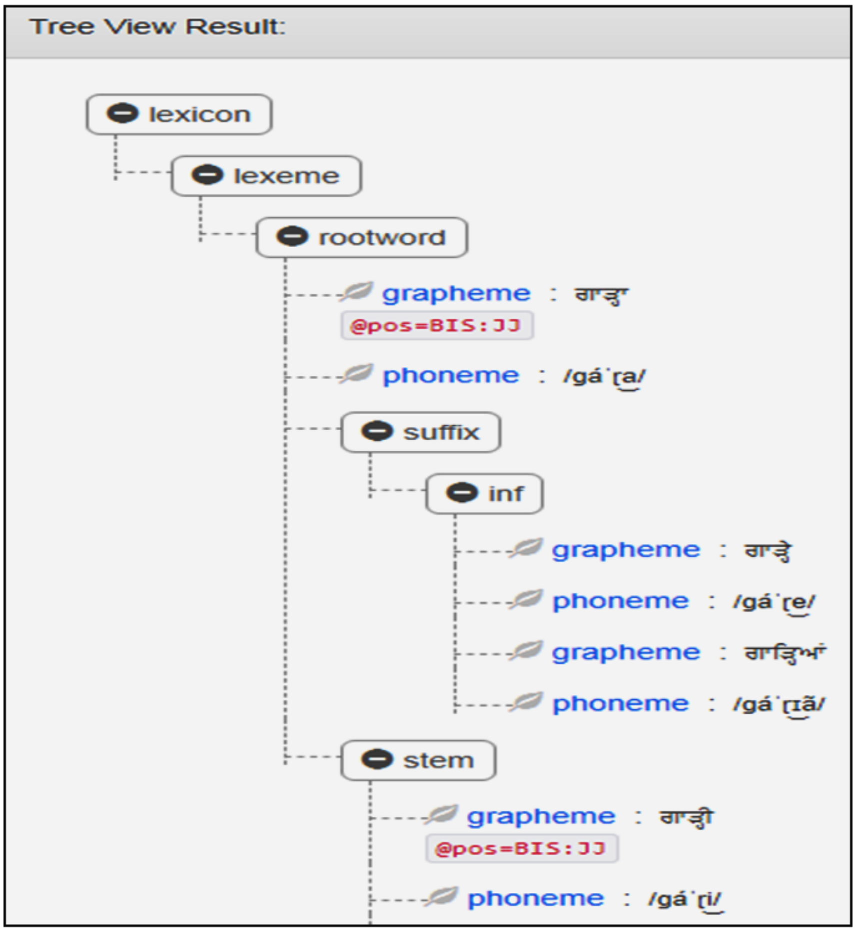


Fig 7/6: Tree view by XML Reader

7.4.6 Adverb ਬਾਹਰਵਾਰ /bahərˈvar/

A sample XML entry of lexicon for a word ਬਾਹਰਵਾਰ /bahərˈvar/:

<lexeme>

<grapheme pos="BIS:RB"> ਬਾਹਰਵਾਰ </grapheme> <phoneme> /bahərˈvar/ </phoneme>

</lexeme>

7.4.7 Postposition ਨਾਲ /nal/

A sample XML entry of lexicon for a word ਨਾਲ /nal/, postposition:

<lexeme>

<grapheme pos="BIS:PSP"> ਨਾਲ </grapheme> <phoneme> /nal/ </phoneme>

</lexeme>

7.4.8 Conjunction ਅਤੇ /əˈte/

A sample XML entry of lexicon for a word ਅਤੇ /əˈte/, conjunction:

<lexeme>

<grapheme pos="BIS:CC"> ਅਤੇ </grapheme> <phoneme> /əˈte/ </phoneme>

</lexeme>

7.4.9 Multi-Word Expressions

Sample xml data of echo words:

<lexeme>

<grapheme MWE="echo"> ਉੱਡ-ਪੁੱਡ</grapheme> <phoneme> /ʊɖɖ-pʊɖɖ/

</phoneme>

<grapheme MWE="echo"> ਉੱਜੜ-ਪੁੱਜੜ</grapheme> <phoneme> /ʊˈdʒdʒəɽ-

pʊˈdʒdʒəɽ/ </phoneme>

</lexeme>

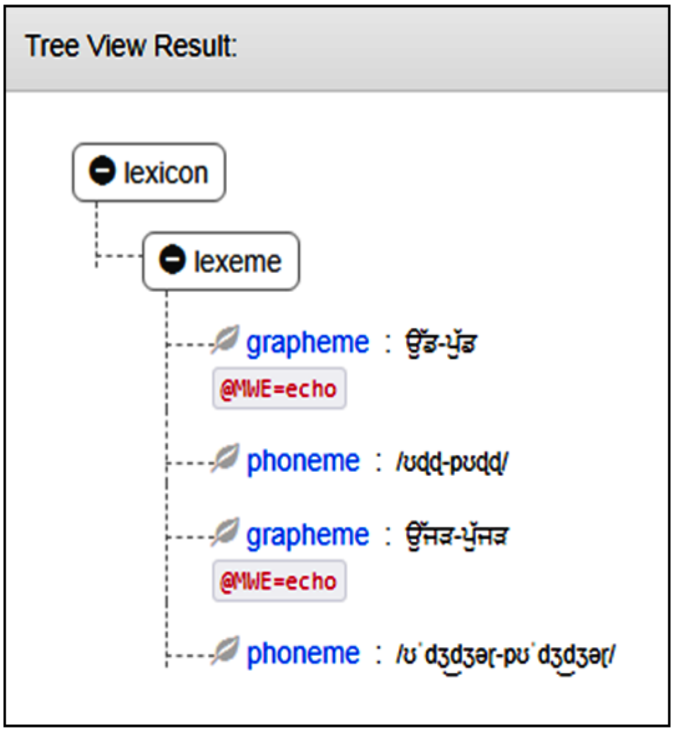


Fig 7/7: Tree view by XML Reader

Sample xml entry of duplicates:

<lexeme>

<grapheme MWE="duplicate"> ਤਾੜ-ਤਾੜ</grapheme> <phoneme> /taɽ-taɽ/ </phoneme>

<grapheme MWE="duplicate"> ਤ੍ਰਿਪ-ਤ੍ਰਿਪ</grapheme> <phoneme> /ˈtərip-ˈtərip/ </phoneme>

</lexeme>

A sample xml entry of abbreviations and Cardinal-ordinal pair:

<lexeme>

<grapheme origin= "eng" pos="BIS: N_NN" > ਡਾਕਟਰ </grapheme> <alias> ਡਾ. </alias>

<phoneme> /ɖakˈʈ̪ər/ </phoneme>

<inf> ਡਾਕਟਰਾਂ </inf> <phoneme> /ɖakʈ̪əˈrã/ </phoneme>

</lexeme>

<lexeme>

<grapheme> ਇੱਕ </grapheme> <alias> 1 </alias> <phoneme> /Ikk/ </phoneme>

</lexeme>

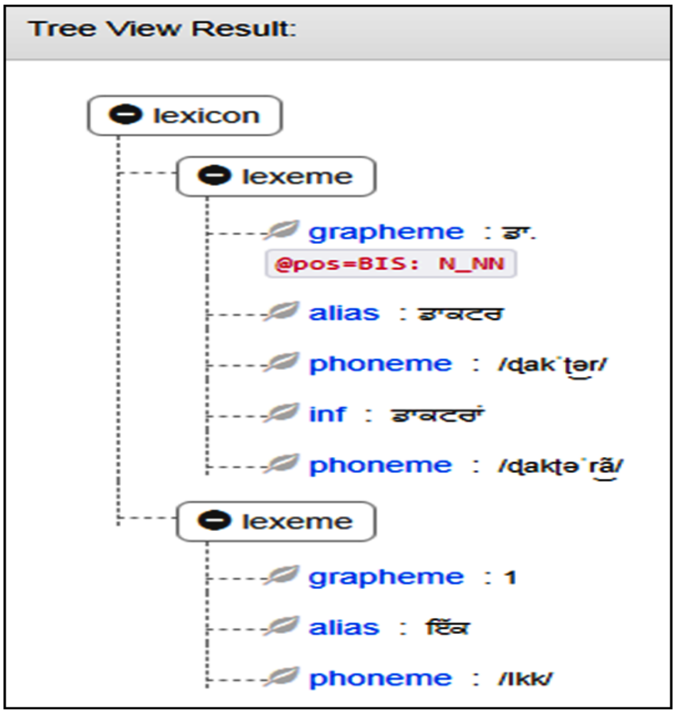


Fig 7/8: Tree view by XML Reader

7.4.10 Homographs

Sample XML Entry of homographs:

<lexeme>

<rootword>

<grapheme pos="JJ"> ਹਰਾ</grapheme> <phoneme> /həˈra/ </phoneme>

<suffix>

<inf>

<grapheme> ਹਰੇ </grapheme> <phoneme> /həˈre/</phoneme>

<grapheme> ਹਰਿਆਂ </grapheme> <phoneme> /həˈrɪã/</phoneme>

<grapheme> ਹਰੀ </grapheme> <phoneme>/həˈri/ </phoneme>

<grapheme> ਹਰੀਆਂ </grapheme> <phoneme> /həˈriã/</phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="MWE"> ਹਰਾ-ਭਰਾ </grapheme> <phoneme> /həˈra-pə̀ˈra/

</phoneme>

<suffix>

<inf>

<grapheme> ਹਰੇ-ਭਰੇ </grapheme> <phoneme> /həˈre-pə̀ˈre/

</phoneme>

<grapheme> ਹਰਿਆਂ-ਭਰਿਆਂ </grapheme> <phoneme> /həˈrɪã-pə̀ˈrɪã/ </phoneme>

<grapheme> ਹਰੀ-ਭਰੀ </grapheme> <phoneme> /həˈri-pə̀ˈri/ </phoneme>

<grapheme> ਹਰੀਆਂ-ਭਰੀਆਂ </grapheme> <phoneme> /həˈriã-pə̀ˈriã/ </phoneme>

</inf>

</suffix>

</stem>

<grapheme pos="BIS:V_VM"> ਹਰਾ</grapheme> <phoneme>/həˈra:/
</phoneme>

<suffix>

<stem>

<grapheme pos="BIS:V_VM"> ਹਰਾਉਣਾ </grapheme> <phoneme> /hərau̯ˈɳa/
</phoneme>

<suffix>

<inf>

<grapheme> ਹਰਾਉਣੇ </grapheme> <phoneme> /hərau̯ˈɳe/ </phoneme>

<grapheme> ਹਰਾਉਣੀ </grapheme> <phoneme>/ hərau̯ˈɳi/
</phoneme>

<grapheme> ਹਰਾਉਣੀਆਂ </grapheme> <phoneme> /hərau̯ˈɳiã/ </phoneme>

<grapheme> ਹਰਾਉਣ </grapheme> <phoneme> /həˈrau̯ɳ/
</phoneme>

<grapheme> ਹਰਾਉਣੋਂ </grapheme> <phoneme> /hərau̯ˈɳõ/
</phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਹਰਾਉਂਦਾ </grapheme> <phoneme> /həraõˈda/ </phoneme>

<suffix>

<inf>

<grapheme> ਹਰਾਉਂਦੇ </grapheme> <phoneme> /həraõˈde/ </phoneme>

<grapheme> ਹਰਾਉਂਦੀ </grapheme> <phoneme> /həraõˈdi/ </phoneme>

<grapheme> ਹਰਾਉਂਦੀਆਂ </grapheme> <phoneme> /həraõˈdiã/ </phoneme>

<grapheme> ਹਰਾਉਂਦਿਆਂ </grapheme> <phoneme> /həraõˈdɪã/ </phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਹਰਾਉਂਦੋਂ </grapheme> <phoneme> /həraõˈdõ/ </phoneme>

<suffix>

<inf>

<grapheme> ਹਰਾਉਂਦੀਓਂ </grapheme> <phoneme> /həraʊ̃ˈdiõ/ </phoneme>

<grapheme> ਹਰਾਉਂਦਿਓ </grapheme> <phoneme> /həraʊ̃ˈdɪo/ </phoneme>

<grapheme> ਹਰਾਉਂਦੀਓ </grapheme> <phoneme> /həraʊ̃ˈdio/ </phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਹਰਾਊਂ </grapheme> <phoneme> /həˈraũ/ </phoneme>

<suffix>

<inf>

<grapheme> ਹਰਾਈਂ </grapheme> <phoneme> /həˈraĩ/ </phoneme>

<grapheme> ਹਰਾਇਓ </grapheme> <phoneme> /həˈraɪo/ </phoneme>

<grapheme> ਹਰਾਊ </grapheme> <phoneme> /həˈrau/ </phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਹਰਾਇਆ </grapheme> <phoneme>
/həˈraɪa/ </phoneme>

<suffix>

<inf>

<grapheme> ਹਰਾਏ </grapheme> <phoneme> /həra͜e/ </phoneme>

<grapheme> ਹਰਾਈ </grapheme> <phoneme> /həˈrai/ </phoneme>

<grapheme> ਹਰਾਈਆਂ </grapheme> <phoneme> /həˈraiã/ </phoneme>

<grapheme> ਹਰਾਇਆਂ </grapheme> <phoneme> /həˈraɪã/ </phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਹਰਾਈਦਾ </grapheme> <phoneme>
/hərai'da/ </phoneme>

<suffix>

<inf>

<grapheme> ਹਰਾਈਦੇ </grapheme> <phoneme> /hərai'de/ </phoneme>

<grapheme> ਹਰਾਈਦੀ </grapheme> <phoneme> /hərai'di/ </phoneme>

<grapheme> ਹਰਾਈਦੀਆਂ </grapheme> <phoneme> /hərai'diã/ </phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਹਰਾਵਾਂ </grapheme> <phoneme> /həra'vã/ </phoneme>

<suffix>

<inf>

<grapheme> ਹਰਾਈਏ </grapheme> <phoneme> /hə'raie/ </phoneme>

<grapheme> ਹਰਾਏਂ </grapheme> <phoneme> /hə'raẽ/ </phoneme>

<grapheme> ਹਰਾਓ </grapheme> <phoneme> /hə'rao/ </phoneme>

<grapheme> ਹਰਾਏ </grapheme> <phoneme> /hə'rae/ </phoneme>

<grapheme> ਹਰਾਉਣ </grapheme> <phoneme> /hərˈaʊɳ/ </phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਹਰਾਵਾਂਗਾ </grapheme> <phoneme> /həravãˈga/ </phoneme>

<suffix>

<inf>

<grapheme> ਹਰਾਵਾਂਗੇ </grapheme> <phoneme> /həraʋãˈge/ </phoneme>

<grapheme> ਹਰਾਏਂਗਾ </grapheme> <phoneme> /həraẽˈga/ </phoneme>

<grapheme> ਹਰਾਓਗੇ </grapheme> <phoneme> /həraoˈge/ </phoneme>

<grapheme> ਹਰਾਏਗਾ </grapheme> <phoneme> /həraeˈga/ </phoneme>

<grapheme> ਹਰਾਉਣਗੇ </grapheme> <phoneme> /həraʊɳˈge/ </phoneme>

</inf>

</suffix>

</stem>

<stem>

<grapheme pos="BIS:V_VM"> ਹਰਾਵਾਂਗੀ </grapheme> <phoneme> /həravãˈgi/ </phoneme>

<suffix>

<inf>

<grapheme> ਹਰਾਵਾਂਗੀਆਂ </grapheme> <phoneme> /həraʋãˈgiã/ </phoneme>

<grapheme> ਹਰਾਏਂਗੀ </grapheme> <phoneme> /həraẽˈgi/ </phoneme>

<grapheme> ਹਰਾਓਗੀਆਂ </grapheme> <phoneme> /həraoˈgiã/ </phoneme>

<grapheme> ਹਰਾਏਗੀ </grapheme> <phoneme> /həraeˈgi/ </phoneme>

<grapheme> ਹਰਾਉਣਗੀਆਂ </grapheme> <phoneme> /həraʊɳˈgiã/ </phoneme>

</inf>

</suffix>

</stem>

</rootword>

</lexeme>

7.5 Conclusion

Phonetically rich PLS data in conformance with PLS 2.0 framework covering segmental as well as suprasegmental features such as stress, tone, gemination, nasalization etc. can be developed based on the representative samples as described above.

Chapter -8
Research Findings and Future Work

8 Research Goal

The main objectives of the proposed research have been:

i. Adaptation of the W3C PLS 1.0 for evolving a framework capturing Punjabi language phonological features.
ii. Corroboration of the major linguistic aspects through analytical study of recorded speech signals for Punjabi Language.
iii. Identification of the challenges for designing of web based Machine-Readable Pronunciation Lexicon Specification in XML.
iv. Design of new lexeme elements to incorporate identified features.

8.1 The Research Undertaken

A given phoneme is not always pronounced the same way in every context. Therefore the concepts of articulatory phonetics need to be explored to model pronunciation. Machine-Readable Pronunciation Lexicon in Punjabi can be spawned by leveraging the existing W3C Pronunciation Lexicon Specification recommendations which are global in nature and need to be internationalized from this perspective. It is a step-in-step inter- disciplinary process which involves study of language specific phonological features using experimental phonetics. The specific emphasis was laid on the study of suprasegmental features of Punjabi to evolve a rule set leveraging the existing knowledge found in linguistic literature. The layered approach was adopted to verify the existing rules and discover exceptions. New knowledge base has been created to report and handle these exceptions by evolving additional rules to augment the machine learning approaches in speech processing. Thus the framework PLS 2.0 has been developed which can capture such model Punjabi lexicon pronunciation in global IPA standard.

The Extensible Markup Language (XML) which can be used both for machine and human consumption however machine readable pronunciation lexicon is the major outcome which will aid production of Punjabi speech systems. The phonology specific to the Punjabi language when systematically approached through experimental effort using computer-aided tools, can help discover the way sounds are differently realized in different environments as governed by the grammar of the language. The phonological rules thus discovered can be used for building computational models of phonological learning i.e. how the phonological rules can be automatically induced by machine learning algorithms.

8.2 Evidence from Quantitative Analysis for Phonological Rules

Quantitative research involves the use of computational, statistical, and mathematical tools to derive results. It is conclusive in its purpose as it tries to quantify the problem and understand how prevalent it is by looking for projectable results largely applicable. Thus the segmental and suprasegmental prosodic features require in-depth analysis for arriving at phonological rules.

Segments, usually phonological units of the language, such as vowels and consonants, are of very short duration. A given feature may be limited to a particular segment but may also be longer (as a suprasegmental feature). Suprasegmental refers to a phonological property of more than one sound segment. Suprasegmental information applies to several different linguistic phenomena (such as pitch, duration, intensity and loudness). The data gathered was annotated at phoneme level for study of segmental features and at syllable level for examining the suprasegmental features. The parameters were recorded as discussed in the previous chapters. The proposed hypothesis was validated and variations reported.

Tone is a very important feature of Punjabi language which makes it distinct from other Indo-Aryan languages. Hence an elaborate study of this has been carried out as discussed in chapters 2 & 3. Stress has not been considered a very crucial parameter by Punjabi linguists.

However it has been given due attention as it becomes relevant from machine perspective. Stress has been dealt at intra-syllabic level within a word which is meaningful for building a lexicon that can be utilized for artificial production of speech via text-to-speech tools. These tools can utilize this stress information to produce near human voice by machine learning of prosodic features incorporated in the data developed based on PLS 2.0. Similarly these features can be leveraged by speech recognition systems for attaining an acceptable level of efficacy in recognizing native speakers' speech.

The steps involved in quantitative research can be divided into:

1. Current hypothesis based on literature survey
2. Collection of appropriate data to verify the hypothesis
3. Analysis of data to validate the hypothesis and report rules along with exceptions
4. Evolve new hypothesis

8.3 Research Findings

8.3.1 Tones

The observational experimental methodology as deliberated in chapter 3 was adopted to report the types of tones observed in Punjabi lexicon based on the slope pattern of the fundamental frequency of the tone bearing vowel (TBU).

8.3.1.1 Verification and Validation

The available hypothesis on high and low tones in Punjabi has by and large been corroborated in both types of tones viz tones arising from supra-laryngeal consonants and independent tones which have been experimentally verified as discussed in chapter 3.

8.3.1.2 Discovery of Allotones

The level tone in Punjabi is not marked and existence of low (HL) and high tone (LH) is well recognized and are not represented orthographically. However Punjabi native speakers handle the tone variations in their speech naturally and predictably.

Allotones are linguistically non-significant variants of tones but are considered important for the development of technologies such as speaker identification, language identification and speech recognition as these may vary from person to person and occasion to occasion. Two new allotones have been discovered viz LHL as an allotone of LH and HLH as an allotone of HL. This phenomenon has been noted in 50-70% of the speakers and very rarely in all speakers in a particular context as elaborated in the table below.

Tone on vowel of syllable under consideration	**Category of words (syllable under consideration)**	**Co-articulation parameters in a syllable**	**Tone/Allotones (percentage of speakers)**
LH	Monosyllabic	Consonant /h/ as coda	LH (50%); LHL (50%)
	Mono/di/ tri/poly-syllabic (initial syllable)	Toneme or conjunct containing /ɦ/ as coda	LH (100%)
	Di/tri/poly-syllabic (medial syllable with short vowel as nucleus)	Toneme or conjunct containing /ɦ/ as onset	LH (100%)
	Di/ tri/poly-syllabic (final open syllable)	Toneme as onset	LH (100%) Tone shifts to nucleus (vowel) of prior syllable
	Tri/-syllabic (final open syllable)	Dipthong (long + long)	LHL (100%)
	Di/ tri-syllabic (final closed syllable)	Consonant /h/ or conjunct containing /ɦ/ as coda	LH (70%); LHL (30%)
			Contd..

Tone on vowel of syllable under consideration	**Category of words (syllable under consideration)**	**Co-articulation parameters in a syllable**	**Tone/Allotones (percentage of speakers)**
HL	Monosyllabic (closed syllable)	Toneme as onset Consonant /h/ as coda Any other consonant as coda	HL (100%) HL (50%); HLH (50%)
	Monosyllabic (open syllable)	Dipthong	HLH (100%)
	Di/ tri/poly-syllabic (initial syllable)	Toneme as onset.	HL (100%)
	Tri/poly-syllabic (medial open syllable and long vowel as nucleus)	Toneme or conjunct containing /ɦ/ in the onset Dipthong (long + short vowel)	HL (100%)
	Di-syllabic (final closed syllable)	Toneme as onset Toneme as coda Dipthong (short + long) and (long + long) and flap / fricative / nasal coda	HL (100%) HL (60%), HLH (40%) HLH (100%)
	Tri-syllabic (final open syllable)	Consonant /h/ or conjunct of /ɦ/ as coda with dipthong (long + long)	HLH (100%)

Table 8/1: **Research Findings on Tones/Allotones**

8.3.1.3 Extrapolation of the Existing Knowledge Base

- The detailed experimental analysis of the co-articulation parameters examined through recording, annotation and quarter-wise slope observations of the fundamental frequency taking tone rich data covering large variety of phonetic contexts lead to indepth understanding of the tone patterns of the Punjabi language.
- The visualization of the tone patterns using the scientific tools has corroborated the perceptual & X-ray studies done by linguists and added conviction.

- The speaker dependent reflection of allotones in certain acoustic contexts has also been discovered.
- Tone in Punjabi gets exhibited on the associated vowel of tonemes (viz nucleus of the syllable containing toneme) however it has been discovered that it shifts to nucleus of prior syllable in the phonetic context of di/tri/poly-syllabic words having toneme as onset and having final open syllable.
- The tone patterns of mono-syllabic words do not find much discussion in the literature. A significant amount of data was analyzed to report the findings.
- Allotone HLH has been discovered in all the speakers in case of open dipthongal monosyllabic words, Final closed dipthongal di-syllabic words having flap/fricative/ nasal coda and dipthongal tri-syllabic words with toneme or Consonant /h/ or conjunct of /ɦ/ as coda.

8.3.2 Lexical Stress

Stress in Punjabi is distributed solely according to a pattern based on the syllables contained within a word. The linear regression technique was used to investigate the relationship between the outcome variable and multiple explanatory variables that are potentially correlated with each other. The statistical analysis of each parameter was carried out. The intra-syllabic stress was calculated to report the stress patterns in Punjabi lexicon across various word categories. The literature survey discusses the possibility of its occurrence on ultimate/penultimate syllable in a word however stress related information is not found in Punjabi dictionaries.

The following research contributions were made:

- Empirical formula for stress function was derived through Linear Regression analysis by modeling the relationship between the dependent variables viz pitch, duration & intensity to determine the extent of contribution each variable makes towards intra-syllabic stress which is significant research contribution as no quantitative research has been reported so far.

The empirical formula was used to calculate the syllable weight for each syllable in a word covering all the words. The heaviest syllable in each word was identified.

- The statistical approach such as Normal Distribution was adopted to analyze this data and stress rules were evolved for each category of words by calculating Mean, Standard Deviation and plotting the normal distribution curve to report the stress marking rules in the Punjabi PLS data.
- These stress rules are largely applicable depending on the position and context of syllables in a word :
    i. Stress on ultimate syllable (majorly applicable)
    ii. No stress (in case toneme is present in the initial syllable)
    iii. Stress on penultimate syllable (discovered in 50 % of the polysyllabic words)

Rule No.	**Rule for marking Intra-syllabic stress**	**Condition**
R1	Ultimate syllable	Di/Tri/Poly syllabic non-tonal words and tonal words except words having toneme in initial syllable
R2	No Stress	Di/Tri/Poly tonal words having toneme in initial syllable
R3	Penultimate syllable	Some Poly syllabic words

Table 8/2: **Rules for Marking Intra-syllabic Stress**

8.3.3 Acoustic Variability of Schwa

As discussed by linguists, schwa in Punjabi is a mid-central vowel as indicated in the vowel triangle shown below. No further study has been reported on variations in its acoustic properties.

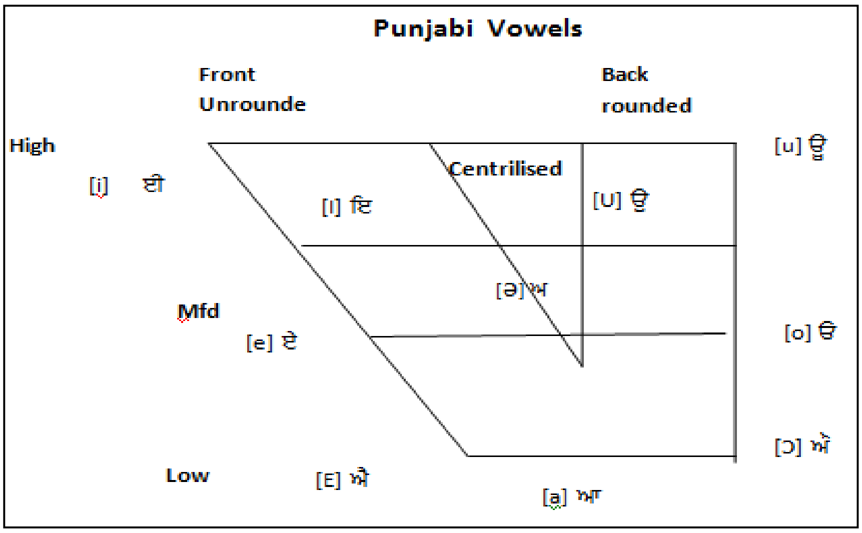


Fig 8/1: **Vowel Triangle**

The schwa has been the subject of much research by phonologists globally. The schwa not written orthographically as a part of consonant cluster however phonetically it is realized as is observed through data annotation. The current Punjabi dictionaries also mark it in the pronunciation. The analysis has been done by taking the different classes of Phonetic context, which has lead to discovery of certain acoustic variations.

Allophones of schwa(ə)	Phonetic context	Vowel height	Vowel frontness
$ə_n$	Nasalized Schwa	Close-Mid	Central
$ə_g$	Schwa in Tri-syllabic Words having Geminated Toneme as onset	Close-Mid	Transition zone front
$ə_r$	Schwa as Release Vowel in Isolated Words	Approaching Near-close	Transition zone front

Table 8/3: **Acoustic Variations of Schwa**

Three allophones of schwa have been discovered:

i. $ə_n$ is Close-Mid and Central

ii. $ə_g$ is Close-Mid and lies on the rear border of transition zone front

iii. $ə_r$ is approaching near-close and lies on the front border of transition zone front

The augmented vowel triangle incorporating acoustic variations of schwa is as below:

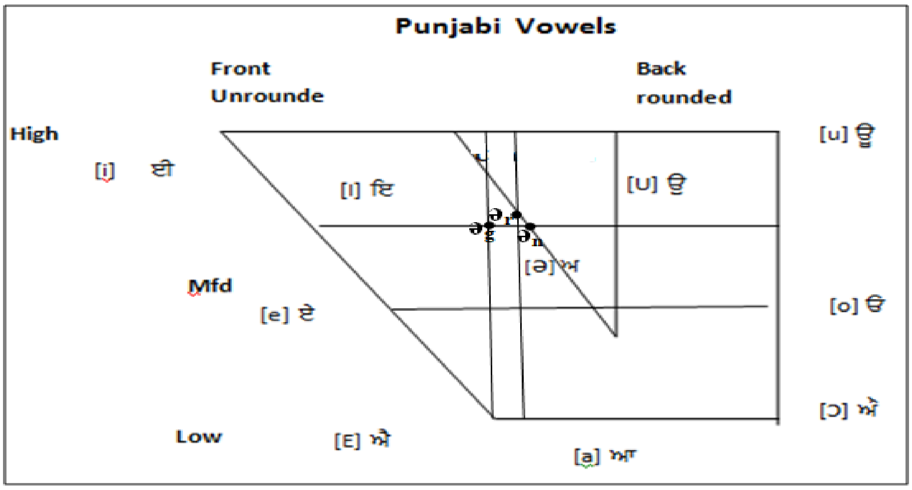


Fig 8/2: **Acoustic Variations of Schwa (augmented vowel triangle)**

The analysis of same set of words in a sentence revealed that the release vowel in a sentence is insignificant in comparision to its occurrence to isolated words.

8.3.4 Pronunciation Lexicon Specification For Punjabi Language Within W3C Framework

The World Wide Web Consortium (W3C) in 2008 recommended the machine readable pronunciation lexicon framework (PLS 1.0) which is being used globally with suitable language specific adaptations as discussed in section 1.7.2.

8.3.4.1 Research Contributions

Grammatical information in Punjabi is majorly encoded in morphology not syntax unlike English.

Therefore the Morpho-syntactic features of Punjabi were examined in correlation with the current PLS framework. Ten additional features were identified.

i. New features:

- Script – To provision for additional Shahmukhi script
- Rootword
- Stem
- Prefix
- Suffix
- Inf
- POS

Morpho-syntactic features

- Origin – To encode borrowed words
- MWE – To accommodate compound, duplicate, echo, named entities etc.
- Meaning – To differentiate homographs

ii. Incorporation of features in PLS framework

- Elements – Rootword, Stem, Suffix, Inf

The primary information to represent Morphological features is rootword which will be treated as element. Similarly Stem, Suffix and Inf constitute the secondary information to be encoded as elements wherever applicable

- Attributes – script, prefix, pos, origin, MWE , meaning

The script attribute is required to have composite data of language having multiple scripts. The prefixes find limited use in lexicon hence can be incorporated as attributes. The pos attribute will be used to define the Part-of-speech of the rootword/stem element. The origin attribute would help in identification of borrowed words. The MWE attribute is required to accommodate multiple words entries which semantically need to be treated as single entity. The meaning attribute will differentiate homographs.

These new elements/attributes (represented in yellow colour) are proposed for addition in the current framework as presented below:

Elements	Attributes	Description
<lexicon>	version xml:base xmlns xml:lang alphabet xml:script	root element for PLS
<meta>	name http-equiv content	element containing meta data
<metadata>		element containing meta data
<lexeme>	xml:id role	the container element for a single lexical entry
<rootword>		Container element for a rootword that contains nested derived root words with their prefixes and suffixes information
<stem>		Container elements for derivational words containing affixes of the root word
<grapheme>	Origin, pos, pre-fix, MWE , meaning	Contains orthographic information for a lexeme, its origin and it's Parts-of-speech label, Pre-fix and multi word expression viz MWE, meaning if any. Origin attribute will

Elements	Attributes	Description
		contain ISO 639-3 of the language from the word has been borrowed. The standard POS tagset will be referred as “BIS”
<suffix>		Element contains all the suffixes of the particular root word that may be nested
<inf>		Container contains all the inflections of a particular stem
<phoneme>	prefer alphabet	contains pronunciation information for a lexeme
<alias>	Prefer	contains acronym expansions and orthographic substitutions
<example>		contains an example of the usage for a lexeme

Table 8/4: **Proposed PLS 2.0 Framework for Punjabi**

The sample data as per this framework covering various categories of words to give a representative set from completeness point of view and also as a guideline to develop machine readable PLS data has been presented in the previous chapter.

8.4 Impact of Research Outcome on Speech Technologies in Punjabi

All the above phonological research findings can be leveraged to implement a computational Phonology model for Punjabi language. The proposed PLS 2.0 framework can be utilized to build large word level speech lexicon corpus containing prosodic information, syntax, and semantics that can be used for machine learning. The specific end use cases are discussed below.

8.4.1 Punjabi Text-to-Speech (TTS) Systems

The Open-source Festival Engine or similar other engines are used to quickly build a TTS prototype which delivers synthetic speech difficult to comprehend by humans. The prototype can be made useable by incorporating prosody to realize human like speech. It may not be easy to have TTS prototype for Punjabi, as Punjabi is tonal which compulsorily requires implementation of prosodic feature of tone, therefore no Punjabi TTS has been developed so far unlike Hindi. The in-depth treatment given to tonal features of Punjabi in this thesis will enable speech researchers in developing a TTS prototype system. The incorporation of the other research outcomes of this thesis can help in getting TTS of useable quality.

8.4.2 Language Identification Systems

F_0 and amplitude contours on a syllable-by-syllable basis are useful parameters. Language –specific prosodic cues such as stress, tone examined in this thesis can be utilized in Punjabi language identification.

8.4.3 Speech Recognition Systems Based on Prosody

Presently the speech recognition systems in Punjabi are in nascent stage. Prosody could be used to improve word recognition in ASR systems. Parameter such as pitch, intensity, and duration of different contexts has been reported in the thesis that will be utilized to generate speech vectors that can be optimized by Punjabi Speech recognition system. The work reported in this thesis can be used to develop language model and pattern matching probabilistic framework which makes use of these prosodic features of the word in question along with the information from word sequence associated.

8.5 Future Research

The foundational work done for Punjabi prosody in this thesis can provide a strong foundation for future research in following areas:

8.5.1 Extension of Work from Word to Sentence Level in Punjabi

8.5.1.1 Intonation Study: The prosodic work currently done at the intra-syllabic level within a word can be extended by recording sentences for studying intonation, juncture etc.

8.5.1.2 Co-articulation Modeling of Punjabi: The syllables having significant co-articulation features can be examined for capturing Morpho-Phonemic features which will help in reconstruction of the phonological knowledge from the speech stream. It may be desirable to capture such features for consonants (other than stops), semi vowels etc as lot of variation has been noted from the data analyzed. The spreading of nasal prosody can also be studied.

8.5.1.3 Speaker Variation: The data can be used for further analysis for reporting variations among male and female speakers and also for capturing acoustic variations across 10 speakers.

8.5.1.4 High Quality Acoustic Models in Punjabi: These rely on availability of large & reliably transcribed training sets that match the underlying distribution of speech in different acoustic environments. The large set of phonetically and prosodically rich data can be generated based on the sample data which can improve the word recognition accuracy.

8.5.1.5 Rule Based Formant Synthesis: The Klatt synthesizer approach requires rule based approach for hand crafting of phonetic units for which PLS data can be utilized. This data can also be useful for unit selection synthesis.

8.5.1.6 Language Identification: The tone patterns of Punjabi can further be investigated and based on tonal feature extraction from multilingual data stream, Punjabi language data can be segregated.

8.5.1.7 Comparative Study of Vowel Features: The acoustic variations of schwa vowel have been reported. Similar study can be done for other vowels.

8.5.1.8 Prosodic Features Based Modeling Techniques for Language Recognition: By capturing the prosodic features such as F_0, duration, Intensity etc. , the model that captures the prosodic information can be developed by using the various modeling techniques such as Neural Network, HMM, GMM, DNN, N-Gram , Histogram etc for Punjabi language speech recognition.

8.5.1.9 Extension of Work to other dialects of Punjabi: The similar data and analysis can be done for other dialects of Punjabi such as Majhi, Doabi and Lehndi.

8.5.1.10 Extension of Work to other Indo-Aryan Languages: The other Indo-Aryan languages are phonetically similar to Punjabi but are non-tonal. The data could be recorded for other languages and similar analysis may be done to corroborate the findings for a specific language.

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Appendix A – WORD LISTS

Chapter 3 – Word list of Tonemes

Monosyllabic

S.No.	Words	IPA transcription	Meaning
1.	ਘਰ	/kə̀r/	Home
2.	ਘੂਸ	/kùs/	Bribe
3.	ਡਿੰਘ	/ɖĩ́g/	Pace
4.	ਤਾਂਘ	/tã́g/	Anxiety
5.	ਪੀਂਘ	/pĩ́g/	Swing
6.	ਊਂਘ	/ṹg/	Doze
7.	ਜੰਘ	/dʒə̃́g/	Thigh
8.	ਮਾਘ	/mág/	Name of month
9.	ਝੱਗ	/tʃə̀g/	Foam
10.	ਝੂਠ	/tʃùʈʰ/	Lie
11.	ਸਾਂਝ	/sã́dʒ/	Partnership
12.	ਬੋਝ	/bódʒ/	Weight
13.	ਮੱਝ	/mə́dʒdʒ/	Buffalo
14.	ਉਂਝ	/ʊ̃́dʒ/	Otherwise
15.	ਛਿੰਝ	/tʃʰĩ́dʒ/	Ring for fighting game
16.	ਜੰਝ	/dʒə̃́dʒ/	Marriage procession
17.	ਬਾਂਝ	/bã́dʒ/	Unproductive woman
18.	ਢਿੱਡ	/ʈìɖɖ/	Belly
19.	ਢੇਰ	/ʈèr/	Heap
20.	ਢੋਲ	/ʈòl/	Drum
21.	ਢੰਗ	/ʈə̃̀g/	Method
22.	ਢਾਈ	/ʈài/	Two and a Half
23.	ਢੂਈ	/ʈùi/	Back
24.	ਸੀਂਢ	/sĩ́ɖ/	Nosy

S.No.	Words	IPA transcription	Meaning
25.	ਸੁੰਢ	/sʊ̃ɖ/	Trunk/dry ginger
26.	ਧੰਨ	/tə̃̀n/	Money
27.	ਧੜ	/tə̀ɽ/	Upper part of body
28.	ਯੁੱਧ	/jʊ́dd/	War
29.	ਕੰਧ	/kə̃́d/	Wall
30.	ਭੁੱਖ	/pʊ̀kkʰ/	Hunger
31.	ਭੂੰਢ	/pʊ̃́ɖ/	Female Pig
32.	ਜੀਭ	/dʒíb/	Tongue

Table 1

Disyllabic

S.No.	Words	IPA transcription	Meaning
1.	ਘੋੜਾ	/kòɖa/	Horse
2.	ਘੜੀ	/kə`ɽi/	Watch
3.	ਘੱਸਾ	/kə̀ssa/	Push with hip
4.	ਘਾਹੀ	/kàhi/	Grass cutter
5.	ਘੁੰਡੀ	/kʊ̃̀ɖi/	Trick/Problem
6.	ਘਿੱਗੀ	/kìggi/	Hiccup caused by crying
7.	ਘੁੰਨਾ	/kʊ̃̀na/	Cunning
8.	ਘੇਰਾ	/kèra/	Circumference
9.	ਘੌਲੀ	/kə`li/	Lazy
10.	ਘੋਟਾ	/kòʈa/	Cramming
11.	ਨਿਘਾਸ	/nigàs/	Warmth
12.	ਅਨਘੜ	/ənkə́ɽ/	Crude
13.	ਚਿੰਘਾੜ	/tʃĩgàɽ/	To cry out
14.	ਉਝਬੁਘ	/ʊ̀dʒəbʊ́ g/	Not in shape
15.	ਨਿੱਘਾ	/nígga/	Warm
16.	ਉੱਘਾ	/ʊ́gg a/	Prominent
17.	ਕੰਘੀ	/kə̃́gi/	Comb

S.No.	Words	IPA transcription	Meaning
18.	ਬੱਘੀ	/bə̀ggi/	Horse driven cart
19.	ਲਘੂ	/lə̀gu/	Small
20.	ਝੰਡਾ	/tʃə̃̀ɖa /	Flag
21.	ਝਾੜੂ	/tʃàɽu/	Broom
22.	ਝਿੜਕ	/tʃìɽək/	Scold
23.	ਝਾਂਜਰ	/tʃã̀dʒər/	Anklet
24.	ਝੋਲੀ	/tʃòli/	Possessing something in one's cloth worn
25.	ਝਾਊਂ	/tʃàũ/	Not vey smart
26.	ਝੂਟਾ	/tʃùʈa/	sense of enjoyment while in a moving vehicle/on swing
27.	ਅਝੱਕ	/ətʃə̀kk /	Bold
28.	ਸੁਝਾ	/sʊ́ʤ a/	Suggestion
29.	ਸੁਝਾਈ	/sʊdʒài/	To suggest
30.	ਰਿਮਝਿਮ	/rɪmtʃìm/	In slow motion
31.	ਹੰਝੂ	/hə̃́dʒu/	Tears
32.	ਬੁੱਝੋ	/bʊ́dʒo/	To put question
33.	ਸੋਝੀ	/sódʒi/	Insight
34.	ਮਾਝੀ	/mádʒi/	Language in Punjab
35.	ਜੰਝੂ	/dʒə̃́dʒu/	Sacred thread
36.	ਢੱਕਣ	/ʈə̀kkəɳ/	Cover
37.	ਢਿੱਲਾ	/ʈìlla/	Loose
38.	ਢਾਬਾ	/ʈàba/	Small Restaurant
39.	ਢਾਡੀ	/ʈàɖi/	Particular Religious Singing Group
40.	ਸੀਂਢਲ	/sĩɖə́ l/	Nosy person
41.	ਬੀਂਢਲ	/bĩɖə́ l/	Munder
42.	ਸੰਢਾ	/sə̃́ɖa /	Bull
43.	ਹੰਢਾ	/hə̃́ɖa /	To wear
44.	ਕੰਢਾ	/kə̃́ɖa /	Edge

S.No.	Words	IPA transcription	Meaning
45.	ਚੂੰਢੀ	/tʃű́ɖi/	To pinch
46.	ਬੁੱਢਾ	/bʊ́ɖɖa/	Old
47.	ਧੂੰਆਂ	/tű́ã/	Smoke
48.	ਧਿਆਨ	/tìan/	Attention
49.	ਧੋਬੀ	/tòbi/	Washerman
50.	ਧਨੁਸ਼	/tənʊ ʃ/	Bow
51.	ਧੰਦਾ	/tə̃́da /	Profession
52.	ਧਨਾਢ	/tənа ɖ/	Rich Person
53.	ਧਰਮ	/tərəm/	Religion
54.	ਧੁੰਨੀ	/tʊ̃̀ni /	Navel
55.	ਇੱਧਰ	/ɪddə́r/	This side
56.	ਪ੍ਰਧਾਨ	/prədán/	Chief
57.	ਮਧੁਰ	/mədʊ́ r/	Sweet
58.	ਅੱਧਾ	/ə́dda/	Half
59.	ਸਿੱਧਾ	/sídda/	Simlpe
60.	ਸੰਧੀ	/sə̃́di /	Joining
61.	ਖਾਧਾ	/k^háda/	Ate
62.	ਗਧਾ	/gə́da/	Donkey
63.	ਗਿੱਧਾ	/gídda/	Type of Ladies' Dance
64.	ਗੁੱਧਾ	/gʊ́dda/	Kneaded
65.	ਭੰਗੀ	/pə̃̀ gi/	Simpleton
66.	ਭੌਂਦੂ	/pɔ̃̀du/	Wanderer
67.	ਭੈਭੀਤ	/pɛ̀pít/	Scared
68.	ਭਸਮ	/pə` sem/	Ash
69.	ਭਿੱਜਣਾ	/pìdʒdʒɳa/	Get wet
70.	ਅਭਿਆਸ	/əbìas/	Practice
71.	ਗੰਭੀਰ	/gə̃bí r/	Serious
72.	ਦੁੱਭਰ	/dʊbbə́r/	To make it difficult

S.No.	Words	IPA transcription	Meaning
73.	ਗਰਭ	/gərə́b/	Pregnant
74.	ਦੁਰ ਲੱਭ	/dʊrlə́bb/	Rare
75.	ਨਾਭੀ	/nábi/	Navel
76.	ਟੋਭਾ	/ʈóba/	Small Water Pond
77.	ਦੜਭਾ	/də́ɽba/	Small congested space

Table 2

Tri-syllabic

S.No.	Words	IPA transcription	Meaning
1.	ਘੂਰਨਾ	/kùrəna/	To stare
2.	ਤਾਂਘਣਾ	/tãgə̀ɳa/	To desire
3.	ਨਿਘਰਨਾ	/nɪgə́rna /	To swallow
4.	ਨਿਘਾਰਨਾ	/nɪgàrna/	To sink
5.	ਪੰਘੂੜਾ	/pə̃gùɽa/	Cradle
6.	ਉਲੰਘਣਾ	/ʊlə̃gə̀ɳa/	Violation
7.	ਊੂੰਘਣਾ	/ʊ̃g ə̀ɳa/	To doze
8.	ਖੰਘਾਲਣਾ	/kʰə̃gàlɳa/	To rinse
9.	ਪੰਘਰਨਾ	/pə̃gə́rna/	To melt
10.	ਝੁਨਝਨਾ	/tʃʊ̀ntʃəna/	Sound making toy
11.	ਝੌਂਪੜੀ	/tʃɔ̃̀pəɽi/	Hut
12.	ਝਗੜਾ	/tʃə̀gəɽa/	Quarrel
13.	ਝੁਕਣਾ	/tʃʊ̀kəɳa/	To bend
14.	ਰਿੱਝਣਾ	/rɪdʒə̀ɳa/	Getting cooked
15.	ਸਾਂਝੀਦਾਰ	/sãdʒìdar/	Partner
16.	ਬੁੱਝਣਾ	/bʊdʒə̀ɳa/	To guess and answer
17.	ਗਿਝਾਉਣਾ	/gɪdʒàʊɳa/	To make habitual
18.	ਉਝਾਰਨਾ	/ʊdʒárna/	To spread
19.	ਢਿੰਢੋਰਾ	/ʈɪ̃̀ɖòra/	Public Announcement
20.	ਢਿਲਕਵਾਂ	/ʈìlkəʋã/	Loose

S.No.	Words	IPA transcription	Meaning
21.	ਢਹਿਣਾ	/ʈ̀əheɳa/	To fall
22.	ਢੂੰਢਣਾ	/ʈ̀ʊ̃ɖəɳa/	To find
23.	ਸੰਢਣਾ	/sə̃ɖ̀əɳa/	Two chords for pulling the bull
24.	ਸੁੰਢੋਲਾ	/sʊ̃ɖ̀e la/	Jaggery and Dry ginger
25.	ਹੰਢਣਸਾਰ	/hə̃ɖə́ɳsar/	Long life
26.	ਹੰਢਾਊ	/hə̃ɖàu/	Durable
27.	ਕਢਾਈ	/kəɖài/	Embroidery
28.	ਗੁਆਂਢਣ	/gʊãɖ̀é ɳ/	Neighbour
29.	ਬੁਢਾਪਾ	/bʊɖàpa/	Old Age
30.	ਗੁਆਂਢੀ	/gʊã́ɖi̥ /	Neighbour
31.	ਧੁੰਦਲਾ	/tʊ̃dəla/	Hazy
32.	ਅੰਧੇਰਾ	/ə̃dè ra/	Darkness
33.	ਸਧਾਰਨ	/sədárən/	Simple
34.	ਕੰਧੂਈ	/kə̃dùi/	Big sewing needle
35.	ਕਿਧਰੋਂ	/kɪdərõ/	From where
36.	ਗੰਧਲਾ	/gə̃dəla/	Muddy
37.	ਦੁਧੀਆ	/dʊdìa/	Milky white
38.	ਨਾਮਧਾਰੀ	/namtàri/	Religious Community
39.	ਬੰਧੂਆ	/bə̃dùa/	Bonded
40.	ਭਸੂੜੀ	/pə̀suɽi/	Stampede
41.	ਨਿਭਾਉਣਾ	/nɪbáʊɳa/	Cope up
42.	ਰੰਭਣਾ	/rə̃bəɳa/	Sound produced by Cow/Bull
43.	ਲੱਭਣਾ	/ləbbəɳa/	To find
44.	ਨਿਰਭੈ	/nírpe/	Unfearful

Table 3

Polysyllabic

S.No.	Words	IPA transcription	Meaning
1.	ਘੱਲੂਘਾਰਾ	/kə̀llukàra/	Massacre
2.	ਸਮਝਦਾਰੀ	/səmdʒə̀dari/	Wisdom
3.	ਚੌਧਰਪੁਣਾ	/tʃɔdə́rpʊɳa/	Purposeless leadership
4.	ਭ੍ਰਿਸ਼ਟਾਚਾਰ	/prìʃʈatʃar/	Corruption

Table 4

Chapter 3 – Word list of Laryngeal Consonant /h/

Monosyllabic

S.No.	Words	IPA transcription	Meaning
1.	ਆਹ	/á/	Sigh
2.	ਸਹਿ	/sɛ́/	Indicating togetherness
3.	ਕੋਹ	/kó/	Mountain
4.	ਖੂਹ	/kʰú/	Well, irrigation well
5.	ਖੋਹ	/kʰó/	Discomfort, uneasiness
6.	ਗਾਹ	/gá/	Disorder, spread of harvested crop awaiting
7.	ਚਾਹ	/tʃá/	Wish, desire, avidity
8.	ਛੋਹ	/ tʃʰó/	Touch, dab, contact, tap
9.	ਢਾਹ	/ʈà/	Fall, defeat, destruction
10.	ਢੋਹ	/ʈò/	Back-rest, rest
11.	ਲੋਹ	/ló/	Iron
12.	ਵਾਹ	/vá/	Wonderful, well-done

Table 5

Disyllabic

S.No.	Words	IPA transcription	Meaning
1.	ਤਬਾਹ	/təbá/	Destroyed, ruined, spoiled
2.	ਤਰਾਹ	/tərá/	Fright, sudden fear
3.	ਵਸਾਹ	/vəsá/	Trust, reliance, faith
4.	ਵਿਆਹ	/vɪá/	Marriage, matrimony
5.	ਆਹਲਾ	/ála/	Superior, excellent
6.	ਇਹਨਾਂ	/énã/	These
7.	ਹਉਕਾ	/hɔka/	Sigh
8.	ਹਸਬ	/həsəb/	According to rules, law
9.	ਹਗਾਰ	/həgar/	Excreta of houseflies
10.	ਹਜ਼ਮ	/həzəm/	Digested

S.No.	Words	IPA transcription	Meaning
11.	ਹਿਸਾਬ	/hɪsab/	Account, calculation, rate
12.	ਹੁਨਰ	/hʊnər/	Art, skill, technique
13.	ਹਾਕਮ	/hakəm/	Ruler, governor, officer
14.	ਹਾਜਰ	/hadʒər/	Present, ready, available
15.	ਹੀਆ	/hia/	Heart, courage, nerve
16.	ਹੀਟਰ	/hiʈər/	Heater
17.	ਹੂਰਾ	/hura/	Fist, box, buffet
18.	ਹੈਵਾਨ	/hɛvan/	Animal, uncivilized person
19.	ਹੋਛਾ	/hotʃʰa/	Blunt, flippant, mean
20.	ਹੋਰ	/hor/	More, else, further
21.	ਹੌਜ	/hɔdʒ/	Water tank, masonry tub
22.	ਅਹਾਰ	/əhar/	Food, diet, meal
23.	ਸਾਹਿਤ	/sahɪt/	Literature, literary art
24.	ਸਾਹਿਬ	/saheb/	Master, lord, boss
25.	ਸ਼ਹੀਦ	/ʃəhid/	Martyr
26.	ਔਹਰ	/ɔhər/	Ailment, diseases, malady
27.	ਅਹਿਦ	/ɛhəd/	Resolve, promise
28.	ਆਹਰ	/ahər/	Impulse, enthusiasm
29.	ਸਾਹਸ	/sahəs/	Courage, boldness, daring
30.	ਸੁਹਜ	/sʊhədʒ/	Grace, beauty, delicacy
31.	ਸ਼ਹਿਰ	/ʃɛhər/	City, town
32.	ਸ਼ੌਹਰ	/ʃɔhər/	Husband
33.	ਸਹਾਇਕ	/səhaɪk/	Assistant, helper, colleague
34.	ਸਹਿਜ	/sɛhədʒ/	Easy, slow, tranquil

Table 6

Trisyllabic

S.No.	Words	IPA transcription	Meaning
1.	ਵਿਦਰੋਹ	/vɪdəró/	Rebellion, defiance, revolt
2.	ਸਹਿਸੁਭਾ	/sɛ̀subà/	Naturally, spontaneously
3.	ਹਿਕਾਇਤੀ	/hɪkaɪti/	Apologal, anecdotal
4.	ਹਿਮਾਚਲ	/hɪmatʃəl/	Himachal Pradesh
5.	ਹੁਲਾਰਾ	/hʊlara/	Swing, oscillation, kick
6.	ਹੂਕਣਾ	/hukəɳa/	To raise, utter cry of pain
7.	ਹੈਸੀਅਤ	/hɛsiət/	Status, position, property
8.	ਹੌਸਲਾਮੰਦ	/hɔslamə̃d/	Courageousness, patience
9.	ਅਹੰਕਾਰ	/əhə̃kar/	Pride, arrogance
10.	ਅਹਿੰਸਕ	/əhĩsək/	Nonviolent, peaceful
11.	ਇਸ਼ਤਿਹਾਰ	/ɪʃtehar/	Advertisement, poster
12.	ਇਤਿਹਾਸ	/ɪtehas/	History, the past
13.	ਸੁਹਿਰਦ	/sʊhɪrd/	Good-hearted, kind, gentle
14.	ਸੁਹੇਲਾ	/sʊhela/	Comfortable, soothing
15.	ਸ਼ਹਾਦਤ	/ʃəhadət/	Martyrdom, self-sacrifice
16.	ਇਮਤਿਹਾਨ	/ɪmtehan /	Examination, test, trial
17.	ਸਿਹਰਾ	/sehəra/	Chaplet, wreath, honour
18.	ਸੁਹਣਾ	/sohəɳa/	Good looking
19.	ਸੁਹਾਗਾ	/sʊhaga/	Borax, tincal, leveller
20.	ਸ਼ਹਿਤੂਤ	/ʃɛhətut/	Mulburry
21.	ਸ਼ਾਹਦੀ	/ʃahədi/	Evidence, testimony
22.	ਸਹਾਇਤਾ	/səhaɪta/	Help, support, relief
23.	ਸਹਾਈ	/səhai/	Who provides help
24.	ਸਹਾਰਨਾ	/səharna/	Bear, suffer, to support
25.	ਸਹਾਰਾ	/səhara/	Support, refuge, shelter

Table 7

Polysyllabic

S.No.	Words	IPA transcription	Meaning
1.	ਅਹਿੰਸਾਵਾਦ	/əhĩsavad/	Doctrine
2.	ਅਹਿਦਨਾਮਾ	/ɛhədnama/	Treaty, formal agreement b/w nations & states
3.	ਸਿਹਤਮੰਦ	/sehətəmə̃d/	Healthy

Table 8

Chapter 3 – Word list having Conjuncts of /ɦ/

Monosyllabic

S.No.	Word	IPA Transcription	Meaning
1.	ਗੋਲ੍ਹ	/gól/	Fruit of mulberry

Table 9

Disyllabic

S.No.	Word	IPA Transcription	Meaning
1.	ਗਾਲ੍ਹੜ	/galə́ɽ/	Squirrel
2.	ਗੁੰਮ੍ਹੜ	/gʊ̃mə́ɽ/	Boil
3.	ਜਿਲ੍ਹਣ	/dʒɪlə́ɳ/	Mire, bog, mud, marsh
4.	ਪੜ੍ਹਾਈ	/pəɽài/	Education, study, teaching
5.	ਪੜ੍ਹਿਆ	/pəɽía/	Read, studied
6.	ਠੁਲ੍ਹਾ	/ʈʰʊlá/	Fat person

Table 10

Trisyllabic

S.No.	Word	IPA Transcription	Meaning
1.	ਖਮ੍ਹਣੀ	/kʰəmə́ɳi/	Multicoloured yarn
2.	ਖਰ੍ਹਵਾ	/kʰərə́va/	Rough, rude, impolite
3.	ਖੁਲ੍ਹਣਾ	/kʰʊlə́ɳa/	To open, become open
4.	ਖੁੱਲ੍ਹਵਾਂ	/kʰʊllə́vã/	Loose, expansible
5.	ਸਲ੍ਹਾਬਾ	/səlàba/	Water-logging, seepage
6.	ਸਿੰਨ੍ਹਣਾ	/sĩnə́ɳa/	To moisten, make wet
7.	ਤਮ੍ਹਾਤੜ	/təmàtəɽ/	Someone like you, you
8.	ਪੜ੍ਹਾਉਣਾ	/pəɽàʊɳa/	To teach, educate, tutor

Table 11

Polysyllabic

S.No.	Word	IPA Transcription	Meaning
1.	ਖਲ੍ਹਾਰਨਾ	/kʰəlàrna/	To stop, to interrupt
2.	ਗੜ੍ਹਕਣਾ	/gəɽə́kəɳa/	To boil, thunder, roar

Table 12

Chapter 4 – Word list of Stress

Di-syllabic

S.No.	Word	IPA transcription
1.	ਸਰਬ	/sərəb/
2.	ਸੜਕ	/səɽək/
3.	ਹਸਬ	/həsəb/
4.	ਹੁਨਰ	/hʊnər/
5.	ਹਜ਼ਮ	/həzəm/
6.	ਉਗਰ	/ʊgər/
7.	ਉਜ਼ਰ	/ʊzər/
8.	ਉਤਸਵ	/ʊtsəʋ/
9.	ਉਤਸੁਕ	/ʊtsʊk/
10.	ਸ਼ਗਨ	/ʃəgən/
11.	ਕਸਕ	/kəsək/
12.	ਗਰਿਫ਼ਤ	/gərɪft/
13.	ਚੁਗਲ	/tʃʊgəl/
14.	ਉਮਰ	/ʊmər/
15.	ਅਣਖ	/əɳəkʰ/
16.	ਅਨੰਦ	/ənə̃d/
17.	ਸੰਕਟ	/sə̃kəʈ/
18.	ਮੰਗਲ	/mə̃gəl/
19.	ਬਸੰਤ	/bəsə̃t/
20.	ਮਲੰਗ	/mələ̃g/
21.	ਫਿੱਕਾ	/pʰɪkka/
22.	ਅੱਗੇ	/əgge/
23.	ਸਜਾ	/sədʒa/
24.	ਪਕਾ	/pəka/
25.	ਬਤਾ	/bəta/
26.	ਬੁਲਾ	/bʊla/

S.No.	Word	IPA transcription
27.	ਫ਼ਿੱਡਾ	/pʰɪḍḍa/
28.	ਫਿਦਾ	/pʰɪda/
29.	ਮਯੂਰ	/məjur/
30.	ਮਨਾ	/məna/
31.	ਕਮਾ	/kəma/
32.	ਸੁਨਾ	/sʊna/
33.	ਰਸਾ	/rəsa/
34.	ਤਣਾ	/təṇa/
35.	ਚਲਾਕ	/tʃəlak/
36.	ਗਿਲਾ	/gɪla/
37.	ਯਸੂ	/ jesu/
38.	ਯਕੀਨ	/jəkin/
39.	ਰਸਤਾ	/rəsta/
40.	ਹਿਸਾਬ	/hɪsab/
41.	ਬਜਾਰ	/bədʒar/
42.	ਮਰੀਜ	/məridʒ/
43.	ਕਰੀਬ	/kərib/
44.	ਉਜੈਨ	/ʊdʒɛn/
45.	ਅਕਾਲ	/əkal/
46.	ਅਫੀਮ	/əpʰim/
47.	ਉਤਾੜ	/ʊtaṛ/
48.	ਉਥਾਨ	/ʊtʰan/
49.	ਅਸਾਨ	/əsan/
50.	ਅਮੀਰ	/əmir/
51.	ਜਬਾਨ	/dʒəban/
52.	ਕਣੀ	/kəṇi/
53.	ਤੁਸਾਂ	/tʊsã/
54.	ਤਦੋਂ	/tədõ/

S.No.	Word	IPA transcription
55.	ਅੰਗੂਰ	/ə̃gur/
56.	ਗਾਜਰ	/gadʒər/
57.	ਗੋਕੁਲ	/gokʊl/
58.	ਨੂਤਨ	/nutən/
59.	ਵੇਟਰ	/ʋeʈər/
60.	ਯੌਵਨ	/jɔʋən/
61.	ਹੈਰਤ	/hɛrət/
62.	ਕੈਡਟ	/kɛɖəʈ/
63.	ਹਾਕਮ	/hakəm/
64.	ਖਾਤਰ	/kʰatər/
65.	ਔਰਤ	/ɔrət/
66.	ਠਾਕਰ	/ʈʰakər/
67.	ਆਕੜ	/akəɽ/
68.	ਚਾਨਣ	/tʃanəɳ/
69.	ਬਾਲਕ	/balək/
70.	ਆਤਿਸ਼	/atɪʃ/
71.	ਸੌਂਕਣ	/sɔ̃kəɳ/
72.	ਤਾਂਡਵ	/tãɖəʋ/
73.	ਪੈਂਡਲ	/pɛ̃ʤ l/
74.	ਪਾਖੰਡ	/pakʰə̃ɖ/
75.	ਚਾਚਾ	/tʃatʃa/
76.	ਫੇਟਾ	/pʰeʈa/
77.	ਜੀਣਾ	/dʒiɳa/
78.	ਮਾਲੀ	/mali/
79.	ਦੇਓ	/deo/
80.	ਲੇਓ	/leo/
81.	ਕੋੜਾ	/koɽa/
82.	ਫੀਤਾ	/pʰita/

S.No.	Word	IPA transcription
83.	ਬੇਨਤੀ	/benti/
84.	ਮੋੜਦਾਰ	/moɽdar/
85.	ਮੌਜੂਦ	/mɔdʒud/
86.	ਊਣਾ	/uɳa/
87.	ਸਾਰਾ	/sara/
88.	ਈਮਾਨ	/iman/
89.	ਰਾਣੀ	/raɳi/
90.	ਕਾਫਲਾ	/kapʰla/
91.	ਖੀਰਾ	/kʰira/
92.	ਗਾਨੀ	/gani/
93.	ਸੀਣਾ	/siɳa/
94.	ਤਾਂਬਾ	/tãba/
95.	ਕਾਂਟਾ	/kãʈa/
96.	ਚਾਂਦੀ	/tʃãdi/
97.	ਪੈਂਤੀ	/pɛ̃ti/
98.	ਵੇਦਾਂਤ	/vedãt/
99.	ਮੂੰਗੀ	/mũgi/
100.	ਮੂੰਜੀ	/mũdʒi/
101.	ਖੂੰਡੀ	/kʰũɖi/

Table 13

Tri-syllabic

S.No.	Words	IPA transcription
1.	ਅਕਰਮਕ	/əkərmək/
2.	ਅਮਿਤਾ	/əmɪta/
3.	ਅਸਫਲ	/əsəpʰəl/
4.	ਬੇਸ਼ਕਲ	/beʃəkəl/
5.	ਬੇਸਿਦਕ	/besɪdək/

S.No.	Words	IPA transcription
6.	ਚਿਲਮਚੀ	/tʃɪlmətʃi/
7.	ਚਿਲਗੋਜ਼ਾ	/tʃɪlgoza/
8.	ਡਾਵਾਂਡੋਲ	/ɖavãɖol/
9.	ਗੈਰਹਾਜ਼ਰ	/gɛrhadʒər/
10.	ਇਕੱਤਰ	/ɪkəttər/
11.	ਜਾਗਣਾ	/dʒagəɳa/
12.	ਜਲਾਲਤ	/dʒəlalət/
13.	ਜਲੋਦਰ	/dʒəlodər/
14.	ਜੋਬਨਵੰਤ	/dʒobənvə̃t/
15.	ਕਾਲਪਨਿਕ	/kalpənɪk/
16.	ਕਸ਼ਮਕਸ਼	/kəʃməkəʃ/
17.	ਖੁਸ਼ਦਿਲੀ	/kʰʊʃdɪli/
18.	ਕੋਰਾਪਣ	/korapəɳ/
19.	ਨੀਲੱਤਣ	/nilettəɳ/
20.	ਪਾਰਦਰਸ਼ਕ	/pardərʃək/
21.	ਪੋਲਾਪਣ	/polapəɳ/
22.	ਰੂਪਾਂਤਰ	/rupãtər/
23.	ਸੂਰਤਮੰਦ	/surətmə̃d/
24.	ਤੰਬਾਕੂ	/tə̃baku/
25.	ਤਪੋਬਨ	/təpobən/
26.	ਤਤਕਰਾ	/tətkəra/
27.	ਟੀਕਾਕਾਰ	/ʈikakar/
28.	ਟਿਕਣਾ	/ʈɪkəɳa/
29.	ਉਜਰਤ	/ʊdʒərət/
30.	ਉਲ਼ਟਣਾ	/ʊlʈəɳa/

Table 14

Poly-syllabic

S.No	word	IPA transcription
1.	ਅਕਿਰਿਆਸ਼ੀਲ	/əkɪrɪaʃil/
2.	ਸੈਂਟੀਮੀਟਰ	/sɛ̃ʈimiʈər/
3.	ਚੇਤਾਵਣੀ	/tʃetavəni/
4.	ਗੁਜਰਾਂਵਾਲਾ	/gʊdʒrãvala/
5.	ਇਕਵਾਸਾਪਣ	/ɪkvasapəɳ/
6.	ਖਾਂਚੇਵਾਲ਼ਾ	/kʰãtʃevala/
7.	ਨਾਕਾਬੰਦੀ	/nakabə̃di/
8.	ਪੰਖੜੀਵਾਲਾ	/pə̃kʰɽivala/
9.	ਰੂਪਾਂਤਰਨ	/rupãtərən/
10.	ਸਾਮੰਤਵਾਦੀ	/samə̃tvadi/
11.	ਸਾਮਰਾਜਵਾਦੀ	/samradʒvadi/
12.	ਸਥਾਨੰਤਰਨ	/stʰanə̃tərən/
13.	ਉਗਰਪੰਥੀ	/ʊgərpə̃tʰi/
14.	ਉਜੱਡਪੁਣਾ	/ʊdʒəɖɖpʊɳa/

Table 15

Appendix B – DATA SHEETS

Chapter 3 – Data sheets of Tonemes

Sample Data sheet 1 (Composite word): ਘੱਲੂਘਾਰਾ **/kə̀llukàra/**

ਘੱਲੂ

Male Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU(HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
M1	199	628	209	203	196	188	HL	0.04
M2	248	348	254	248	246	243	HL	0.07
M3	256	321	263	259	256	248	HL	0.10
M4	224	1135	249	229	218	205	HL	0.06
Average	**232**	**608**	**244**	**235**	**229**	**221**	**HL**	**0.07**

Table 1: Data of Male Speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
F1	295	450	307	292	290	289	HL	0.07
F2	IP	IP	IP	IP	IP	IP	IP	IP
F3	323	402	331	325	322	316	HL	0.06
F4	280	778	301	282	272	264	HL	0.07
F5	IP	IP	IP	IP	IP	IP	IP	IP
F6	309	371	316	309	309	305	HL	0.07
Average	**302**	**500**	**314**	**302**	**298**	**294**	**HL**	**0.07**

Table 2: Data of Female Speakers

ਘਾਰਾ

Male Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
M1	179	149	183	180	179	176	HL	0.13
M2	256	125	258	258	256	252	HL	0.12
M3	243	293	257	245	239	231	HL	0.19
M4	214	297	230	215	207	204	HL	0.15
Average	**223**	**216**	**232**	**225**	**220**	**216**	**HL**	**0.15**

Table 3: Data of Male Speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
F1	325	315	325	315	297	278	HL	0.21
F2	IP	IP	IP	IP	IP	IP	IP	IP
F3	335	328	335	328	321	304	HL	0.15
F4	292	278	292	278	275	275	HL	0.14
F5	IP	IP	IP	IP	IP	IP	IP	IP
F6	301	298	301	298	298	290	HL	0.16
Average	**313**	**305**	**313**	**305**	**298**	**287**	**HL**	**0.17**

Table 4: Data of Female Speakers

Sample Data sheet 2: ਰਿੱਝਣਾ **/rɪdʒdʒə́ɳa /**

Male Speakers	**F_0 in (HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU(HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	25%	25%	25%		
M1	191	324	177	191	196	201	LH	0.11
M2	266	156	263	266	267	269	LH	0.10
M3	232	296	224	230	236	239	LH	0.09
M4	217	403	207	218	221	222	LH	0.06
Average	**227**	**266**	**219**	**226**	**230**	**232**	**LH**	**0.09**

Table 5: Data of Male Speakers

Female Speakers	**F_0 in (HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU (HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	**25%**	**25%**	**25%**		
F1	289	419	278	289	293	296	LH	0.06
F2	301	850	282	301	311	313	LH	0.05
F3	314	433	298	313	320	325	LH	0.10
F4	345	474	329	346	352	353	LH	0.09
F5	346	346	333	344	350	354	LH	0.08
F6	309	428	297	309	314	317	LH	0.09
Average	**317**	**492**	**303**	**317**	**323**	**326**	**LH**	**0.08**

Table 6: Data of Female Speakers

Sample Data sheet 3 (Dipthong): ਢਾਈ /ṱăi/

Male Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU(HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
M1	173	229	182	160	175	175	HLH	0.46
M2	261	150	267	261	258	258	HL	0.35
M3	242	155	255	230	242	242	HLH	0.51
M4	201	187	211	192	192	206	HLH	0.34
Average	**205**	**190**	**216**	**194**	**203**	**208**	**HLH**	**0.44**

Table 7: Data of Male Speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	**25%**	**25%**	**25%**		
F1	308	462	322	279	294	337	HLH	0.39
F2	332	362	343	321	318	345	HLH	0.33
F3	333	312	345	318	319	351	HLH	0.44
F4	309	192	329	302	295	308	HLH	0.45
F5	365	128	374	365	361	361	HLH	0.44
F6	319	300	353	315	294	312	HLH	0.43
Average	**328**	**293**	**344**	**317**	**314**	**336**	**HLH**	**0.41**

Table 8: Data of Female Speakers

Sample Data sheet 4: ਧਰਮ **/tə̀rəm/**

Male Speakers	**F_0 in (HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU(HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	25%	25%	25%		
M1	187	627	207	196	182	165	HL	0.08
M2	272	274	280	272	270	266	HL	0.11
M3	262	308	265	264	263	256	HL	0.15
M4	218	184	223	220	216	212	HL	0.10
Average	**235**	**348**	**244**	**238**	**233**	**225**	**HL**	**0.11**

Table 9: Data of Male speakers

Female Speakers	**F_0 in (HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU (HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	**25%**	**25%**	**25%**		
F1	297	327	307	299	297	287	HL	0.13
F2	321	410	331	322	322	311	HL	0.13
F3	317	379	328	325	316	299	HL	0.12
F4	278	519	300	283	272	256	HL	0.14
F5	343	299	349	349	344	330	HL	0.16
F6	293	611	307	307	291	268	HL	0.17
Average	**308**	**424**	**320**	**314**	**307**	**292**	**HL**	**0.14**

Table 10: Data of Female speakers

Sample Data sheet 5: ਭ੍ਰਿਸ਼ਟਾਚਾਰ **/prìʃʈatʃar/**

Male Speakers	**F0 in(HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU(HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	25%	25%	25%		
M1	177	612	196	185	170	156	HL	0.08
M2	270	249	275	272	270	263	HL	0.08
M3	236	544	238	247	239	221	HL	0.11
M4	214	926	229	225	211	194	HL	0.05
Average	**224**	**583**	**235**	**232**	**223**	**209**	**HL**	**0.08**

Table 11: Data of Male speakers

Female Speakers	**F_0 in (HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU (HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	**25%**	**25%**	**25%**		
F1	302	928	296	312	309	292	HL	0.07
F2	341	707	341	348	346	328	HL	0.06
F3	312	629	334	319	302	294	HL	0.07
F4	281	820	296	295	282	251	HL	0.08
F5	IP							
F6	338	736	342	350	342	319	HL	0.12
Average	**315**	**764**	**322**	**325**	**316**	**297**	**HL**	**0.08**

Table 12: Data of Female speakers

Chapter 3 – Data sheets of Consonant /h/

Sample Data sheet 1: ਖੂਹ /**kʰú**/

Male Speakers	**F_0 in (HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU (HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	**25%**	**25%**	**25%**		
M1	181	251	154	192	198	181	LHL	0.43
M2	258	202	239	265	267	263	LHL	0.43
M3	235	200	234	245	236	225	LHL	0.53
M4	203	271	178	201	219	215	LHL	0.33
Average	**219**	**231**	**201**	**226**	**230**	**221**	**LHL**	**0.43**

Table 13: Data of Male speakers

Female Speakers	**F_0 in (HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU (HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	**25 %**	**25%**	**25%**		
F1	307	317	287	291	316	332	LH	0.35
F2	343	471	319	331	363	357	LHL	0.33
F3	295	875	291	299	333	252	LHL	0.38
F4	324	347	285	321	348	340	LHL	0.31
F5	282	713	347	372	214	197	LHL	0.38
F6	310	525	274	288	325	356	LH	0.24
Average	**310**	**541**	**301**	**317**	**317**	**306**	**LHL + LH**	**0.33**

Table 14: Data of Female speakers

Sample Data sheet 2: ਢਾਹ /**ṭà**/

Male Speakers	**F_0 in (HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU (HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	**25%**	**25%**	**25%**		
M1	159	232	157	139	165	175	HLH	0.48
M2	230	293	231	221	230	237	HLH	0.17
M3	217	229	243	224	224	217	HL	0.43
M4	188	245	188	171	191	202	HLH	0.35
Average	**199**	**250**	**205**	**189**	**203**	**208**	**HLH + HL**	**0.36**

Table 15: Data of Male speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
F1	271	454	281	252	254	295	HLH	0.39
F2	261	327	274	261	247	262	HLH	0.37
F3	250	536	296	280	227	195	HL	0.30
F4	298	382	314	279	294	304	HLH	0.38
F5	346	192	358	331	340	354	HLH	0.42
F6	270	390	275	278	255	272	HLH	0.30
Average	**283**	**380**	**300**	**280**	**270**	**280**	**HLH + HL**	**0.36**

Table 16: Data of Female speakers

Sample Data sheet 3: ਵਸਾਹ **/vəsá/**

Male Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
M1	166	233	138	163	185	179	LHL	0.37
M2	239	198	220	234	248	257	LH	0.39
M3	223	206	218	227	225	224	LHL	0.44
M4	NT							
Average	**209**	**212**	**192**	**208**	**219**	**220**	**LHL + LH**	**0.40**

Table 17: Data of Male speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
F1	266	318	246	251	271	296	LH	0.30
F2	305	392	283	283	309	345	LH	0.27
F3	283	465	255	256	286	336	LH	0.38
F4	275	435	269	277	289	265	LH	0.19
F5	339	230	317	328	349	361	LH	0.34
F6	257	232	251	251	261	266	LH	0.23
Average	**288**	**345**	**270**	**274**	**294**	**312**	**LH**	**0.29**

Table 18: Data of Female speakers

Sample Data sheet 4: ਵਿਦਰੋਹ **/vɪdəró/**

Male Speakers	**F_0 in (HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU (HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	**25%**	**25%**	**25%**		
M1	181	194	152	180	199	191	LHL	0.47
M2	246	178	227	245	255	256	LH	0.37
M3	231	183	223	238	236	228	LHL	0.35
M4	IP							
Average	**219**	**185**	**201**	**221**	**230**	**225**	**LHL + LH**	**0.40**

Table 19: Data of Male speakers

Female Speakers	**F_0 in (HZ/Sec)**	**Slope in (HZ/Sec)**	**Cross-Sectional Slope of TBU (HZ/Sec)**				**Contour of tone**	**Duration of TBU**
			25%	**25%**	**25%**	**25%**		
F1	281	337	253	267	292	312	LH	0.27
F2	303	422	285	290	310	328	LH	0.22
F3	Non- Tonal							
F4	301	284	277	289	315	324	LH	0.33
F5	339	232	311	338	354	353	LHL	0.30
F6	298	978	279	282	319	313	LHL	0.18
Average	**304**	**451**	**281**	**293**	**318**	**326**	**LHL + LH**	**0.26**

Table 20: Data of Female speakers

Chapter 3 – Data sheets of Conjuncts of /ɦ/

Sample Data sheet 1: ਗੋਲ੍ਹ /**gól/**

Male Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
M1	169	262	140	161	180	195	LH	0.06
M2	251	170	230	247	261	267	LH	0.04
M3	223	259	195	217	236	245	LH	0.12
M4	186	274	158	174	199	214	LH	0.11
Average	**207**	**241**	**181**	**200**	**219**	**230**	**LH**	**0.08**

Table 21: Data of Male speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
F1	260	246	249	250	262	279	LH	0.24
F2	323	259	314	314	321	343	LH	0.32
F3	303	277	278	295	312	326	LH	0.30
F4	282	147	261	277	292	297	LH	0.43
F5	329	186	319	326	332	341	LH	0.25
F6	232	143	226	230	232	240	LH	0.31
Average	**288**	**210**	**275**	**282**	**292**	**304**	**LH**	**0.31**

Table 22: Data of Female speakers

Sample Data sheet 2: ਸਲ੍ਹਾਬਾ **/səlàba/**

Male Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
M1	175	415	187	181	173	158	HL	0.11
M2	272	226	282	277	269	261	HL	0.14
M3	235	268	243	242	235	219	HL	0.15
M4	195	423	208	201	192	179	HL	0.11
Average	**219**	**333**	**230**	**225**	**217**	**204**	**HL**	**0.13**

Table 23: Data of Male speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
F1	276	411	291	286	273	254	HL	0.13
F2	304	381	319	311	300	286	HL	0.12
F3	317	519	340	328	311	288	HL	0.13
F4	253	353	271	258	248	235	HL	0.15
F5	334	459	345	343	334	312	HL	0.12
F6	283	380	294	292	285	262	HL	0.13
Average	**295**	**417**	**310**	**303**	**292**	**273**	**HL**	**0.13**

Table 24: Data of Female speakers

Sample Data sheet 3: ਖਲ੍ਹਾਰਨਾ **/kʰəlàrna/**

Male Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
M1	145	58	148	147	145	143	HL	0.18
M2	241	75	242	242	242	240	HL	0.18
M3	IP							
M4	220	237	220	203	185	178	HL	0.22
Average	**203**	**123**	**203**	**197**	**191**	**187**	HL	**0.19**

Table 25: Data of Male speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
F1	270	342	289	282	264	243	HL	0.17
F2	293	171	303	293	290	289	HL	0.19
F3	285	153	295	288	282	278	HL	0.17
F4	228	313	240	226	222	219	HL	0.21
F5	287	192	291	289	285	283	HL	0.20
F6	218	121	226	220	215	212	HL	0.23
Average	**264**	**215**	**274**	**266**	**260**	**254**	**HL**	**0.20**

Table 26: Data of Female speakers

Sample Data sheet 4: ਗਾਲ੍ਹੜ **/galə́ɽ/**

Male Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
M1	204	264	202	204	206	202	LHL	0.09
M2	282	143	282	286	283	279	LHL	0.11
M3								
M4	212	101	212	214	212	211	LHL	0.09
Average	**233**	**169**	**232**	**235**	**234**	**231**	**LHL**	**0.10**

Table 27: Data of Male speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
F1	304	554	282	297	309	327	LH	0.11
F2	344	560	326	338	347	365	LH	0.11
F3	355	135	355	358	357	351	LHL	0.16
F4	292	158	284	290	294	298	LH	0.13
F5	341	260	331	335	344	356	LH	0.12
F6	284	283	277	281	288	292	LH	0.14
Average	**320**	**325**	**309**	**317**	**323**	**332**	**LH +LHL**	**0.13**

Table 28: Data of Female speakers

Sample Data sheet 5: ਠੁਲ੍ਹਾ /ʈʰʊlá/

Male Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
M1	197	179	196	198	197	196	LHL	0.20
M2	IP							
M3	IP							
M4	215	67	215	217	216	213	LHL	0.24
Average	**206**	**123**	**206**	**208**	**207**	**205**	**LHL**	**0.22**

Table 29: Data of Male speakers

Female Speakers	F_0 in (HZ/Sec)	Slope in (HZ/Sec)	Cross-Sectional Slope of TBU (HZ/Sec)				Contour of tone	Duration of TBU
			25%	25%	25%	25%		
F1	322	140	310	321	328	329	LH	0.21
F2	309	129	302	304	312	320	LH	0.23
F3	340	267	326	332	346	359	LH	0.21
F4	287	188	280	289	291	288	LHL	0.14
F5	351	112	351	353	350	350	LHL	0.27
F6	325	253	309	323	335	335	LH	0.14
Average	**322**	**182**	**313**	**320**	**327**	**330**	**LHL + LH**	**0.20**

Table 30: Data of Female speakers

Appendix C- GRAPHS

Chapter 3- Graphs of Tonemes

1. ਢਾਈ ʈăi/

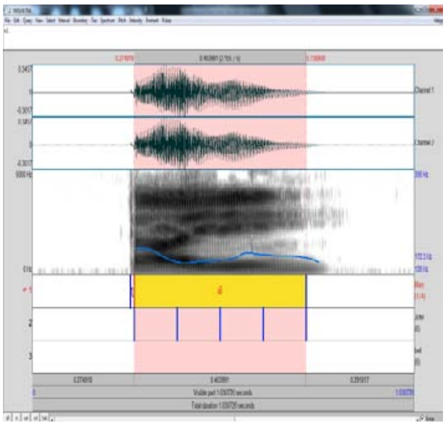


Fig 1: Male pitch sample

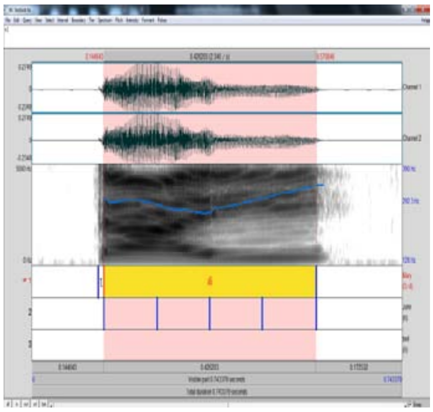


Fig 2: Female pitch sample

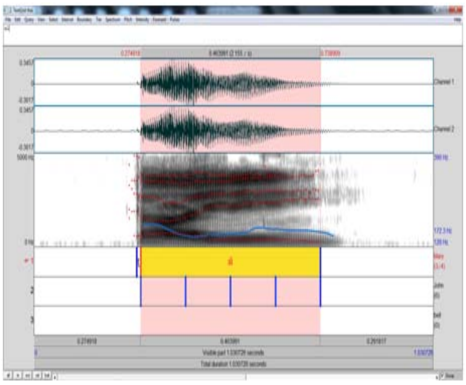


Fig 3: Male formant sample

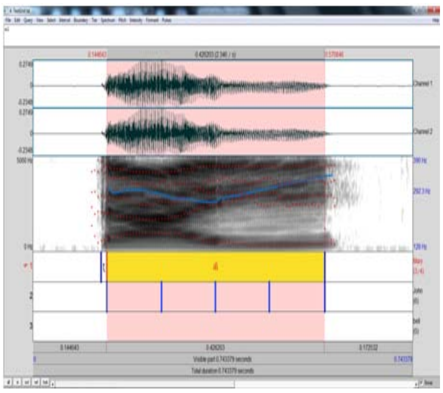


Fig 4: Female formant sample

2. ਧਿਆਨ **/tìan /**

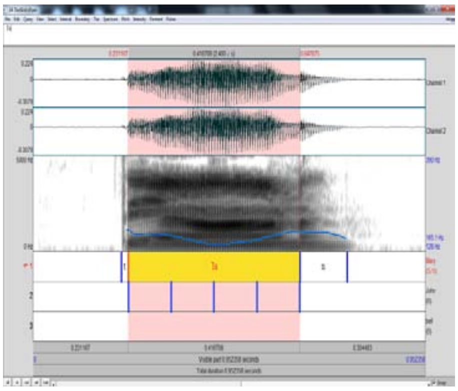


Fig 5: Male pitch sample

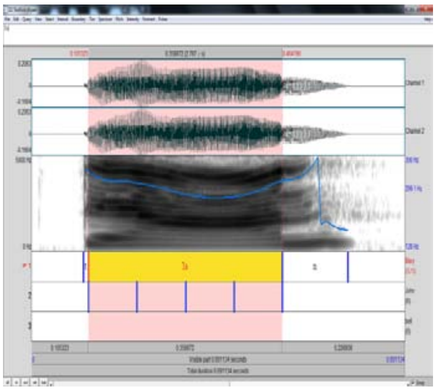


Fig 6: Female pitch sample

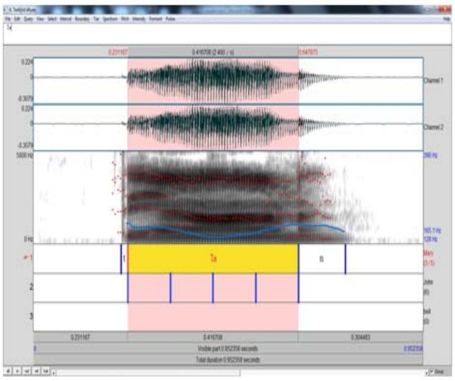


Fig 7: Male formant sample

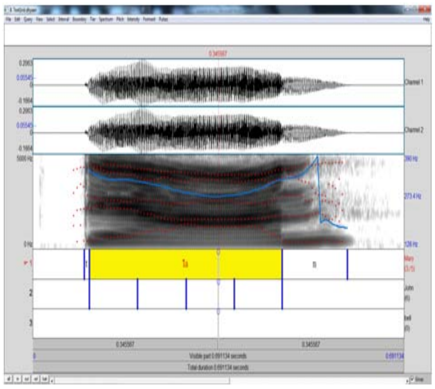


Fig 8: Female formant sample

3. ਚੌਧਰਪੁਣਾ /tʃɔdə́rpʊɳa/

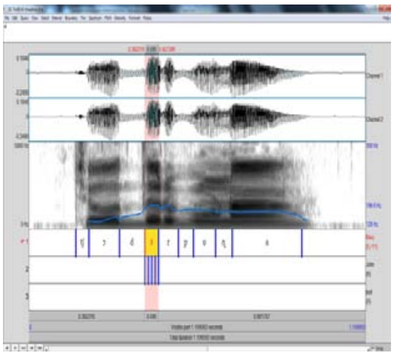


Fig 9: Male pitch sample

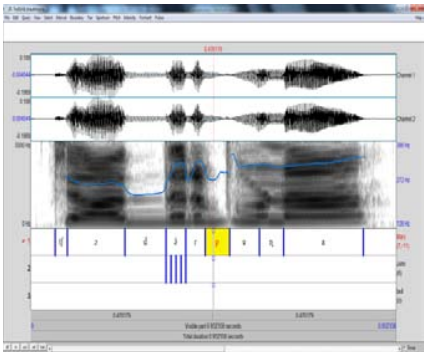


Fig 10: Female pitch sample

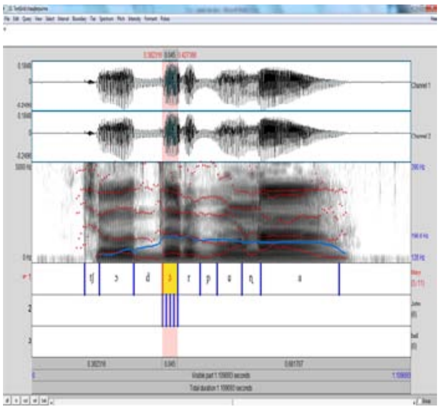


Fig 11: Male formant sample

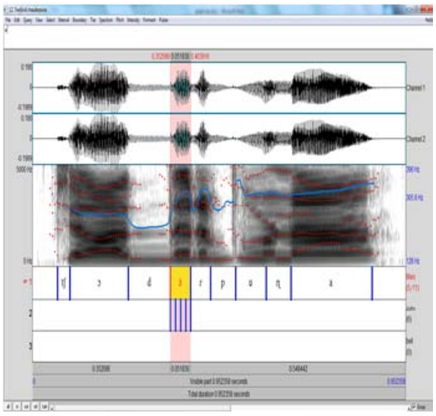


Fig 12: Female formant sample

4. ਭੁੰਦ /pʊ̀d̪/

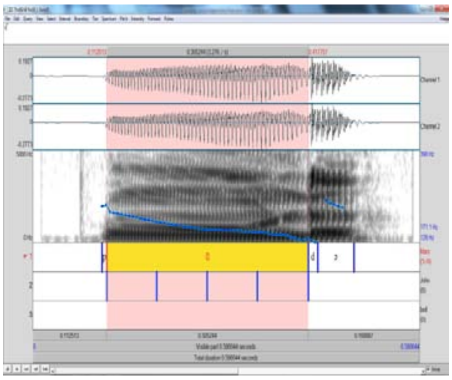


Fig 13: Male pitch sample

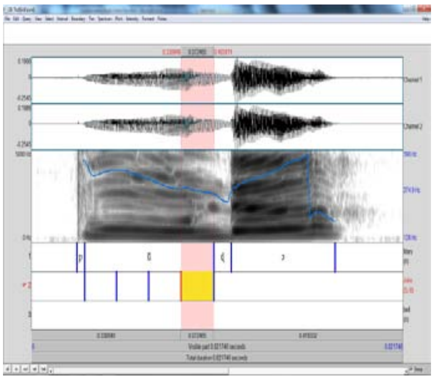


Fig 14: Female pitch sample

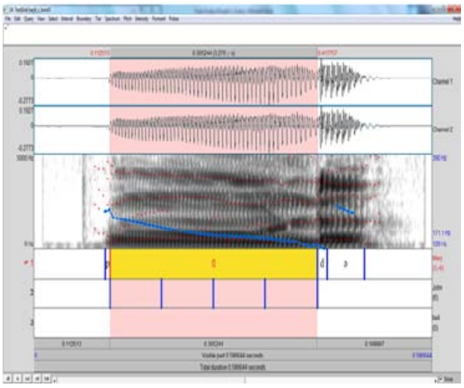


Fig 15: Male formant sample

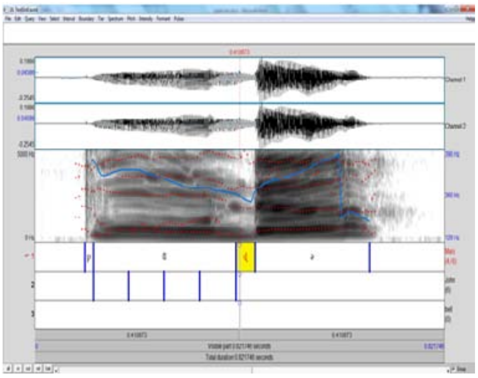


Fig 16: Female formant sample

5. ਨਿਭਾਉਣਾ /nɪbàʊɳa/

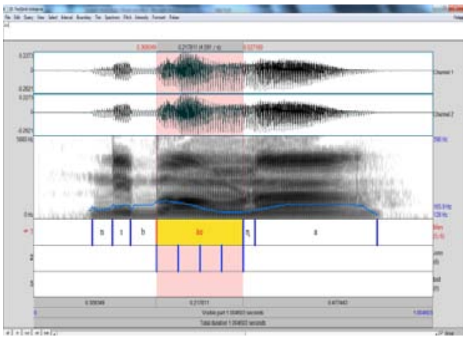


Fig 17: Male pitch sample

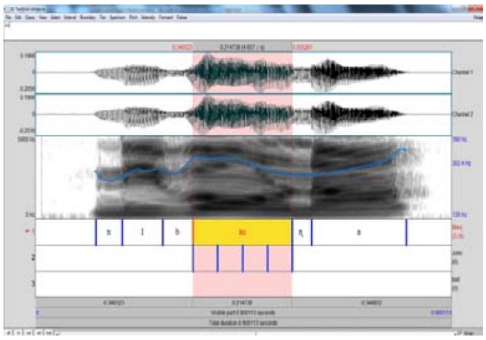


Fig 18: Female pitch sample

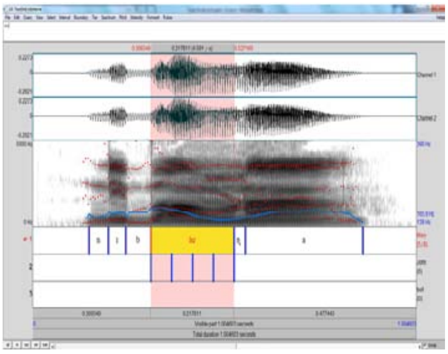


Fig 19: Male formant sample

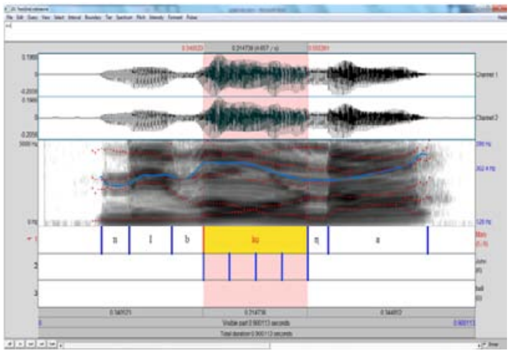


Fig 20: Female formant sample

6. ਢੂੰਢਣਾ /ʈʊ̀ɖəɳa/

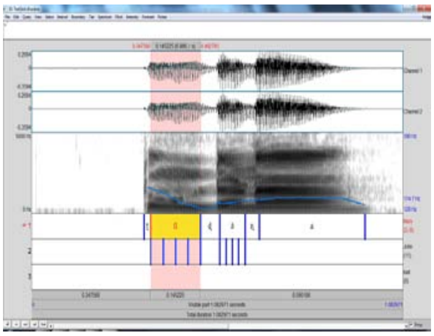


Fig 21: Male pitch sample

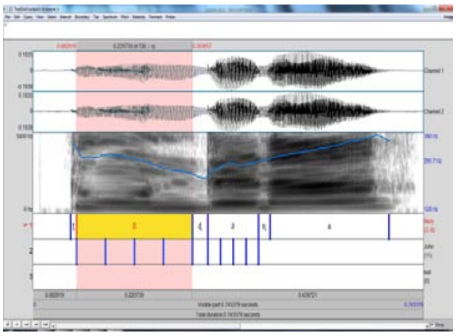


Fig 22: Female pitch sample

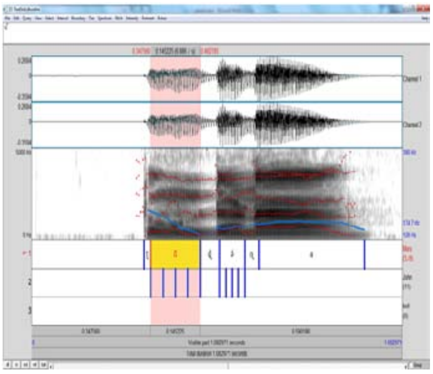


Fig 23: Male formant sample

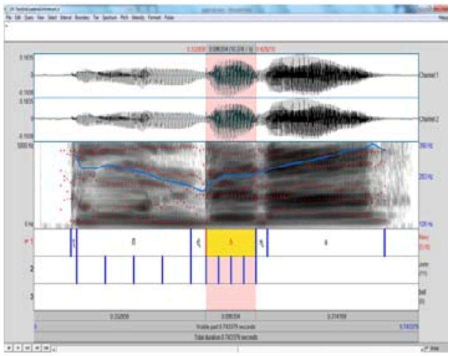


Fig 24: Female formant sample

7. ਨਾਮਧਾਰੀ **/namtàri/**

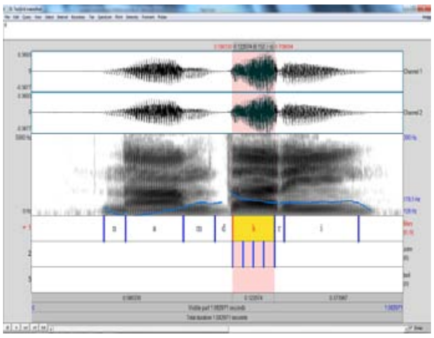


Fig 25: Male pitch sample

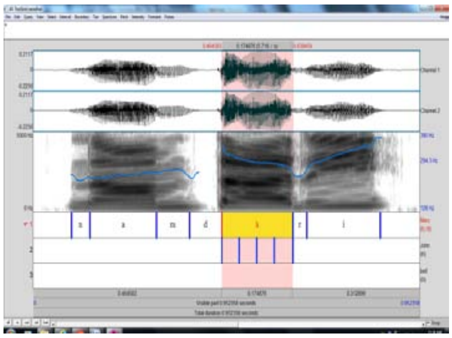


Fig 26: Female pitch sample

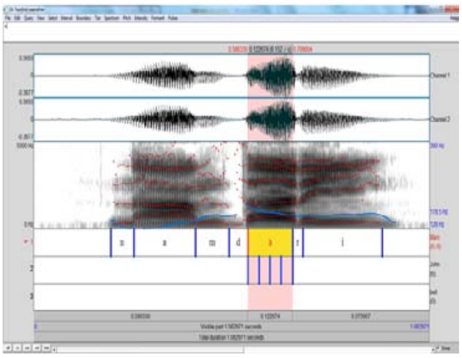


Fig 27: Male formant sample

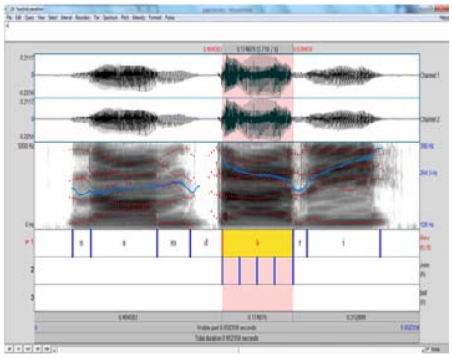


Fig 28: Female formant sample

8. ਉਝਬੁਘ /ʊ́dʒbʊ́g/

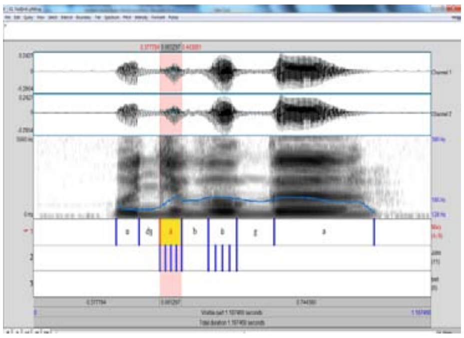


Fig 29: Male pitch sample

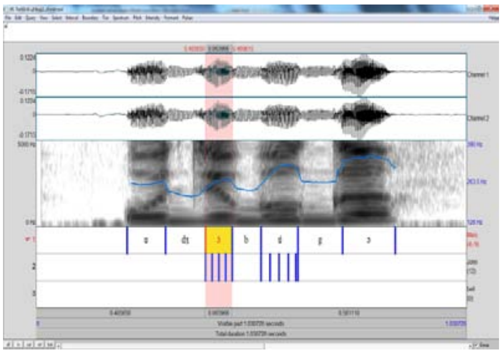


Fig 30: Female pitch sample

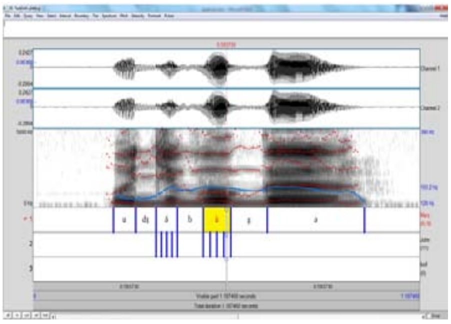


Fig 31: Male formant sample

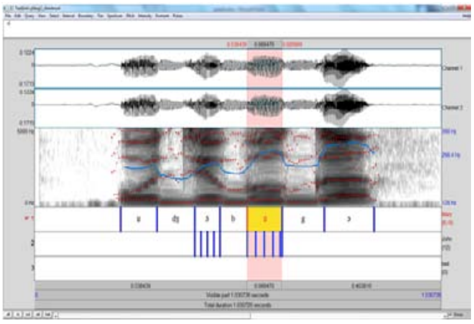


Fig 32: Female formant sample

9. ਦੁਧੀਆ /dʊdîa/

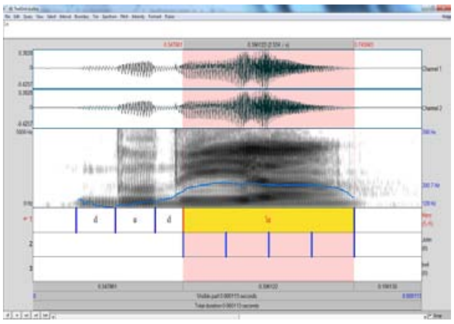


Fig 33: Male pitch sample

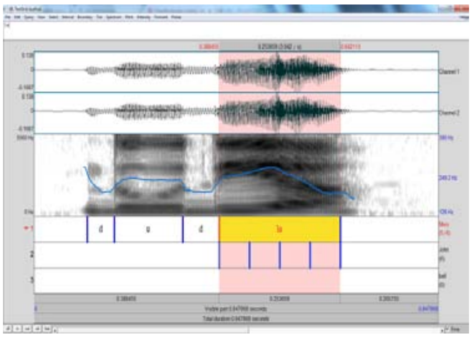


Fig 34: Female pitch sample

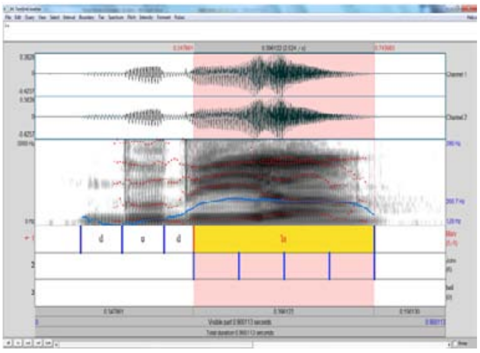


Fig 35: Male formant sample

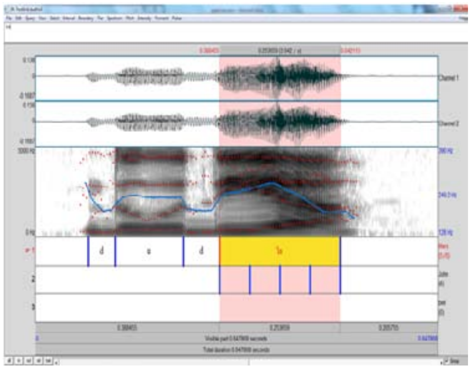


Fig 36: Female formant sample

10. ਸੁਞਾਅ /sŏdʒa/

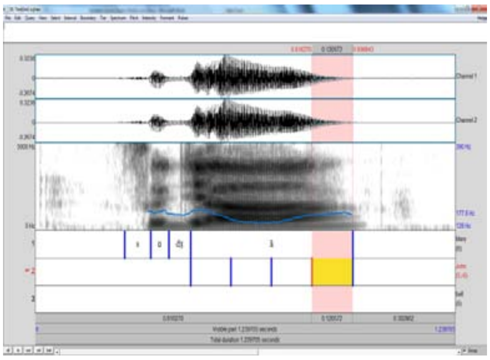


Fig 37: Male pitch sample

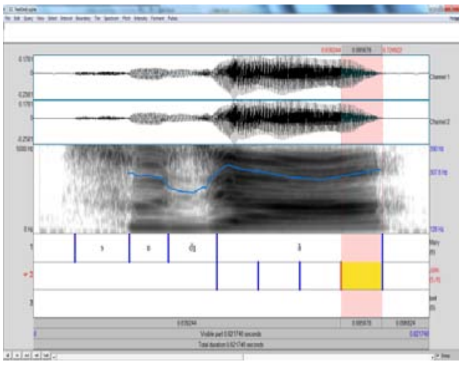


Fig 38: Female pitch sample

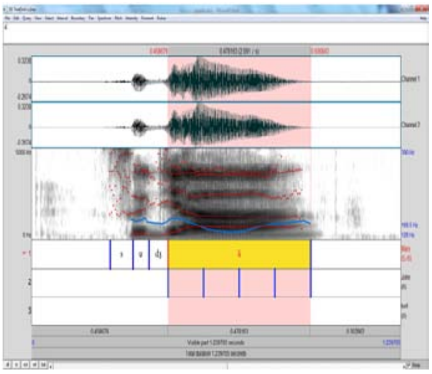


Fig 39: Male formant sample

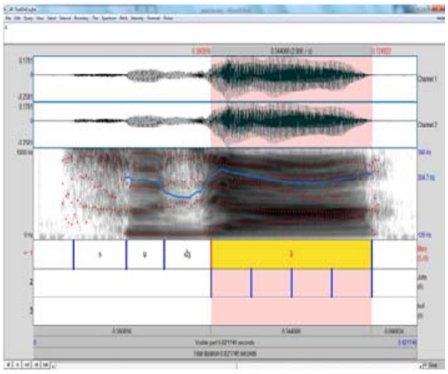


Fig 40: Female formant sample

11. ਸੁਝਾਈ /sʊdʒăi/

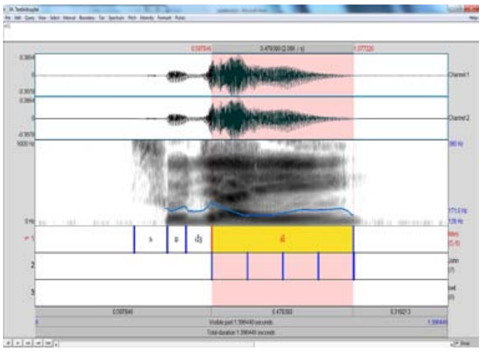


Fig 41: Male pitch sample

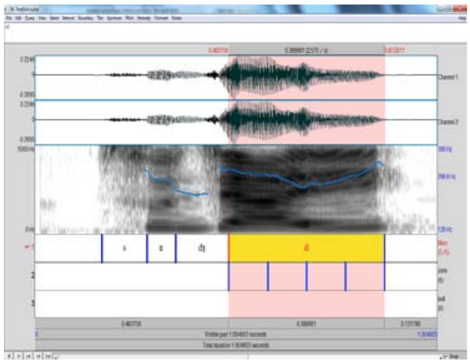


Fig 42: Female pitch sample

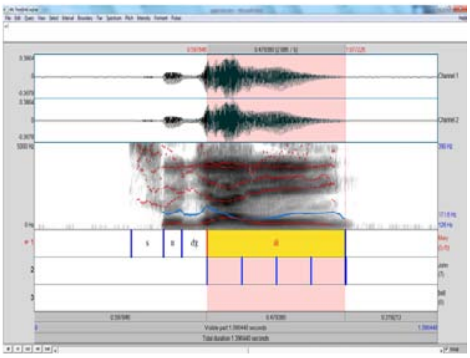


Fig 43: Male formant sample

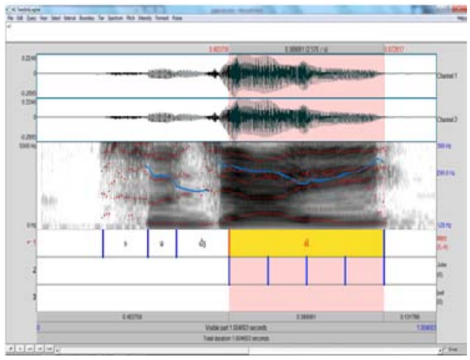


Fig 44: Female formant sample

12. ਨਿਘਾਸ /nigăs/

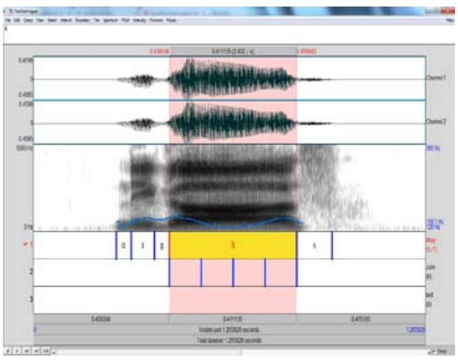


Fig 45: Male pitch sample

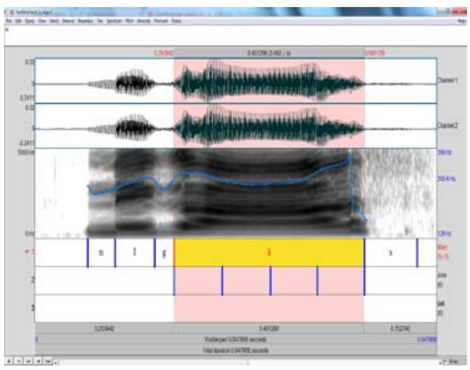


Fig 46: Female pitch sample

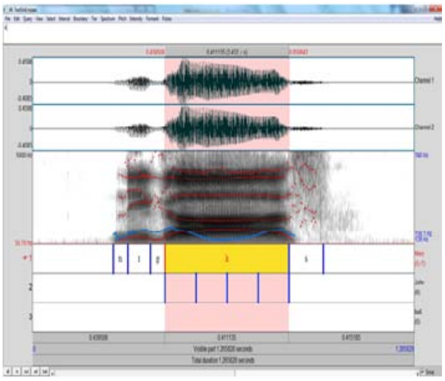


Fig 47: Male formant sample

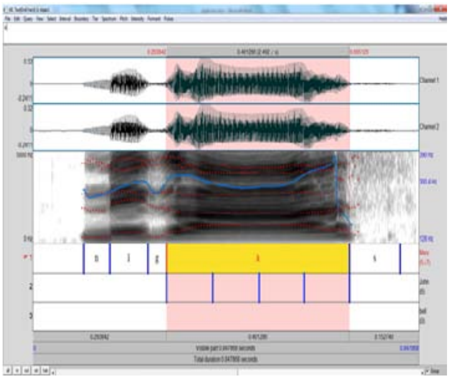


Fig 48: Female formant sample

13. ਚਿੰਘਾੜ /tʃĩgăɽ/

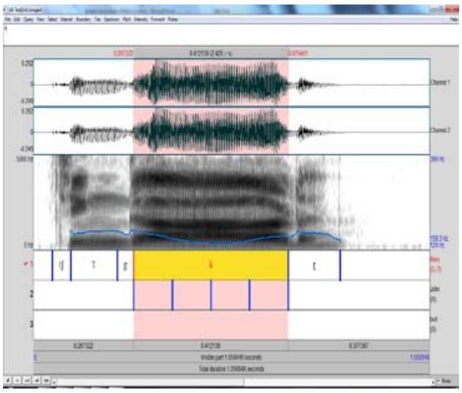


Fig 49: Male pitch sample

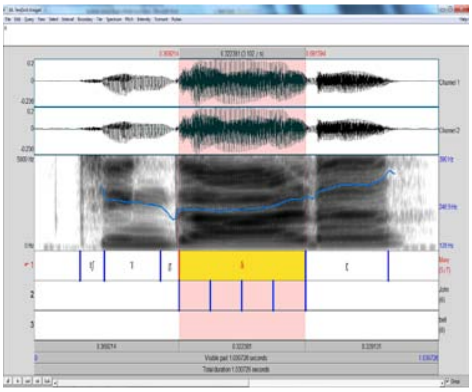


Fig 50: Female pitch sample

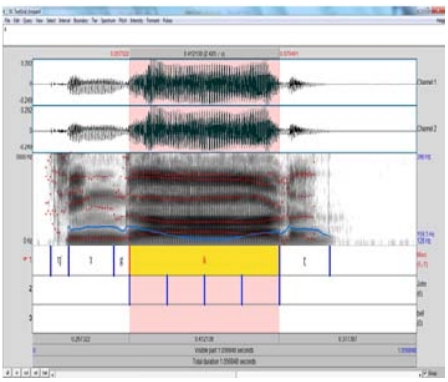


Fig 51: Male formant sample

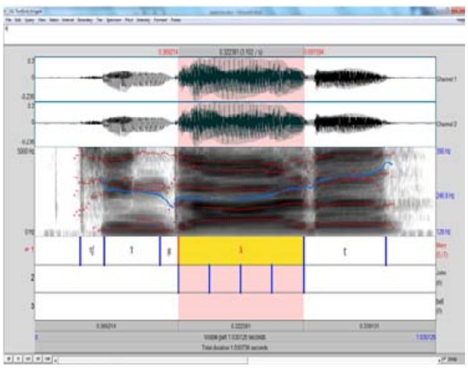


Fig 52: Female formant sample

14. ਪ੍ਰਧਾਨ /prədăn/

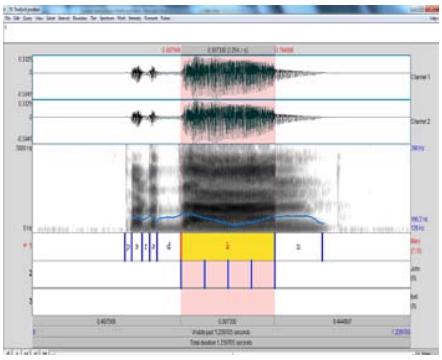


Fig 53: Male pitch sample

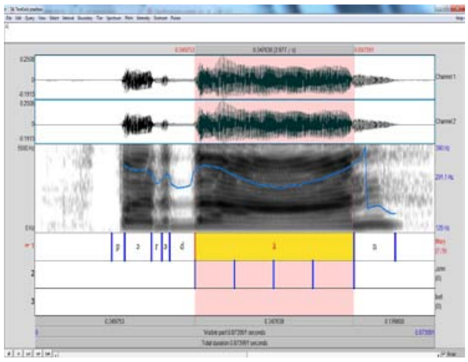


Fig 54: Female formant sample

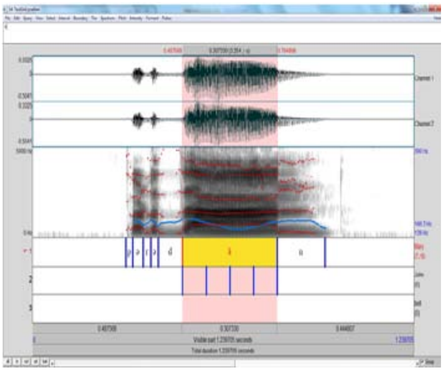


Fig 55: Male formant sample

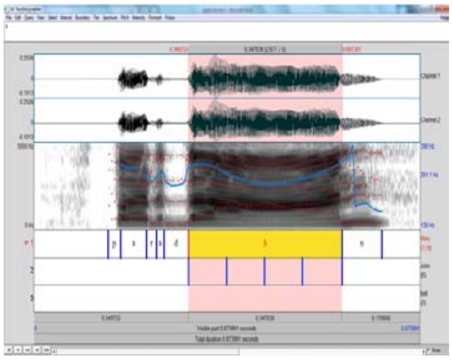


Fig 56: Female formant sample

Chapter 3- Graphs of Consonent /h/

1. ਵਾਹ /vá/

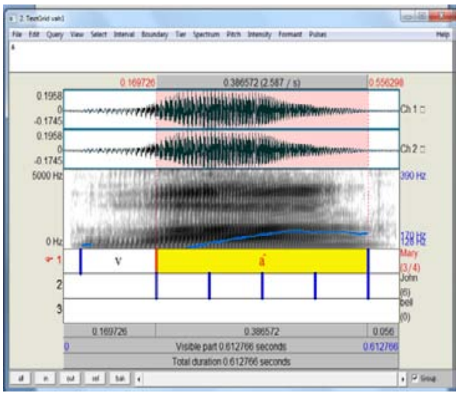


Fig 57: Male pitch sample

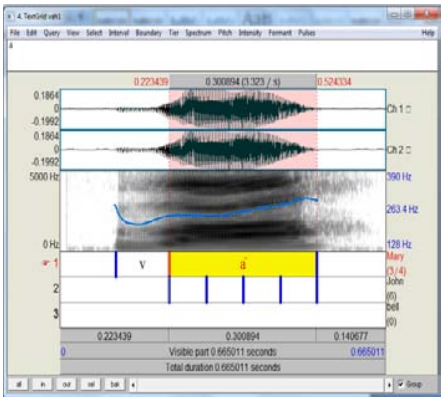


Fig 58: Female pitch sample

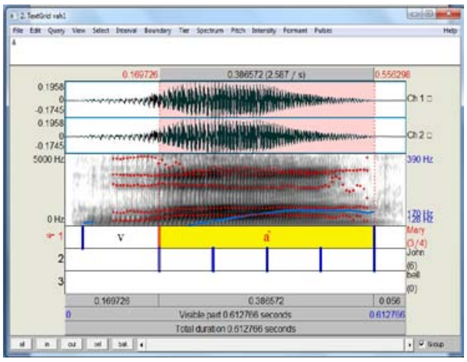


Fig 59: Male formant sample

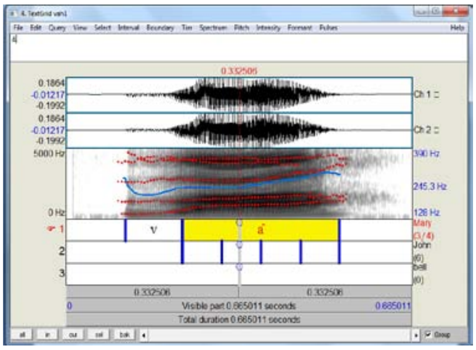


Fig 60: Female formant sample

2. ਸਹਿ /sɛ̂/

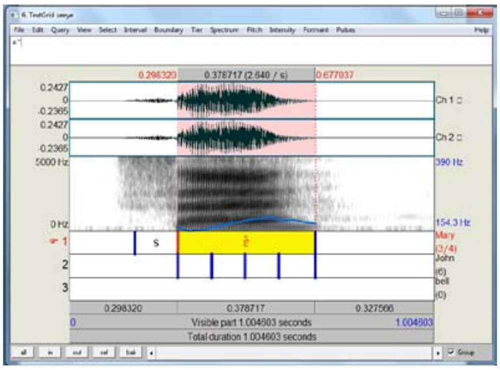


Fig 61: Male pitch sample

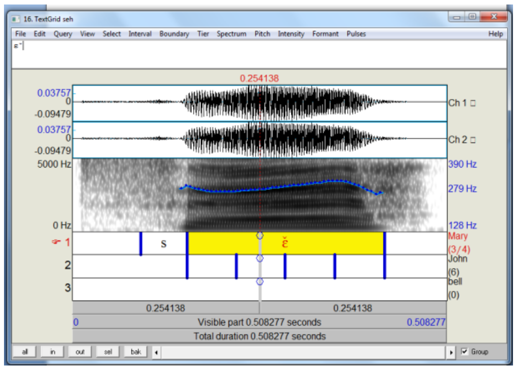


Fig 62: Female pitch sample

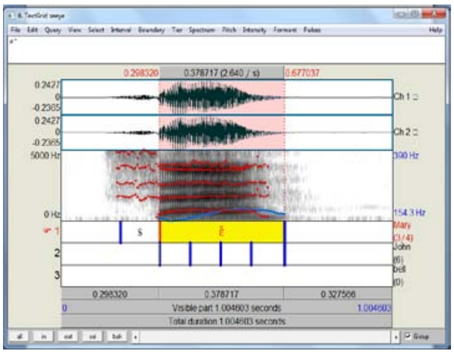


Fig 63: Male formant sample

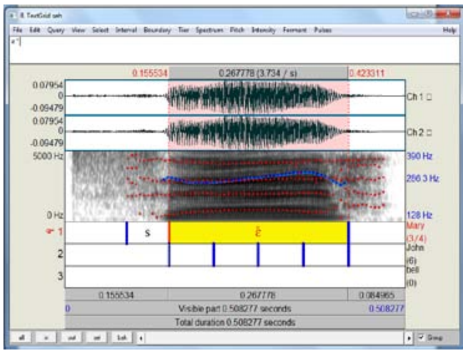


Fig 64: Female formant sample

3. ਢੋਹ /t̪ô/

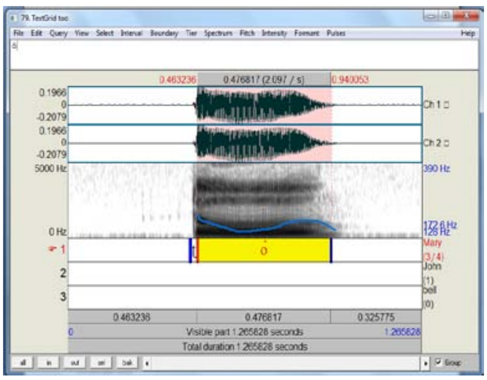


Fig 65: Male pitch sample

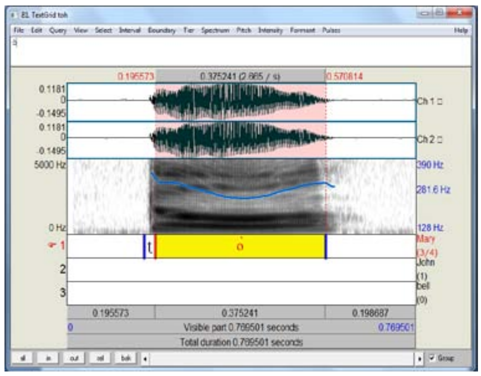
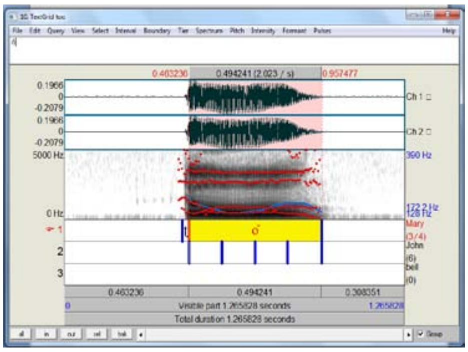


Fig 66: Female pitch sample



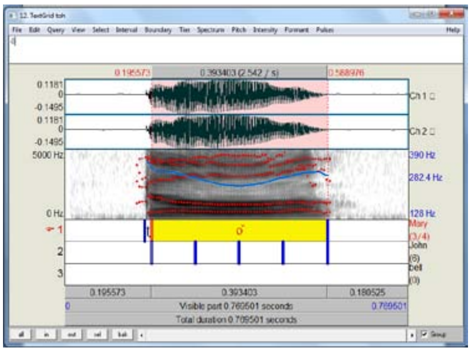
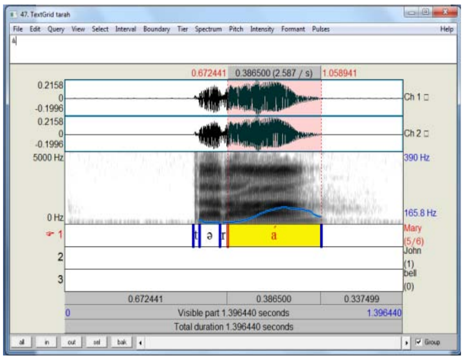


Fig 67: Male formant sample

Fig 68: Female formant sample

4. ਤਰਾਹ /tərá/



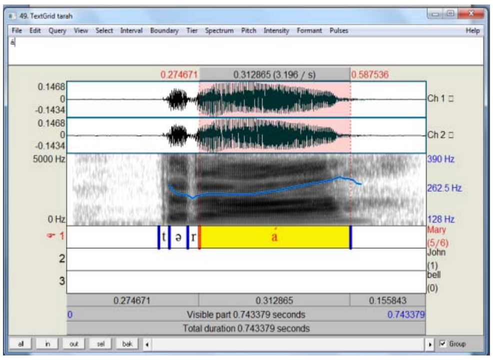
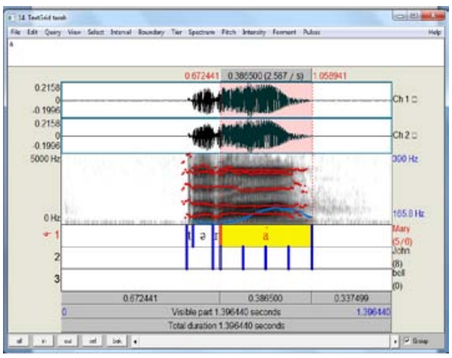


Fig 69: Male pitch sample

Fig 70: Female pitch sample



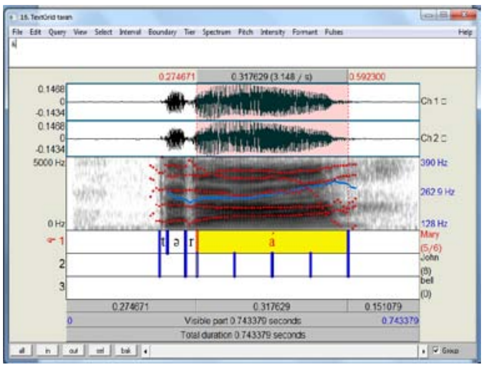


Fig 71: Male formant sample

Fig 72: Female formant sample

Chapter 3- Graphs of Conjuncts of /ɦ/

1. **ਗੋਲ਼ /gól/**

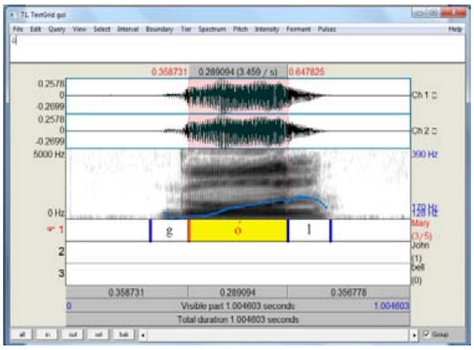


Fig 73: Male pitch sample

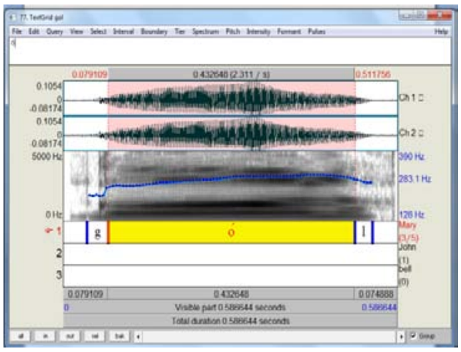


Fig 74: Female pitch sample

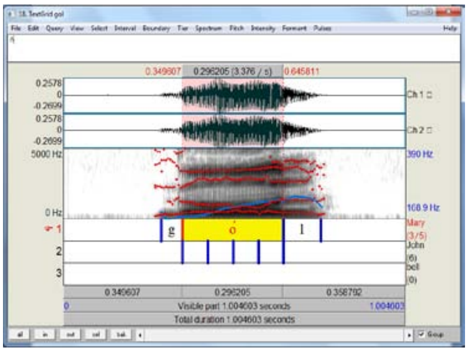


Fig 75: Male formant sample

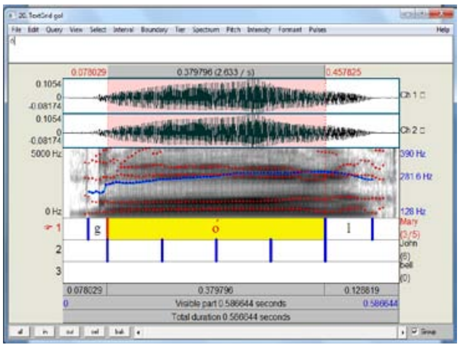


Fig 76: Female formant sample

2. **ਖੁੱਲ੍ਹਵਾਂ /kʰʊllə́vã/**

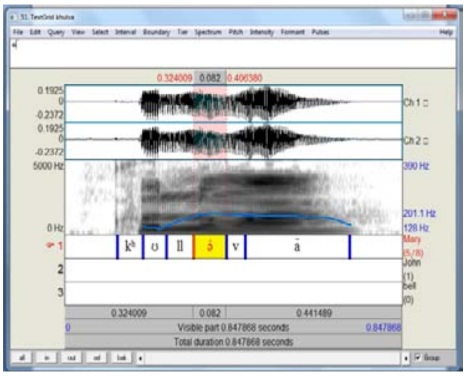


Fig 77: Male pitch sample

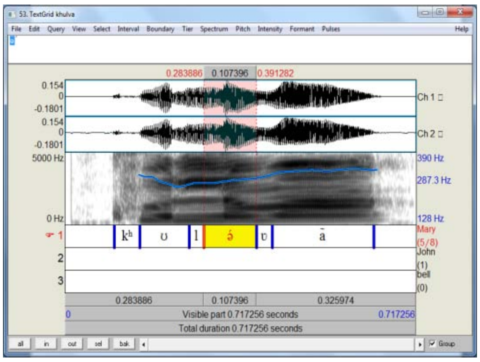


Fig 78: Female pitch sample

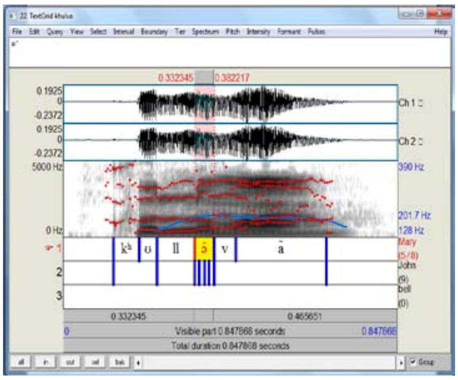


Fig 79: Male formant sample

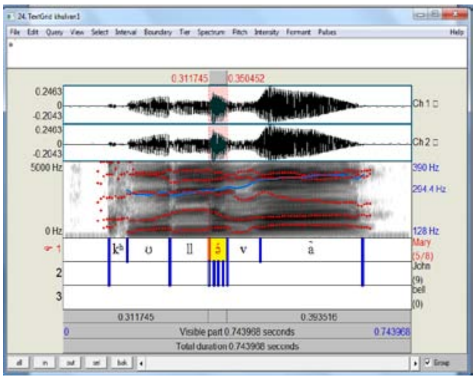


Fig 80: Female formant sample

3. ਸਿੰਨ੍ਹਣਾ /sĩnə́ɳa/

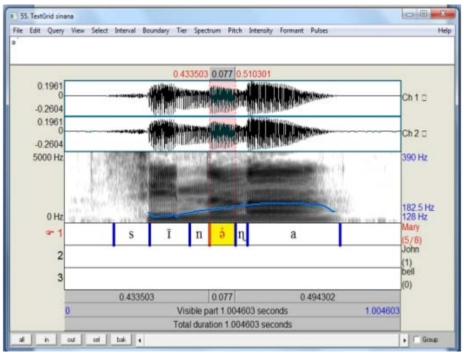


Fig 81: Male pitch sample

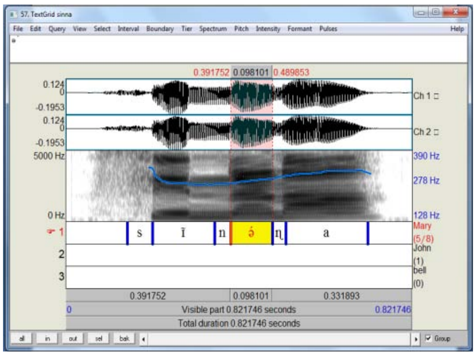


Fig 82: Female pitch sample

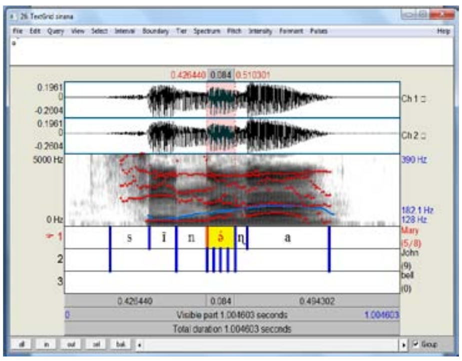


Fig 83: Male formant sample

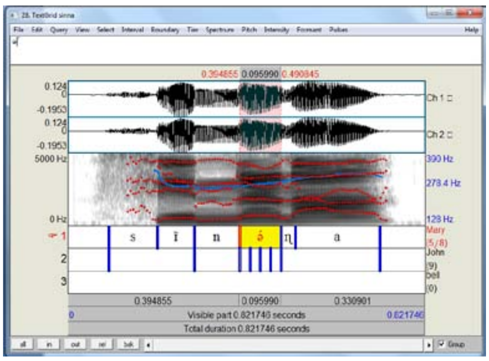


Fig 84: Female formant sample

4. ਪੜ੍ਹਾਉਣਾ /pəɽàʊɳa/

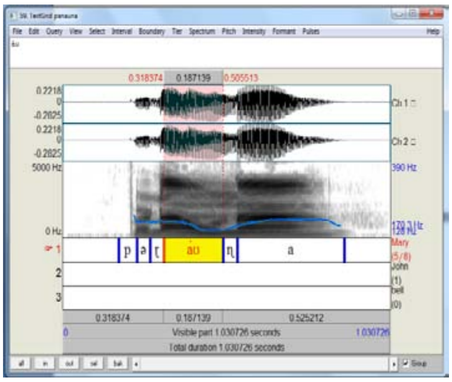


Fig 85: Male pitch sample

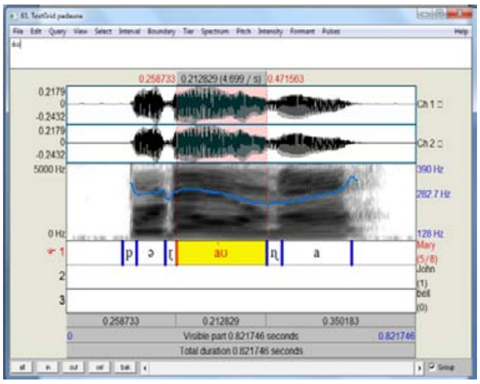


Fig 86: Female pitch sample

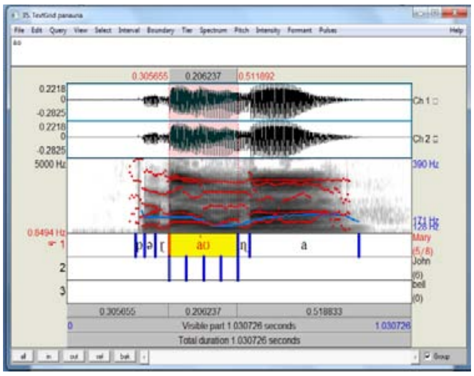


Fig 87: Male formant sample

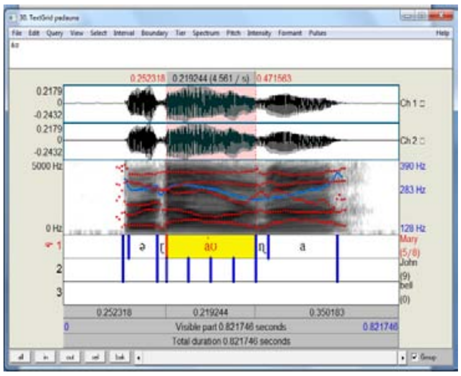


Fig 88: Female formant sample

5. ਪੜ੍ਹਿਆ /pəɽía/

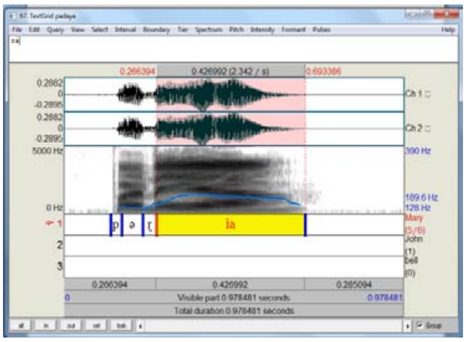


Fig 89: Male pitch sample

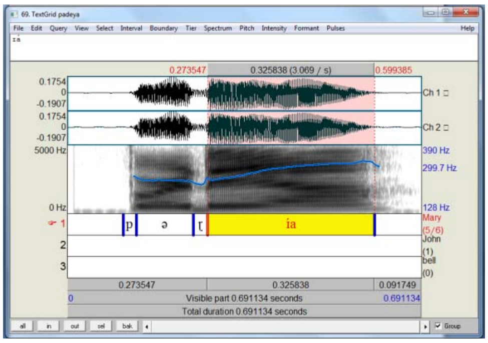


Fig 90: Female pitch sample

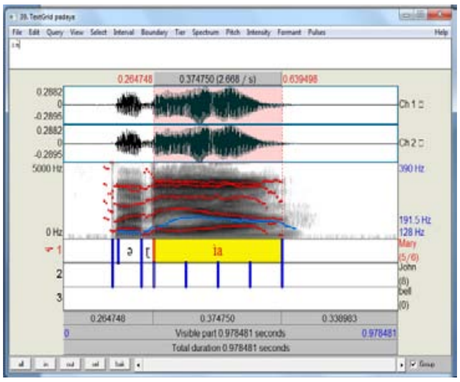


Fig 91: Male formant sample

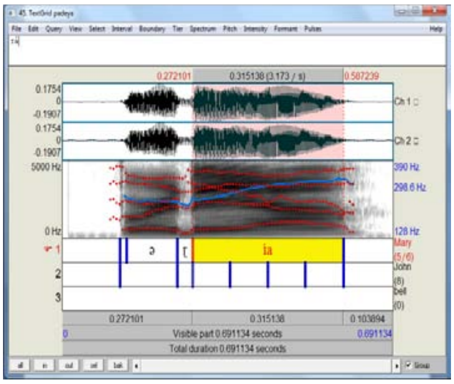


Fig 92: Female formant sample

6. ਪੜ੍ਹਾਈ /pəɽâi/

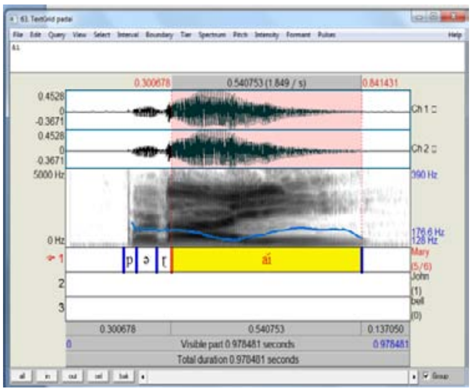


Fig 93: Male pitch sample

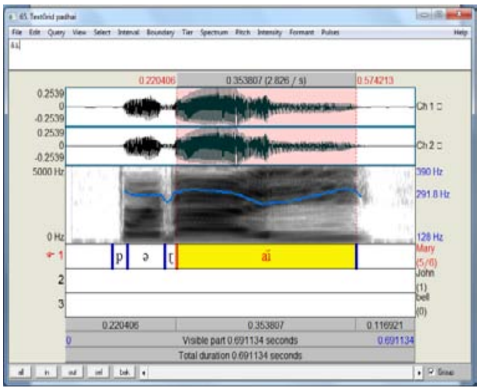


Fig 94: Female pitch sample

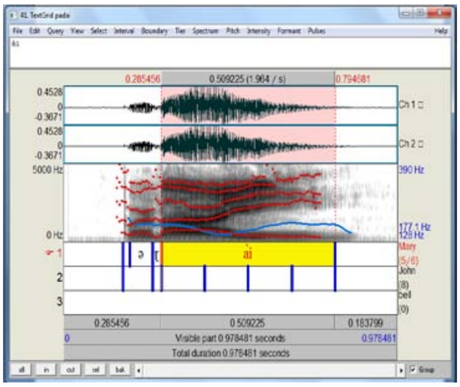


Fig 95: Male formant sample

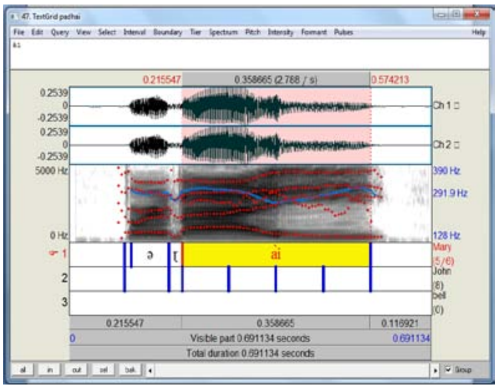


Fig 96: Female formant sample

Chapter 3- MATLAB code for plotting Independent tone graphs

```
[x,fs]=wavread('C:\Users\tempS\Desktop\Matlab\chidak.wav');
y=x(:,1);
[fx,tt]=fxrapt(y,fs,'u');
subplot(2,1,1),plot(y)
hold on
subplot(2,1,2),plot(fx)
```

Appendix D – ANNEXURES

Chapter 4 – Experimental Study of Lexical Stress

Annexure I

Di-syllabic non-tonal words

S. No.	Word	Syllabic weight		Intra-syllabic stress (s_i in %)
		s1	s2	
1.	ਸਰਬ /sərəb/	58.78	59.59	1.38
2.	ਸੜਕ /səɽək /	59.43	60.5	1.80
3.	ਹਸਬ / həsəb /	58.34	61.43	5.30
4.	ਸ਼ਗਨ / ʃəgən /	59.77	61.61	3.08
5.	ਕਸਕ / kəsək /	58.97	60.57	2.71
6.	ਅਣਖ / əɳəkʰ/	60.88	61.64	1.25
7.	ਹੁਨਰ /hʊnər/	63.5	65.8	3.62
8.	ਉਗਰ /ʊgər/	64.31	65.47	1.80
9.	ਉਜ਼ਰ /ʊzər/	59.55	59.98	0.72
10.	ਚੁਗਲ /t͡ʃʊgəl/	61.29	61.17	-0.20
11.	ਅਨੰਦ /ənə̃d/	59.66	60.53	1.46
12.	ਸੰਕਟ /sə̃kəʈ/	60.2	61.56	2.26
13.	ਅੱਗੇ /əgge/	59.23	60.97	2.94
14.	ਸਜਾ /səd͡ʒa/	60.33	62.36	3.36
15.	ਪਕਾ /pəka/	60.04	61.35	2.18
16.	ਬਤਾ /bəta/	56.37	60.05	6.53
17.	ਬੁਲਾ /bʊla/	56.28	60.19	6.95
18.	ਫਿੱਡਾ /pʰɪdda/	61.44	59.2	-3.65
19.	ਫਿਦਾ /pʰɪda/	61.12	61.54	0.69
20.	ਮਨਾ /məna/	59.6	62.4	4.70
21.	ਕਮਾ /kəma/	59.82	60.32	0.84
22.	ਸੁਨਾ /sʊna/	61.41	63.21	2.93
23.	ਰਸਾ /rəsa/	58.15	62.54	7.55
				Contd...

S. No.	Word	Syllabic weight		Intra-syllabic stress (s_i in %)
		s1	s2	
24.	ਤਣਾ /təɳa/	59.04	61.47	4.12
25.	ਗਿਲਾ /gɪla/	56.51	61.08	8.09
26.	ਯਸੂ /yəsu/	60.26	65.86	9.29
27.	ਰਸਤਾ /rəsta/	58.15	63.36	8.96
28.	ਤੁਸਾਂ /tʊsã /	62.25	64.39	3.44
29.	ਤਦੋਂ / tədõ/	60.08	61.98	3.16
30.	ਉਮਰ /ʊmər /	63.77	66.15	3.73
31.	ਕਈ / kəɳi/	63.46	68.9	8.57
32.	ਮੰਗਲ /mə̃gəl /	61.63	67.67	9.80
33.	ਬਸੰਤ / bəsə̃t/	57.26	63.85	11.51
34.	ਮਲੰਗ /mələ̃g /	60.99	64.12	5.13
35.	ਉਤਸਵ / ʊtsəv/	59.41	65.37	10.03
36.	ਉਤਸੁਕ /utsʊk/	60.59	66.22	9.29
37.	ਗਰਿਫਤ /gərɪpʰt/	58.38	62.63	7.28
38.	ਗਾਜਰ /gad͡ʒər/	57.53	60.62	5.37
39.	ਗੋਕੁਲ /gokul/	58.26	62.83	7.84
40.	ਨੂਤਨ /nutən/	59.57	62.97	5.71
41.	ਵੋਟਰ /votər/	57.82	61.17	5.79
42.	ਯੌਵਨ /yɔvən/	59.76	62.83	5.14
43.	ਹੈਰਤ /hɛrət/	60.75	62.89	3.52
44.	ਕੈਡਟ /kɛdət/	59.82	60	0.30
45.	ਹਾਕਮ /hakəm/	59.38	65.95	11.06
46.	ਸੌਂਕਣ /sɔ̃kəɳ/	62.01	64.62	4.21
47.	ਤਾਂਡਵ /tãɖəv/	59.33	63.06	6.29
48.	ਪੈਂਡਲ /pɛ̃ɖ l/	59.9	63.49	5.99
49.	ਔਰਤ /ɔrət/	60.54	64.04	5.78
50.	ਚਾਚਾ /t͡ʃat͡ʃa/	58.8	61.82	5.14
51.	ਫੇਟਾ /pʰeʈa/	61.28	62.5	1.99
52.	ਮਾਲੀ /mali/	59.8	61.54	2.91
53.	ਕੋੜਾ /koɽa/	64.5	68.3	5.89

S. No.	Word	Syllabic weight		Intra-syllabic stress (s_i in %)
		s1	**s2**	
54.	ਫੀਤਾ /pʰita/	63.3	66.96	5.78
55.	ਤਾਂਬਾ /tãba/	58.74	61.42	4.56
56.	ਕਾਂਟਾ /kãta/	58.52	63.27	8.12
57.	ਚਾਂਦੀ /t͡ʃãdi/	60.21	62.17	3.26
58.	ਪੈਂਤੀ /pɛ̃ti/	59	63	6.78
59.	ਮੂੰਗੀ /mũgi/	59.63	62.48	4.78
60.	ਠਾਕਰ /ʈʰakər/	61.2	64.87	6.00
61.	ਖਾਤਰ /kʰatər/	60.5	63.65	5.21
62.	ਆਕੜ /akəɽ/	60.63	64.75	6.80
63.	ਚਾਨਣ /t͡ʃanəɳ/	64.77	66.75	3.06
64.	ਪਖੰਡ /pakʰə̃ɖ/	64.41	63.71	-1.09
65.	ਬਾਲਕ /balək/	59.39	63.26	6.52
66.	ਸਾਰਾ /sara/	59.72	64.03	7.22
67.	ਮੂੰਜੀ /mũd͡ʒi/	62.85	65.3	3.90
68.	ਰਾਣੀ /raɳi/	61.37	66.79	8.83
69.	ਕਾਫਲਾ /kapʰla	61.68	66.07	7.12
70.	ਜੀਣਾ / d͡ʒiɳa/	58.23	64.87	11.40
71.	ਖੀਰਾ /kʰira/	63.02	65.37	3.73
72.	ਗਾਨੀ /gani/	63.38	67.27	6.14
73.	ਸੀਣਾ /siɳa/	61.07	65.69	7.57
74.	ਖੂੰਡੀ /kʰõɖi/	64.3	66.41	3.28
75.	ਮਯੂਰ /məjur/	62.01	63.15	1.84
76.	ਚਲਾਕ /t͡ʃəlak/	61.83	60.23	-2.59
77.	ਯਕੀਨ /jəkin/	59.35	63.38	6.79
78.	ਹਿਸਾਬ /hɪsab/	62.19	62.43	0.39
79.	ਬਜਾਰ /bəzar/	58.11	59.56	2.50
80.	ਮਰੀਜ /mərid͡ʒ/	63.13	62.56	-0.90
81.	ਕਰੀਬ /kərib/	61.89	61.56	-0.53
82.	ਉਜੈਨ /ʊd͡ʒɛn/	59.62	60.16	0.91
83.	ਅਕਾਲ /əkal/	59.4	62.01	4.39

S. No.	Word	Syllabic weight		Intra-syllabic stress (s_i in %)
		s1	s2	
84.	ਅਫੀਮ /əpʰim/	60.52	64.71	6.92
85.	ਉਤਾੜ /ʊtaɽ/	60.75	63.11	3.88
86.	ਉਥਾਨ /ʊtʰan/	61.58	63.29	2.78
87.	ਅਸਾਨ /əsan/	60.6	63.27	4.41
88.	ਅਮੀਰ /əmir/	61.39	65.56	6.79
89.	ਜਬਾਨ /d͡ʒəban/	59.84	63.97	6.90
90.	ਅੰਗੂਰ /ə̃gur/	62.78	65.36	4.11
91.	ਮੌਜੂਦ/mɔd͡ʒud/	59.8	59.36	-0.74
92.	ਵੇਦਾਂਤ/vedãt/	59.25	60.38	1.91
93.	ਈਮਾਨ/iman/	66.57	67.39	1.23
94.	ਬੇਨਤੀ/benti/	57.11	61.75	8.12
95.	ਮੋੜਦਾਰ/moɽdar/	60.02	62.43	4.02

Annexure II

Di-syllabic Supra-Laryngeal tonal words

S. No.	Word	Syllabic weight		Intra-syllabic stress (s_i in %)
		s1	**s2**	
1	ਝੂਠ (/tʃùtʰ/)	68.47	58.63	-14.36
2	ਘਰ (/kə̀r/)	66.64	57.57	-13.60
3	ਘਿੱਗੀ (/kìggi/)	68.94	60.92	-11.63
4	ਝਿੜਕ (/tʃìɽək/)	70.20	63.04	-10.20
5	ਧੁੰਨੀ (/tʊ̃̀ɳi /)	72.25	65.41	-9.46
6	ਧੋਬੀ (/tòbi/)	69.67	63.29	-9.15
7	ਢਾਡੀ (/ʈàɖi/)	68.07	62.94	-7.53
8	ਭੈਭੀਤ (/pɛ̀bít/)	66.94	62.23	-7.04
9	ਢਹਿਣਾ (/ʈə̀hɪɳa/)	68.39	63.61	-6.99
10	ਢਾਬਾ (/ʈàba/)	67.74	63.00	-6.99
11	ਘੁੰਨਾ (/kʊ̃̀ɳa /)	70.08	65.39	-6.70
12	ਘਾਹੀ (/kàhi/)	65.78	61.38	-6.69
13	ਝੱਗ (/tʃə̀gg/)	67.76	63.77	-5.88
14	ਢਿੱਲਾ (/ʈìlla/)	70.43	66.31	-5.85
15	ਘੜੀ (/kə̀ɖ /)	67.06	63.22	-5.73
16	ਧਰਮ (/tə̀ɾəm/)	69.67	66.09	-5.13
17	ਘੋਟਾ /kòʈa/	67.74	64.33	-5.05
18	ਭਸਮ (/pə̀səm/)	70.01	66.47	-5.05
19	ਘੇਰਾ /kèɾa/	66.07	62.76	-5.01
20	ਝੋਲੀ (/tʃòli/)	68.71	65.40	-4.81
21	ਘੌਲੀ /kɔ̀li/	68.06	65.34	-3.99
22	ਝੂਟਾ (/tʃùʈa/)	66.34	63.90	-3.68
23	ਢੱਕਣ (/ʈə̀kkəɳ/)	68.76	66.27	-3.63
24	ਝਾਂਜਰ (/tʃɑ̃̀ʤ ər/)	66.01	63.74	-3.43
25	ਘੁੰਡੀ (/kʊ̃̀ɖ /)	67.65	65.60	-3.04

S. No.	Word	Syllabic weight		Intra-syllabic stress (s_i in %)
		s1	s2	
26	ਝਾੜੂ (/tʃàɖu/)	67.23	65.28	-2.90
27	ਭੰਗੀ (/pə̃̀gi/)	69.44	67.65	-2.57
28	ਧਨੁਸ਼ (/tənʊʃ/)	70.15	68.41	-2.49
29	ਘੋੜਾ (/kòɖa/)	65.35	64.27	-1.65
30	ਘੂਰਨਾ (/kùɾəna/)	66.31	65.22	-1.64
31	ਝੰਡਾ /tʃə̃̀ɖa/	66.03	65.07	-1.46
32	ਭੌਂਦੂ (/pɔ̃̀du/)	68.96	68.05	-1.31
33	ਧਨਾਢ (/tənaɖ/)	65.96	65.53	-0.64
34	ਚਿੰਘਾੜ (/tʃĩgáɽ/)	66.58	66.84	0.38
35	ਕਢਾਈ (/kəɖái/)	66.85	67.18	0.50
36	ਕੰਧੂਈ (/kə̃dúi/)	68.95	69.71	1.11
37	ਸੁਝਾਈ (/sʊdʒái/)	65.73	66.49	1.15
38	ਸੁਝਾਅ (/sʊdʒáə/)	66.23	66.99	1.15
39	ਗੰਭੀਰ	64.34	65.65	2.04
40	ਨਿਘਾਸ (/nɪgás/)	65.49	67.56	3.16
41	ਪ੍ਰਧਾਨ (/pɾədán/)	68.56	70.98	3.52
42	ਸੰਧੀ (/sə̃dí/)	65.11	67.52	3.70
43	ਚੂੰਢੀ (/tʃũɖí/)	70.19	73.04	4.06
44	ਹੰਢਾਉ (/hə̃ɖáu/)	63.15	65.91	4.37
45	ਰਿਮਝਿਮ (/ɾɪmdʒìm/)	65.43	68.81	5.16
46	ਨਾਭੀ (/nabí/)	62.15	65.43	5.29
47	ਟੋਭਾ (/ʈobá/)	65.12	68.63	5.39
48	ਅਨਘੜ (ənkəɽ)	62.84	66.34	5.57
49	ਅਝੱਕ (/ədʒdʒə́k/)	62.87	66.84	6.30
50	ਅਭਿਆਸ (abias)	62.53	66.70	6.67
51	ਸੀਂਢਲ (/sĩɖə́l/)	65.64	70.09	6.78
52	ਮਧੁਰ (/mədʊ́r/)	63.35	68.53	8.18
53	ਨਿਰਭੈ (/nɪɾbɛ́/)	63.07	68.23	8.19
54	ਖਾਧਾ (/kʰadá/)	59.90	64.85	8.26

S. No.	Word	Syllabic weight		Intra-syllabic stress (s_i in %)
		s1	s2	
55	ਦੁਰ ਲੱਭ /dʊrləˊbb /	63.12	69.30	9.79
56	ਦੜਭਾ (/dəɽbá/)	63.47	70.15	10.53
57	ਦੁੱਭਰ	60.44	67.51	11.70
58	ਗਧਾ (/gədá/)	60.85	68.08	11.88
59	ਅੱਧਾ (/əddá/)	57.53	64.54	12.19
60	ਗੁੱਧਾ (/gʊddá/)	59.95	67.65	12.83
61	ਗੁਆਂਢਣ (/gʊãɖ́ˊɳ/)	62.04	70.10	12.99
62	ਬੀਂਢਲ /bĩɖ́ˊl/	62.10	70.85	14.09
63	ਦੁਧੀਆ (/dʊdìa/)	59.53	68.02	14.26
64	ਬੁੱਢਾ (/bʊɖɖá/)	58.70	67.08	14.29
65	ਗਿੱਧਾ (/gɪddá/)	58.03	66.41	14.45
66	ਇੱਧਰ (/ɪdd̀ ə̀r/)	59.53	71.70	20.45

Annexure III

Di-syllabic laryngeal words

S. No.	Word	Stress (s1)	Stress (s2)	%age increase of stress (s_i)
1.	ਸਹਾਇਕ /səhaɪk/	64.62	62.63	-3.07
2.	ਸਹਾਈ /səhai/	64.89	62.92	-3.04
3.	ਪੜ੍ਹਾਈ /pəɽài/	68.4	67.23	-1.7
4.	ਸਹਿਜ /sɛhədʒ/	62.76	62.8	0.07
5.	ਹੈਵਾਨ /hɛvan/	61.58	61.89	0.5
6.	ਸਾਹਿਬ /saheb/	62.52	62.95	0.69
7.	ਹੋਛਾ /hotʃʰa/	63.57	64.26	1.07
8.	ਸ਼ੌਹਰ /ʃɔhər/	64.53	65.23	1.09
9.	ਹਾਜਰ /hadʒər/	60.64	61.58	1.55
10.	ਹੂਰਾ /hura/	63	64.19	1.89
11.	ਅਹਿਦ /ɛhəd/	62.34	63.57	1.98
12.	ਆਹਰ /ahər/	63	64.65	2.61
13.	ਔਹਰ /ɔhər/	63.55	65.85	3.62
14.	ਤਬਾਹ /təbá/	61.73	64.39	4.31
15.	ਤਰਾਹ /tərá/	64.16	67.15	4.66
16.	ਹੀਟਰ /hiʈər/	61.1	65.15	6.63
17.	ਪੜ੍ਹਿਆ /pɒ ɽía/	64.4	69.16	7.39
18.	ਠੁਲ੍ਹਾ /ʈʰʊlá/	63.64	69.31	8.91
19.	ਵਸਾਹ /vəsá/	58.9	64.84	10.8
20.	ਇਹਨਾਂ /énã/	60.81	68.02	11.87
21.	ਆਹਲਾ /ála/	54.61	61.31	12.28
22.	ਗਾਲ੍ਹੜ /galə́ɽ/	60.69	68.6	13.04
23.	ਗੁੰਮ੍ਹੜ /gʊ̃mə́ɽ/	60.89	69.27	13.75
24.	ਜਿਲ੍ਹਣ /dʒɪlə́ɳ/	58.8	67.5	14.8

Annexure IV

Tri-syllabic non-tonal words

S. No.	Word	Stress (s1)	Stress (s2)	Stress (s3)	s3-s2/s2*100 (%age increase of stress (s_i)
1.	ਬੇਸਿਦਕ /besɪdək/	60.60	62.31	61.39	-1.48
2.	ਕਸ਼ਮਕਸ਼ /kəʃməkəʃ/	60.90	61.80	61.16	-1.04
3.	ਤੰਬਕੂ /tə̃baku/	56.74	58.13	57.54	-1.01
4.	ਕੋਰਾਪਣ /korapəɳ/	59.21	62.27	62.43	0.26
5.	ਤਤਕਰਾ /tətkəra/	58.59	62.73	63.56	1.33
6.	ਡਾਵਾਂਡੋਲ /ḍavãḍol/	54.82	59.76	60.75	1.65
7.	ਜਲਾਲਤ /dʒəlalət/	55.87	58.32	59.31	1.69
8.	ਗੈਰਹਾਜ਼ਰ /gɛrhadʒər/	57.28	59.10	60.33	2.08
9.	ਟੀਕਾਕਾਰ /ṭikakar/	58.96	62.03	63.78	2.82
10.	ਚਿਲਮਚੀ /tʃɪlmətʃi/	62.27	62.64	64.51	2.98
11.	ਬੇਸ਼ਕਲ /beʃəkəl/	55.97	57.34	59.05	2.99
12.	ਜੋਬ ਨਵੰਤ /dʒobənvə̃t/	56.12	60.06	62.00	3.24
13.	ਉਲ਼ਟਣਾ /ʊḷṭəɳa/	59.18	62.71	65.00	3.66
14.	ਟਿਕਣਾ /ṭɪkəɳa/	60.17	62.03	64.48	3.95
15.	ਤਪੋਬਨ /təpobən/	58.19	59.70	62.08	3.98
16.	ਅਕਰਮਕ /əkərmək/	54.69	59.99	62.84	4.75

S. No.	Word	Stress (s1)	Stress (s2)	Stress (s3)	s3-s2/s2*100 %age increase of stress (s_i)
17.	ਸੂਰਤਮੰਦ /surətmə̃d/	60.92	60.98	63.88	4.75
18.	ਚਿਲਗੋਜ਼ਾ /tʃɪlgoza/	59.51	56.84	59.71	5.05
19.	ਕਾਲਪਨਿਕ /kalpənɪk/	58.67	58.94	62.02	5.24
20.	ਪੋਲਾਪਣ /polapəɳ/	62.17	59.44	62.62	5.36
21.	ਨੀਲੱਤਣ /nilettəɳ/	58.30	57.70	60.91	5.56
22.	ਪਾਰਦਰਸ਼ਕ /pardərʃək/	58.77	56.08	59.42	5.96
23.	ਜਲੋਦਰ /dʒəlodər/	56.62	57.71	61.78	7.05
24.	ਅਮਿਤਾ /əmɪta/	56.52	59.18	63.63	7.53
25.	ਇਕੱਤਰ /ɪkəttər/	56.09	59.67	64.49	8.08
26.	ਰੂਪਾਂਤਰ /rupãtər/	56.99	58.06	63.02	8.54
27.	ਅਸਫਲ /əsəpʰəl/	56.84	59.24	64.45	8.78
28.	ਉਜਰਤ /ʊdʒərət/	56.48	56.59	61.56	8.79
29.	ਜਾਗਣਾ /dʒagəɳa/	54.65	55.44	61.14	10.26
30.	ਖੁਸ਼ਦਿਲੀ /kʰʊʃdɪli/	65.13	61.95	68.68	10.85

Annexure V

Tri-syllabic Supra-Laryngeal tonal words

S. No.	Word	IPA	Stress (s1)	Stress (s2)	Stress (s3)	s3-s2/s2*100 %age increase of stress (s_i)
1.	ਸੁੰਢੋਲਾ	/sʊ̃ɖóla/	65.54	67.59	64.52	-4.54
2.	ਭਸੂੜੀ *	/pɘ̀ suɽi/	69.71	68.98	66.35	-3.8
3.	ਢਿੰਢੋਰਾ*	/ʈɪ̃̀dora/	68.1	67.22	65.42	-2.68
4.	ਸਧਾਰਨ	/sədárən/	66.17	67.18	65.57	-2.41
5.	ਅੰਧੇਰਾ	/ə̃dè ɾa/	64.25	67.93	66.71	-1.79
6.	ਨਿਭਾਉਣਾ	/nɪbaʊɳa/	65.54	68.37	67.45	-1.34
7.	ਨਿਘਾਰਨਾ	/nɪgáɾna/	63.08	65.41	64.96	-0.68
8.	ਬੁਢਾਪਾ	/bʊɖápa/	61.59	65.56	65.2	-0.55
9.	ਹੰਢਣਸਾਰ	/hə̃ɖə́ɳsaɾ/	61.14	67.09	67.44	0.52
10.	ਗਿਝਾਉਣਾ	/gɪdʒáʊɳa/	60.67	66.54	67.43	1.34
11.	ਤਾਂਘਣਾ	/tãgə̀ɳa /	64.22	67.48	69.02	2.28
12.	ਪੰਘਰਨਾ	/pə̃gə̀rna/	62.76	66.53	68.72	3.28
13.	ਊਂਘਣਾ	/ũgə́ɳa/	62.83	66.95	70.07	4.65
14.	ਸੰਢਣਾ	sə̃ɖ́ ɳa/	64.12	68.19	71.43	4.75
15.	ਝੁਕਣਾ*	/tʃʊ̀kəɳa /	69.74	62.75	66.1	5.33
16.	ਭ੍ਰਿਸ਼ਟਾਚਾਰ*	/prɪ̀ʃʈatʃaɾ/	68.13	63.8	67.29	5.46
17.	ਸਾਂਝੀਦਾਰ	/sãdʒídaɾ/	59.21	62.06	65.89	6.18
18.	ਨਿਘਰਨਾ	/nɪgə́rna/	62.63	64.37	68.44	6.33
19.	ਗੰਧਲਾ	/gə̃d́ la/	61.93	67.47	72.15	6.93
20.	ਧੁੰਦਲਾ	/tʊ̃̀d la/	67.86	63.23	68.14	7.76
21.	ਝਗੜਾ*	/tʃə̀gɽa/	68.36	61.11	66.32	8.53
22.	ਝੌਂਪੜੀ*	/tʃɔ̃̀pɘ ɖi/	68.09	60.65	66.15	9.06
23.	ਉਝਬੁਘ	/ʊdʒə́bʊ̀g/	62.6	59.01	64.52	9.34
24.	ਭਿੱਜਣਾ*	/pɪ̀dʒdʒəɳa /	70.61	61.5	69.64	13.23
25.	ਲੱਭਣਾ	/ləbbə̀ɳa/	61.65	63.27	72.02	13.83

S. No.	Word	IPA	Stress (s1)	Stress (s2)	Stress (s3)	s3-s2/s2*100 %age increase of stress (s_i)
26.	ਬੁੱਝਣਾ	/bʊdʒdʒə́ɳa/	58.7	62.72	71.42	13.87
27.	ਕਿਧਰੋਂ	/kɪɗ̤́ ɾõ/	65.08	62.83	71.92	14.47
28.	ਰਿੱਝਣਾ	/ɾɪdʒdʒə́ɳa/	60.21	61.61	71.77	16.49

Annexure VI

Tri-syllabic laryngeal words

S. No.	Word	Syllabic weight			Intra-syllabic stress (si in %)
		s1	s2	s3	
1.	ਸਲ੍ਹਾਬਾ /səlàba/	66.43	67.81	62.37	-8.03
2.	ਖਲ੍ਹਾਰਨਾ /kʰəlàrna/	62.01	64.04	62.75	-2.02
3.	ਇਤਿਹਾਸ /ɪtehas/	61.53	64.86	63.92	-1.46
4.	ਇਸ਼ਤਿਹਾਰ /ɪʃtehar/	59.64	64.78	64.07	-1.09
5.	ਅਹੰਕਾਰ /əhə̃kar/	59.74	62.14	62.61	0.76
6.	ਇਮਤਿਹਾਨ /ɪmtehan/	64.65	66.21	66.91	1.05
7.	ਸ਼ਹਿਤੂਤ /ʃɛhətut/	67.67	67.58	68.29	1.05
8.	ਸੁਹੇਲਾ /sʊhela/	63.81	63.79	65.05	1.98
9.	ਸਿਹਤਮੰਦ /sehətəmə̃d/	66.37	66.38	68.14	2.65
10.	ਸਹਿਸੁਭਾ /sɛ̀subà/	59.25	60.36	62.09	2.87
11.	ਸਹਾਰਨਾ /səharna/	64.63	63.03	64.92	3.00
12.	ਹੂਕਣਾ /hukəɳa/	59.39	62.58	64.48	3.03
13.	ਹੁਲਾਰਾ /hʊlara/	59.82	60.86	62.90	3.35
14.	ਸ਼ਾਹਦੀ /ʃahədi/	63.43	63.13	65.25	3.37
15.	ਸਿਹਰਾ /sehəra/	66.58	66.54	69.36	4.25
16.	ਸਹਾਇਤਾ /səhaɪta/	64.25	63.10	65.81	4.30
17.	ਸੁਹਣਾ /sohəɳa/	65.38	67.45	70.43	4.42
18.	ਸਹਾਰਾ /səhara/	63.82	62.40	65.25	4.57
19.	ਹੈਸੀਅਤ /hɛsiət/	58.83	61.99	65.01	4.86
20.	ਸਿੰਨ੍ਹਣਾ /sĩnə́ɳa/	64.17	66.98	70.42	5.14
21.	ਖੁਲ੍ਹਣਾ /kʰʊlə́ɳa/	63.45	67.79	71.43	5.36
22.	ਅਹਿੰਸਕ /əhĩsək/	61.44	61.42	65.00	5.83
23.	ਖੁੱਲ੍ਹਵਾਂ /kʰʊllə́vã/	66.01	68.26	72.90	6.80
24.	ਹਿਮਾਚਲ /hɪmatʃl/	60.56	59.63	63.82	7.02
25.	ਹਿਕਾਇਤੀ /hɪkaɪti/	58.76	59.48	63.95	7.51
26.	ਖਮ੍ਹਣੀ /kʰəmə́ɳi/	59.33	64.62	70.46	9.03
27.	ਖਰ੍ਹਵਾ /kʰərə́va/	63.98	63.74	69.99	9.81
28.	ਵਿਦਰੋਹ /vɪdəró/	58.60	57.60	67.74	17.61

Annexure VII

Poly-syllabic words

S. No.	Word	Syllabic weight				
		s1	s2	s3	s4	s5
1.	ਅਕਿਰਿਆਸ਼ੀਲ /əkɪrɪaʃil/	58.52	59.53	60.67	57.58	-
2.	ਰੂਪਾਂਤਰਨ /rupãtərən/	55.43	57.99	60.85	60.31	-
3.	ਖਾਂਚੇਵਾਲ਼ਾ /kʰãtʃevala/	56.95	61.63	62.08	61.53	-
4.	ਪੰਖੜੀਵਾਲਾ /pə̃kʰɽivala/	57.94	59.80	62.28	62.56	62.25
5.	ਗੁਜਰਾਂਵਾਲਾ /gʊdʒrãvala/	54.22	51.92	60.39	62.07	62.20
6.	ਨਾਕਾਬੰਦੀ /nakabə̃di/	57.07	61.28	60.08	60.95	-
7.	ਇਕਵਾਸਾਪਣ /ɪkvasapəɳ/	53.71	57.01	60.82	61.85	-
8.	ਸੈਂਟੀਮੀਟਰ /sɛ̃ʈimiʈər/	58.04	62.21	61.10	62.21	-
9.	ਉਗਰਪੰਥੀ /ʊgərpə̃tʰi/	51.81	58.96	60.73	62.69	-
10.	ਉਜੱਡਪੁਣਾ /ʊdʒəɖɖpʊɳa/	57.40	58.04	57.13	60.30	63.39
11.	ਚੇਤਾਵਣੀ /tʃetavəni/	58.36	59.19	59.35	62.75	-
12.	ਸਾਮਰਾਜਵਾਦੀ /samradʒvadi/	58.09	61.49	56.60	54.06	60.73

Chapter 6 – Correlation of Morpho-Syntactic features with lexical representation and its co-articulation

Annexure I

POS for Punjabi

S. No.	Categories			Label	Annotation Convention
	Top-level	Sub-type - level 1	Sub-type - level 2		
1	**Noun**			**N**	**N**
1.1		Common		NN	N__NN
1.2		Proper		NNP	N__NNP
1.4		Nloc		NST	N__NST
2	**Pronoun**			**PR**	**PR**
2.1		Personal		PRP	PR__PRP
2.2		Reflexive		PRF	PR__PRF
2.3		Relative		PRL	PR__PRL
2.4		Reciprocal		PRC	PR__PRC
2.5		Wh-word		PRQ	PR__PRQ
2.6		Indefinite		PRI	PR_PRI
3	**Verb**			**V**	**V**
3.1		Main		VM	V__VM
3.1.2			Non-finite	VNF	V__VM__VNF
3.1.3			Infinitive	VINF	V__VM__VINF
3.1.4			Gerund	VNG	V__VM__VNG
3.2		Auxiliary		VAUX	V__VAUX
4	**Adjective**			**JJ**	
5	**Adverb**			**RB**	
6	**Demonstrative**			**DM**	**DM**
6.1		Deictic		DMD	DM__DMD
6.2		Relative		DMR	DM__DMR
6.3		Wh-word		DMQ	DM__DMQ
6.4		indefinite		DMI	DM_DMI
7	**Postposition**			**PSP**	

S. No.	Categories	Label	Annotation Convention	Label	Annotation Convention
8	**Conjunction**			**CC**	**CC**
8.1		Co-ordinator		CCD	CC__CCD
8.2		Subordinator		CCS	CC__CCS
9	**Particles**			**RP**	**RP**
9.1		Default		RPD	RP__RPD
9.2		Classifier		~~CL~~	~~RP__CL~~
9.3		Interjection		INJ	RP__INJ
9.4		Intensifier		INTF	RP__INTF
9.5		Negation		NEG	RP__NEG
10	**Quantifiers**			**QT**	**QT**
10.1		General		QTF	QT__QTF
10.2		Cardinals		QTC	QT__QTC
10.3		Ordinals		QTO	QT__QTO
11	**Residuals**			**RD**	**RD**
11.1		Foreign word		RDF	RD__RDF
11.2		Symbol		SYM	RD__SYM
11.3		Punctuation		PUNC	RD__PUNC
11.4		Unknown		UNK	RD__UNK
11.5		Echowords		ECH	RD__ECH