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RESEARCH PAPER

Acoustic Analysis of Dawoodi Consonants: A Severely Endangered Language of Northern Pakistan

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ABSTRACT

Dawoodi (previously known as Domaaki) is an Indo Aryan language, spoken by very limited number of speakers in Gilgit. All Dawoodi speakers are multilingual and prefer to use other languages due to which Dawoodi is moving towards language death. The present study aims to develop the phonemic inventory of Dawoodi language. For the present study, qualitative approach is used in identification of sounds and phonemic analysis. Quantitative approach is carried out to figure out the acoustic cues of the sounds, which are presented in mean values. Moreover, palatography is also carried out to clarify the place of articulation of certain phonemes. The findings show that Dawoodi has large consonant and vowel inventories. Phonemic analysis reveals that Dawoodi has 36 consonant segments including voiced, voiceless and aspirated voiceless consonants. However, all the consonants do not occur at all three positions of the word. Acoustic analysis was carried out to measure VOT, closure duration and burst for the identification of stops. Fricatives are measured in terms of friction, V1 and V2 duration. Affricates were identified through closure, friction and total duration. Other consonants have vowels like formant structures (fainter) and their formant frequencies were measured.

KEYWORDS Acoustic Analysis, Consonants, Dawoodi, Phonemic Analysis

Introduction

Dawoodi is an Indo- Aryan language spoken by small number of people in Northern areas of the Pakistan (Weinreich, 2010) where many other languages like Brushiski, Shina, Urdu and somehow English are also spoken (Buddruss, 1983). Dawoodi is the "language of Dooms" a scattered minority group considered as outsiders as they migrated to Gilgit from Kashmir (Weinreich, 2015). In past, Dawoodi speakers had worked as blacksmiths and musicians, but recently they are engaged in many other professions as well.

There are two dialects of Dawoodi; Dawoodi spoken in Hunza and Dawoodi spoken in Nagar as immigrants settled in these two areas. There are some differences at morphological, syntactic and lexical levels but these differences do not create any hurdle to communicate with each other (Weinreich, 2008). Doomaki speakers are multilingual and prefer to speak other languages instead of Dawoodi because it is considered as inferior language. This negative attitude towards language leads to the death of language as majority of the speakers shifted towards other regional languages.

Moreover, people feel ashamed to identify themselves as native speakers of Dawoodi (Weinreich, 2015).

There are many studies conducted to highlight the endangerment of the death of the language but none of them focused on the linguistic features of the language. Present study is investigated the consonant inventory and acoustic properties of consonants of Dawoodi language.

Literature Review

Language is a system of linguistic communication having verbal (written and spoken) and non-verbal modes of communication in a particular society (Wardhaugh and Fuller, 2015). Many people have ability to speak more than one language as they use different languages in different situations according to requirement, known as multilingualism (Wardhaugh, 2006). In every multilingual society, there is always a dominant language and others are less dominant. Pakistan is also a multilingual country where Urdu and English are said to be dominant and many regional and less dominant languages are present like Punjabi, Gojri, Shina, Pashto, Dawoodi and many others (Rahman, 2003).

In Gilgit Baltistan many languages are spoken including Brushiski, Shina, Wakhi, Dawoodi and many others. Due to rich diversity of language, People are moving towards most dominant languages. Therefore, some languages are moving towards death, as their speakers are decreasing day by day. Dawoodi is one of the endangered languages of Gilgit Baltistan. Different people studied different aspects of the language.

Weinreich (2008) studied the verities of Dawoodi language. He explored that there are two different varieties of Dawoodi spoken in two different regions Hunza and Nagar. Both dialects have few differences at morphological, syntactic and lexical levels but people can communicate without any hurdle. Moreover, he also highlights the endangerment of the language as majority of the speakers switched to other regional languages and only older people use Dawoodi for communication which are limited in number. Kreutzmann (2005) investigate the linguistic diversity in Eastern Hindukush and Karakoram. It is reported that these areas have rich language diversity. Brushiski and Shina are spoken by large number of people. Dawoodi has very limited number of speakers in limited areas.

Backstrom & Radloff (1992) investigate the Northern Pakistan's languages. It is investigated that Dawoodi speakers are very less in numbers. People of Mominabad, a village in Hunza, use Dawoodi language but those people are also bilingual and use Burushaski as well which is more dominant language. It is also observed that people in workplace and home commonly use Burushaski.

Weinreich (2010) reported the language shift in northern areas of Pakistan by giving special reference to Dawoodi and Pashto. According to him, Dawoodi speakers are decreasing in number day by day. It is believed that Dawoodi is the language of low-class people that is why Dawoodi speakers are unwilling to speak the language. It is observed that language shift cause language death. It can be avoided by motivating Dawoodi speakers to speak Dawoodi instead of other languages

Weinreich (2015) reported the ethno-linguistic diversity. He focuses on the language attitudes of speakers towards their mother tongues in the region of Gilgit Baltistan. Dawoodi speakers have negative attitude towards their language because it is

considered as the language of low cast and they were hesitant to recognize themselves as the native of Dawoodi language.

Tikkanen (2011) studied case system of Dawoodi language and compared it with other Indo Aryan languages. He reported that most Indo Aryan languages are fusional and Shina is agglutinative. Dawoodi is the combination of agglutinative and fusional. Buddruss (1983) discussed that Dawoodi speakers can speak Burushaski, Shina and Urdu as well. Majority of the vocabulary in Dawoodi is borrowed from Shina and Burushaski. There are also commonalities on phonemes level.

Lorimer (1939) studied the Dawoodi language. It was the very first work on Dawoodi language. He discussed the history and common features of the language. He explores phonology and morphology of language briefly and just highlights some phonemes of the language. It is observed that Dawoodi is an endangered language and researcher mostly focused on the factors of endangerment. Present study deals with phonemic and acoustic analysis of Dawoodi consonants, in order to develop the consonantal inventory of the language.

Material and Methods

Methodology includes research design, population and data collection. Methodology for the present study is discussed below:

Research Design

Mixed method approach is used in the present study. Qualitative approach is used to collect the data in the form of recordings. Furthermore, data is analyzed qualitatively in order to identify the consonants and to figure out the minimal pairs, voicing contrast and word level distribution of identified consonants. Quantitative approach is carried out to find the acoustic cues of the phonemes.

Population

Weinreich (2008) reported that there are two dialects of Dawoodi spoken in Hunza and Nagar. Therefore, for the present study, native speakers of Dawoodi were the participants. Participants were the residents of Hunza and Nagar in Gilgit Baltistan.

Sample

Seven native speakers of Dawoodi language participated in the study. Five male and two female speakers of Dawoodi selected conveniently. Participants were more than twenty years old. All speakers were multilingual.

Research Tools

Universal paragraphs for transcription (North wind) and Indo-Iranian Swadesh word list, which is comprised of 207 words, were used as research tools to collect data for the study. Data was collected in the form of audio recordings from selected participants.

Data Collection Procedure

For data collection, the word list and passage will be recorded through Zoom H5 audio recorder in a noise-free environment. After identification of the phonemes of the

language, minimal pairs will be figured out. Moreover, voicing contrast and word level distribution at initial, medial and final position will also be observed. In order to find out the acoustic cues, the consonants will be recorded from the same speakers in VCV context whereas vowels will be recorded in CVC context.

Data is collected in different times for different purposes. Initially, the word list and passage were recorded through Zoom H5 audio recorder in a noise-free environment. After identification of the sounds, minimal pairs, word level distribution and voicing contrasts were figured out. Palatography was also carried out to find out the place of articulation of some sounds. Finally, consonants are recorded in VCV context where C was the target consonant for the purpose of acoustic analysis.

Result and Discussion

Consonant Scheme

Consonant inventories vary from language to language and range from 6-122 phonemes. Languages having more than 34 sounds fall under the category of large consonant inventory (Maddieson, 1984). Therefore, Dawoodi language has large consonant inventory having 36 consonant sounds.

Table 1
Consonant inventory of Dawoodi

	Bilabial	**Dental**	**Alveolar**	**Post alveolar**	**Retroflex**	**Palatal**	**Velar**	**Glottal**
Stops	p b	ʈ ɖ	t d				k g	
	pʰ	ʈʰ	tʰ				kʰ	
Fricatives			s z	ʃ	ʂ	ɕ	x ɣ	h
Affricates			ts	tʃ dʒ		tɕ dʑ		
				tʃʰ		tɕʰ		
Nasal	m		n			ɲ	ŋ	
Tap			ɾ					
Lateral			l		ɭ			
Glides	w					j		

Table 2
Minimal Pairs of Dawoodi Consonants

Phoneme	**Word**	**Meaning**	**Phoneme**	**Word**	**Meaning**
p	pɑʃ	Fertilizer	b	bɑʃ	language
pʰ	pʰəɾ	to turn	ʃ	ʃəɾ	scattered
b	bəbʊɾ	equal in weight	p	pəbʊɾ	less
ʈ	ʈək	to break	t	tək	to tie
ʈʰ	ʈʰəp	Dark	ʈ	ʈəp	to set on fire
ɖ	ɖək	Hope	d	dək	to hit
t	təm	to close the door	ʈ	ʈəm	to swim
tʰ	tʰəŋ	to push	t	təŋ	cloudy
d	dəm	to fell fruit from tree	ɖ	ɖəm	bravery
k	kɑdʒɪk	Where	s	sɑdʒɪk	equal share
kʰ	kʰɑ	to eat	j	jɑ	heart
g	geɪ	Went	ʃ	ʃeɪ	dust

s	səɣu	blender used to blend lassi	ʃ	ʃəɣu	shortage of water in fields
z	zərəp	to beat	k^h	k^hərəp	rich
ʃ	ʃəʈ	Strength	ʂ	ʂəʈ	discharge of air
ʂ	ʂəpɪkɑ	Bread	l	ləpɪkɑ	a girl, who eats fast
ʂ	ʂɑ	six	ʃ	ʃɑ	alright
χ	xər	to roast	h	hər	stream
ɣ	ɣʊr	sad	x	xʊr	to snort
h	hɑʃ	to bite	x	xɑʃ	green wood
ts	ətsi	up	ʃ	əʃi	like this
tʃ	tʃəpɪr	to steal	m	məpɪr	old
$tʃ^h$	tʃhəm	Drought	tʃ	tʃəm	pain
dʒ	dʒərəm	fell the wall with water	ʃ	ʃərəm	shame
tʂ	tʂəm	Pain	ʂ	ʂəm	escape of air
$tʂ^h$	$tʂ^h$əʊ	to milk	ʂ	ʂəʊ	much salty
dʐ	dʐəmẽ	Crossbow	k	kəmẽ	very little
m	ləm	a lighted coal	p	ləp	half part
n	nʊk	Nose	m	mʊk	a pearl
ɲ	ɲɔ:m	Name	ɭ	ɭɔ:m	condition/ status
ŋ	eŋ	They	ɾ	eɾ	do
ɾ	ɾʊʈ^h	Blood	h	hʊʈ^h	hand
l	ləp	Bite	d	dəp	box of flour
ɭ	ɭʊm	red coal	b	bʊm	dried
w	wəɔ	to call	ʃ	ʃəɔ	to switch the light off
j	jɑ	Heart	dʒ	dʒɑ	go

Voicing Contrast

Dawoodi language has three way voicing contrast as voiced, voiceless and voiceless aspirated, which is observed in stops and affricates. Fricatives have two way voicing contrast as voiced and voiceless. Nasal, laterals, tap and glides are voiced without any voiceless counterpart.

Table 3
Voicing contrast of Dawoodi Consonants

	voiceless	voiced	voiceless aspirated
Stops	p	b	p^h
	ʈ	ɖ	ʈ^h
	t	d	d^h
	k	g	k^h
Fricatives	s	z	
	x	ɣ	
Affricates	tʃ	dʒ	$tʃ^h$
	tʂ	dʐ	$tʂ^h$

Table 4
Word level distribution of Dawoodi consonants

		Initial		Medial		Final	
Stops	p	pɑʃ	fertilizer	ʃəpʊs	Blanket	urp	rain
	pʰ	pʰʊlɑ	flower	əpʰʊk	Marsh		
	b	bəpo	yesterday night	kəbɛ	When		
	ʈ	ʈo	sun	bɪʈor	Husband	pərəʈ	equal
	ʈʰ	ʈʰi:dʒɪk	where	ʈʰəʈʰɪ	Here	bʊʈʰ	much
	ɖ	ɖɔɪ	two	ɪnɖɪlɑ	Breast		
	t	təm	to close the door	dʒoto	Child	kot	with
	tʰ	ʈʰi:k	correct	ətʰɑ	eight times	bʊtʰ	stone
	d	dəɔ	law	bʊdɑrɛ	Shoes		
	k	Kisik	what	ʃəʊkʊlɛ	king's family	kəmɪk	less
	kʰ	kʰəʃɑ	mouth	nɪkʰɪlenɑ	Left	əkʰ	eye
	g	gəʃkɑ	rope	ʈgɔn	Egg		
Fricative	s	sər	lake	kisik	What	mɔs	meat
	z	zɪmɪn	earth	heɪzɑʈəs	like this		
	ʃ	ʃono	dog	dʒɑʃɪr	Pull	beɪʃ	sit
	ʂ	ʂəpɪkɑ	bread	əʂɪŋ	This	jʊpʊʂ	broom
	ʃ̊	ʃ̊əp	to drink	ʃ̊əʃ̊ɑ	Generous	ʊʃ̊	taking rest
	x	xurũntʃ	cloud	ɖəxəl	demoniac	gu:lɑx	respectable
	ɣ	ɣoɲo	seed	tʃəɣɑ	Talk		
	h	heɪ	that				
Affricates	ts	tsəp	hold	ətsɪ	Up	əmɪts	us
	tʃ	tʃʊkɪr	sew	ətʃɑsɪk	Goat		
	tʃʰ	tʃʰɑ	is			ətʃʰ	eye
	dʒ	dʒɑʃɪr	pull	kɑ:dʒɪk	Where		
	ʈʃ	ʈʃəm	pain				
	ʈʃʰ	ʈʃʰəɔ	to milk			ʈʃʰɛʈʃʰ	field
	ɖʒ	ɖʒəlo	tall man	lʊdʒʊm	Pearl		
Nasals	m	melɪ	wife	kɪrmɑ	Snake	ʈʊm	tree
	n	nʊk	nose	pɑnɪ	Water	mʊn	say
	ɲ	ɲ ɔ:m	name	ɣoɲ o	Seed		
	ŋ			ʃ̃iŋɑ	Horn	pʰəʈɑlɪŋ	feather
Tap	ɾ	rʊʈʰ	blood	kirma	Snake	tʃʌr	grass
Lateral	l	lɪpɪr	throw	konɑlɪ	Stick	lɛl	know
	ɭ	ɭʊm	to hold	ɭəmɭəm	to shine		
Glides	w	wəkʈ	time	ɖʱkʰɪlweɪn	Shown		
	j	jɑ	heart	dʒujɑ	Louce		

Acoustic Properties of Dawoodi Consonants

Consonant sounds have different acoustic properties. All consonants vary from each other acoustically. Stops, fricatives and affricates have differences in air blockage and release. Nasals and glides have different formant frequencies.

Stops

According to Kent and Read (1996), stops are measured in terms of closure duration, voice onset time (hereafter VOT) and burst. There are 12 stops present in Dawoodi language, articulated from four different places of articulation including bilabial, dental, alveolar and velar.

VOT (Voice Onset Time)

VOT is said to be interval between release of stops and start of voicing. VOT is extensively studied across the languages. it is said to be one of the major acoustic cues of stop, which demonstrated that VOT either be long if closure duration is further back (Peterson & Lehiste, 1960) or it could be shorter when articulators move fast (Stevens et al, 1986). In order to measure the VOT, total six tokens were recorded and analyzed.

Table 5
VOT of Dawoodi stops by voicing type

	Unaspirated Voiced	Aspirated Voiceless	Unaspirated Voiceless
Bilabial	-0.006666	0.038131	0.014600
Dental	-0.0111377	0.0559122	0.0095917
Alveolar	-0.0104778	0.0542988	0.0123478
Velar	-0.0138347	0.075705	0.0205415

Mean VOT of Dawoodi stops according to voicing type

Table 5 clearly indicates that in Dawoodi aspirated stops have largest VOT than unaspirated. Among unaspirated stops, voiceless stops have longest VOT and voiced stops have lowest VOT. Therefore, Dawoodi stops have the sequence as "voiceless aspirated > voiceless unaspirated > voiced unaspirated", which is also observed in other Indo-Aryan languages including Hindko (Kiani, et al, 2012) and Pahari (Khan & Bukhari, 2011).

VOT by Place of Articulation

As Dawoodi stops are articulated from 4 different places like bilabial, dental, alveolar and velar. The table below shows the mean VOT in terms of place of articulation

Table 6
Mean VOT according to place of articulation

Place of Articulation	Mean VOT
Bilabial	0.015355
Dental	0.018122067
Alveolar	0.018722933
Velar	0.0274706

Analyzed data reveals that Velar stops have longest VOT, and bilabial stops have shortest VOT, whereas dental and alveolar have average VOT, among which VOT for alveolar is largest than dental stops.

It is observed that in Dawoodi stops mean VOT is different in different places of articulation. It follows the sequence as "velar> alveolar> dental> bilabial", which is similar in Hazara Hindko- an Indo Aryan language (Rashid, 2015).

Closure Duration

According to Kent & Read (1996), "the closure duration of plosives is known as the acoustic interval corresponding to the articulatory occlusion" (Rashid, 2015). In this section, closure duration of Dawoodi stops will be discussed in terms of voicing and place of articulation.

Table 7
Closure duration of Dawoodi stops

	Unaspirated Voiced	Aspirated Voiceless	Unaspirated Voiceless
Bilabial	0.059981334	0.133705335	0.116474
Dental	0.089695167	0.083822335	0.084415
Alveolar	0.096852667	0.105534835	0.115291835
Velar	0.080039834	0.090410665	0.1021425

It is shown that unaspirated voiceless stops (p, ʈ, t, k) have highest closure duration and unaspirated voiced stops (b, ɖ, d, g) have lowest closure duration. Whereas closure duration of aspirated voiceless stops (p^h, $ʈ^h$, t^h, k^h) falls between unaspirated (voice and voiceless) stops. Closure duration of Dawoodi stops follow the sequence "unaspirated voiceless> aspirated voiceless> unaspirated voiceless" in terms of voicing type.

Closure Duration by Place of Articulation

The figure below highlights the closure duration in terms of place of articulation.

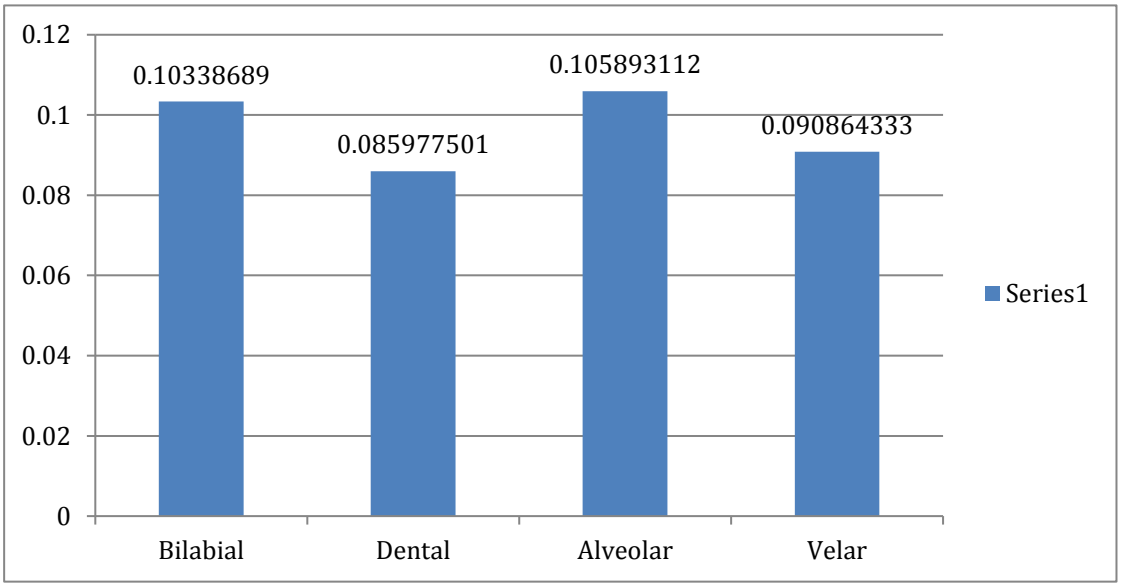

Fig 1 Closure duration of Dawoodi stops according to place of articulation

It is observed that alveolar stops have highest closure duration and dental stops have lowest closure duration. Bilabial and velar stops lie between alveolar and dental stops respectively. It does not prove the findings by (Rashid, 2015) that VOT and closure duration have reverse relation as when closure duration increases then VOT decreases. Dawoodi stops do not have this reverse relation between VOT and closure duration.

Burst

Burst is mostly seen in terms of place of articulation. Halle et al (1957) claim that bilabial stops have low frequency whereas alveolar stops have higher frequency and velar stops lie between the two having mid frequency. According to Stevens & Blumstein (1978) bilabial stops have falling burst spectrum, alveolar have rising and velar have compact spectrum. In this section, burst for Dawoodi stops will be observed in terms of place of articulation.

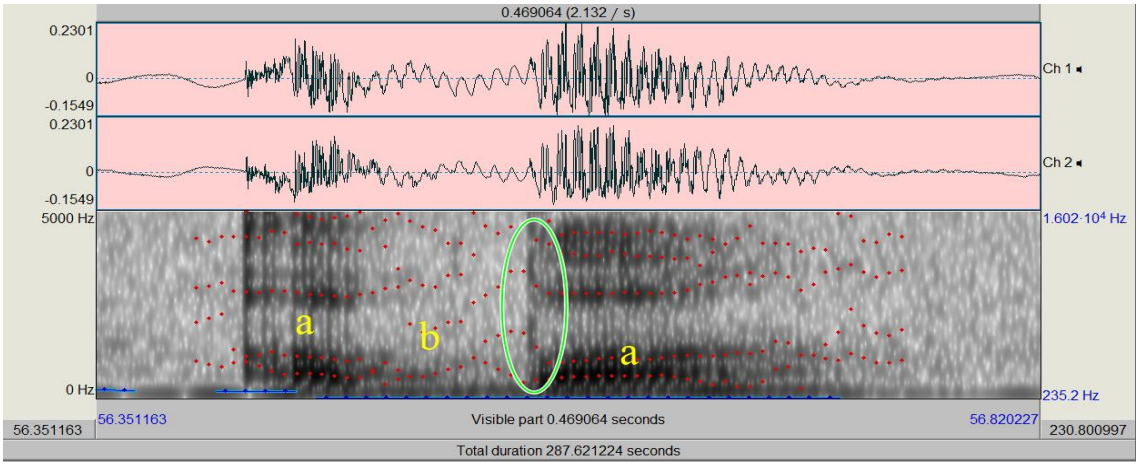

Fig 2 Burst spectrum of bilabial voiced /b/

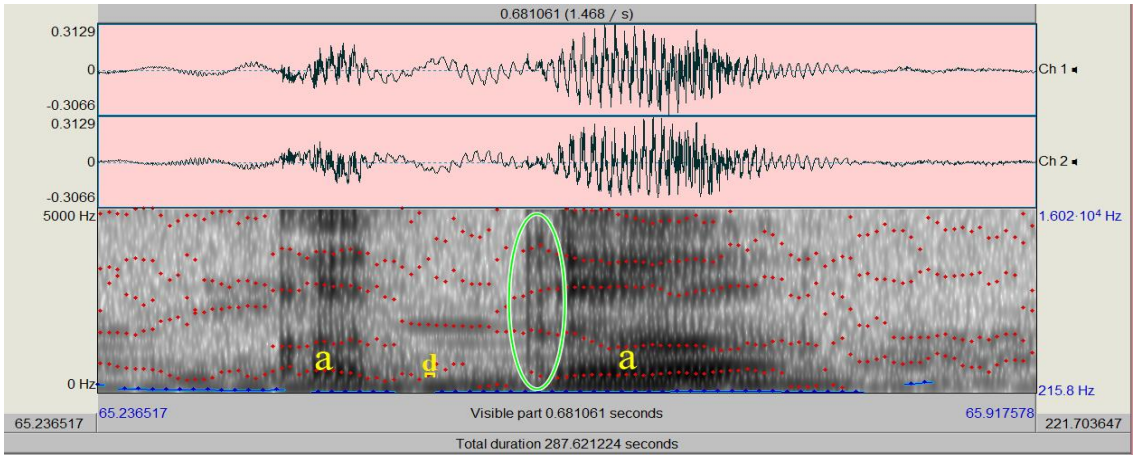

Fig 3 Burst spectrum of voiced dental /ḍ/

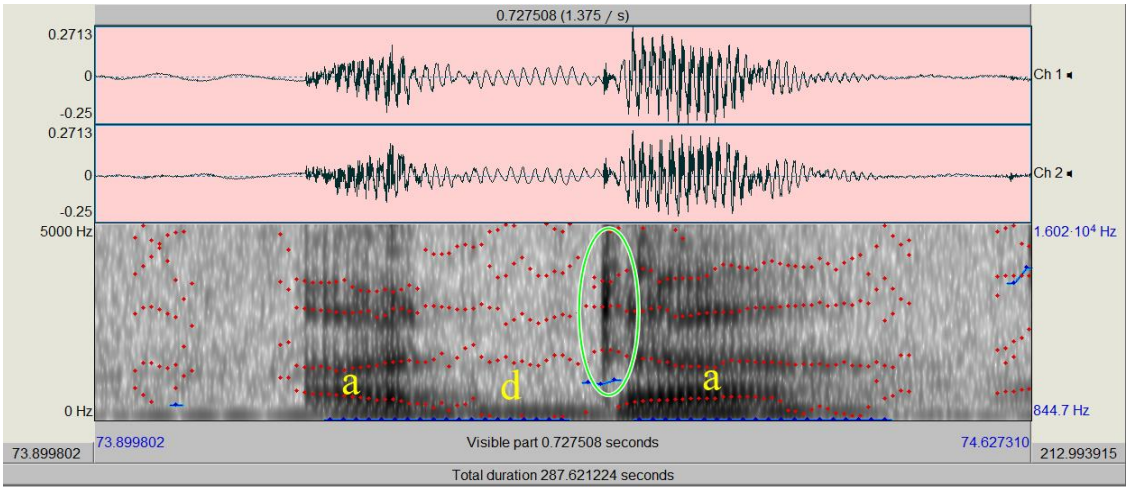

Fig 4 Burst spectrum of alveolar voiced stop /d/

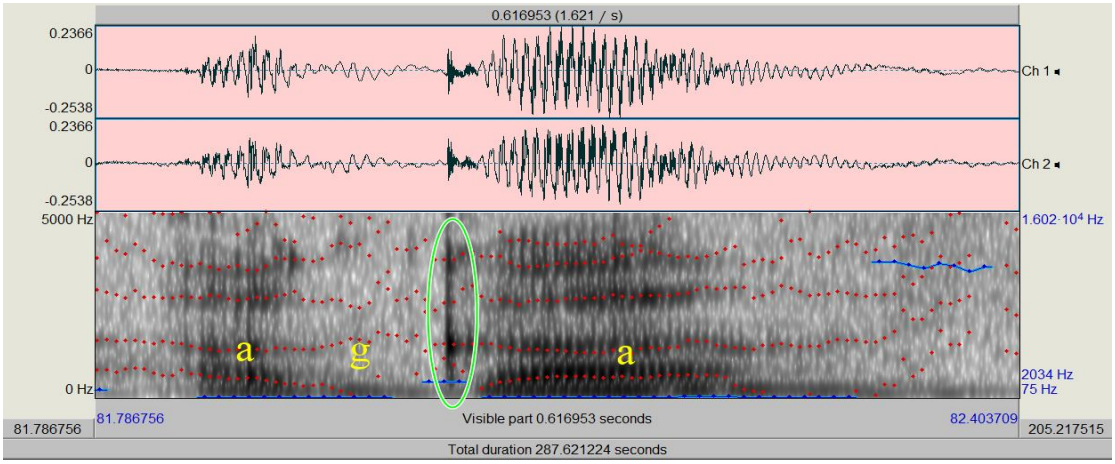

Fig 5 Burst spectrum of velar voiced stop /g/

Table 8
Burst in Dawoodi stops

Stops	Burst Spectrum
Bilabial	Falling
Dental	Rising
Alveolar	Rising (strong)
Velar	Compact

Fig 2 indicates the burst spectrum of bilabial stops, which shows that bilabial burst s falling as it is fainter. Fig 3 shows the burst spectrum for dental which, indicates that burst is rising. Alveolar stops' burst is shown in fig 4, which is also rising. As dental and alveolar stops' burst is rising but there is slight difference. Burst for dental stop is weaker as compared to alveolar which is stronger one. In fig 5, burst spectrum for velar stop is given, which shows that velar stop has compact burst. Burst for Dawoodi stops prove the idea of Stevens & Blumstein (1978).

Fricatives

According to Ladefoged & Johnson, (2014) in fricatives, "close approximation of two articulators so that the airstream is partially obstructed and turbulent airflow is produced" Friction duration along with preceding and following vowels duration are the major acoustic cues to determine the fricatives. Dawoodi language have 8 fricatives, articulated from six different places of articulation including alveolar, post alveolar, retroflex, palatal, velar and glottal.

Table 9
Acoustic cues of Dawoodi fricatives

Fricatives	Friction Duration	V1 Duration	V2 Duration
s	0.147514	0.102188	0.263451
z	0.119791	0.115709	0.295326
ʃ	0.147513	0.102771	0.261875
ʂ	0.142387	0.090188	0.267576
ʃ̬	0.124611	0.125027	0.269045
x	0.154149	0.116168	0.276443
ɣ	0.078608	0.151411	0.293572
h	0.106683	0.116667	0.254499

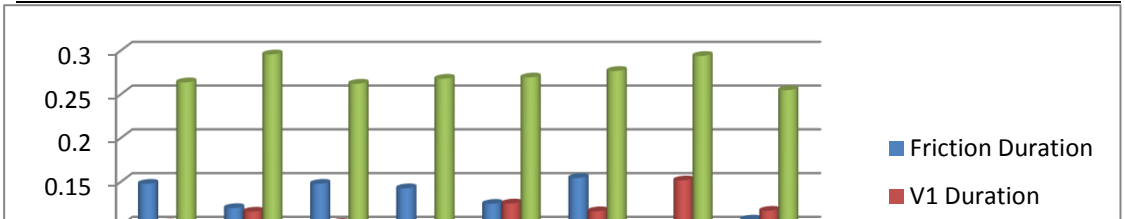

Fig 6 Acoustic contrast of Dawoodi fricatives

The fig 6 shows the friction duration, duration of preceding vowel (hereafter V1) and duration of following vowel (hereafter V2) of eight Dawoodi fricatives. It is observed that velar voiceless fricative /x/ has highest friction duration and its voiced counterpart /ɣ/ has lowest friction duration. Other fricatives lie between velar voiced and voiceless fricatives. Duration of V1 is lowest as compared to V2 duration for all fricatives.

It is observed that friction duration along with V1 and V2 duration are strong acoustic cue for Dawoodi fricatives. Friction duration of voiceless fricatives is higher than voiced fricatives. Vowels follow the same trends for all the fricatives, as V2 duration is higher than V1 duration. Spectrogram of all fricatives clearly show the turbulence noise which indicates that Dawoodi fricatives have strident and non-strident. Dawoodi has five strident including (s, z, ʃ, ʂ and ʃ̡) having strong turbulence noise and three non-strident including (x, ɣ, h) with weak turbulence noise as compare to strident.

Affricates

Affricates are the sounds, having the characteristics of both stops and fricatives as air blockage is like stops and release like fricatives. Acoustically, affricates are measured in terms of closure duration and friction duration. There are seven affricates in Dawoodi articulated from three different places of articulation including, alveolar, post alveolar and palatal. In terms of voicing type, affricates are unaspirated voiceless, aspirated voiceless and unaspirated voiced.

Table 10
Acoustic cues of Dawoodi affricates

Affricates	Closure duration	Friction duration	Total duration
ts	0.08557	0.08932	0.17489
tʃ	0.0921	0.0633	0.1554
tʃʰ	0.0684	0.1092	0.1776
dʒ	0.0674	0.0751	0.1425
tʂ	0.0845	0.0659	0.1504
tʂʰ	0.0825	0.1169	0.1994
dʒ	0.0604	0.0758	0.1362

It is shown that aspirated voiceless affricates have higher total duration and unaspirated voiced affricates have lowest total duration. Friction duration is higher than closure duration in all voiced and aspirated voiceless affricates. Unaspirated voiceless affricates show different trend. Post alveolar and palatal unaspirated voiceless affricates have higher, whereas alveolar unaspirated voiceless affricate has lower closure duration than friction duration.

It is observed that friction duration is higher than closure duration in all voiced, aspirated voiceless and post alveolar voiceless affricates. Total duration is higher in aspirated voiceless affricates and lower in voiced affricates, whereas unaspirated voiceless affricates lie between the two. Moreover, alveolar stop /t/ has highest closure duration and post alveolar /ʃ/ has highest friction duration in isolation as compare to affricates.

Nasals

Nasal sounds involve nasal cavity in the production of sounds along with oral cavity. According to Ladefoged (2001), nasals show a clear sudden change in spectrogram during closure. Moreover, nasals have vowels like formants structure but with some variation as it has dimmer bands than vowels.

The table below shows the formant frequencies of nasals. It is seen that F1 is lowest whereas F3 is higher in all nasal phonemes. F1 is higher in /m/ and lower in /n/, whereas /ɲ/ and /ŋ/ lie between the two. F2 and F3 show the different pattern. /ɲ/ has highest F2 and F3 whereas /ŋ/ has lowest F2 and /n/ has lowest F3.

Table 11
Formant frequencies of Dawoodi nasals

Nasals	F1`	F2	F3
m	381.89790	1666.67232	2777.31092
n	257.94507	1726.75220	2713.81425
ɲ	278.95332	1886.08142	2791.19492
ŋ	262.41837	1523.05603	2750.02707

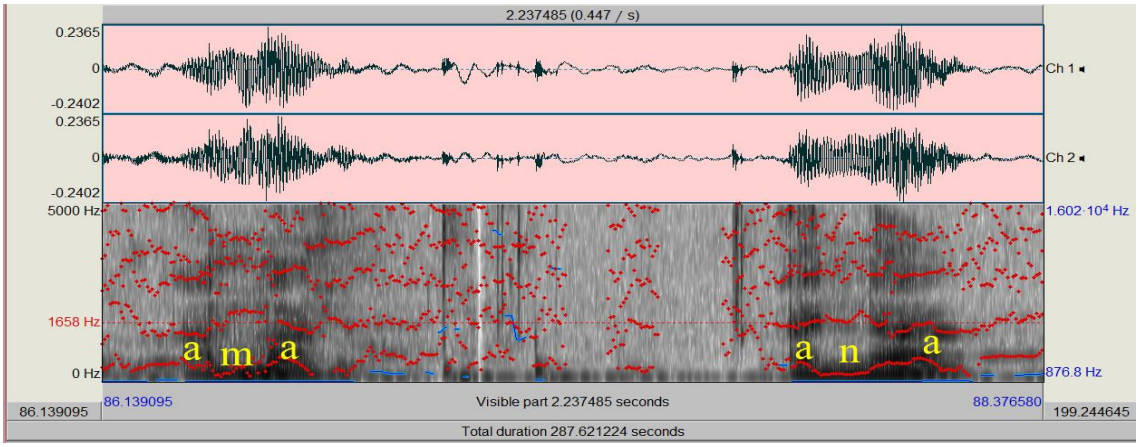

Fig. 7 Spectrogram of /m/ and /n/

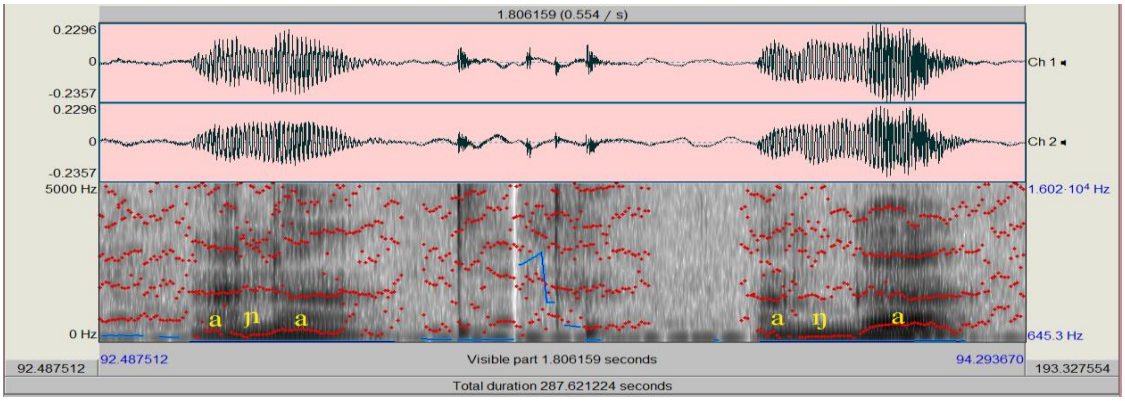

Fig. 8 Spectrogram of /ɲ/ and ŋ/

The figures 7 and 8 show the spectral cues of Dawoodi nasals. It is observed that nasals have vowel like formant structure but dimmer than vowels. Mean F1, F2 and F3 of Dawoodi nasals are 295.3037 Hz, 1700.6405 Hz and 2758.0868 Hz respectively. All the formant frequencies are lower than English as English nasals F1, F2 and F3 are 300 Hz, 2500 Hz and 3250 Hz respectively (Ladefoged, 2001).

Laterals

According to Steven (1998), "the articulation of lateral is such that the air is split due to central contact, as a result, affects the middle and high frequencies; this characteristic differentiates acoustically liquids from vowels or glides". Dawoodi has 2 lateral sounds, alveolar /l/ and retroflex /ɭ/.

Table 12
Formant frequencies of lateral phonemes

Place of articulation	Laterals	F1	F2	F3
Alveolar	l	304.439750	1800.93383	3054.140067
Retroflex	ɭ	278.702483	1857.55963	3014.441034

The table 12 indicates the formant frequencies of the lateral sounds. It is shown that /l/ has highest F1 and F3 whereas /ɭ/ has highest F2. The fig below shows the spectral cues of lateral phonemes. /i/ and /ɭ/ have formant structure like nasals, as formants are like vowels but dimmer than vowels. It is also observed that /ɭ/ has more dimmer formants than /l/.

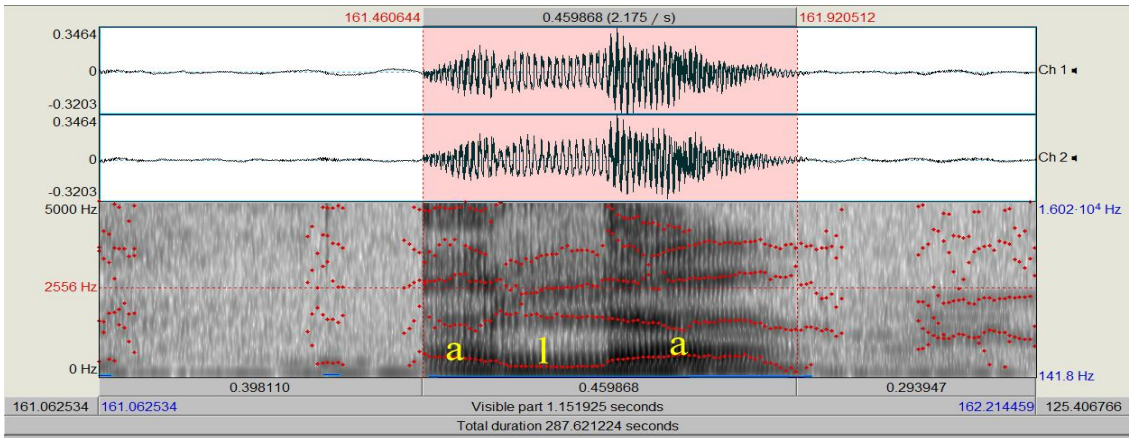

Fig. 9 Spectrogram of Dawoodi lateral sound /l/.

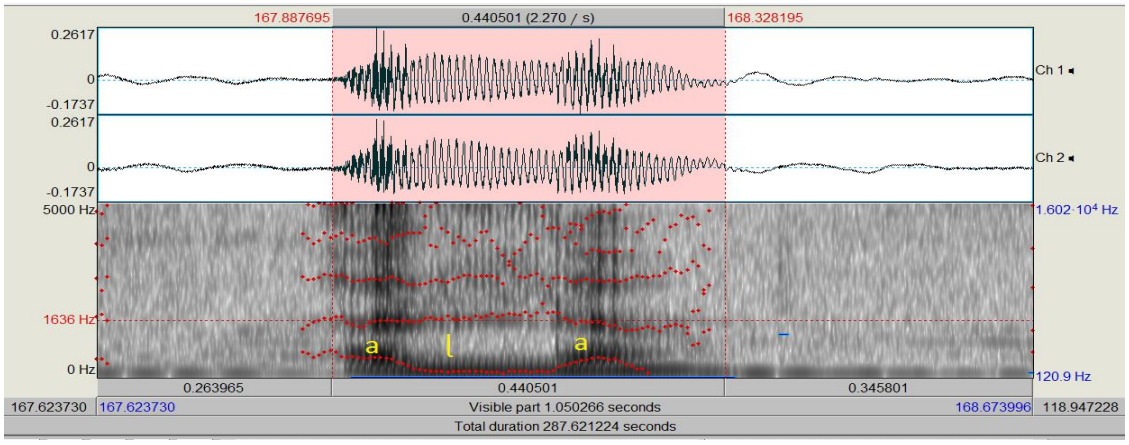

Fig. 10 Spectrogram of /ɭ/

Tap

According to Ladefoged & Johnson (2014), "A tap or a flap is caused by a single contraction of the muscles so that one articulator is thrown against another. It is often just a very rapid stop gesture. In a tap, the tip of the tongue simply moves up to contact the roof of the mouth in the dental or alveolar region, and then moves back to the floor of the mouth along the same path."

Dawoodi has single tap /ɾ/, articulated from alveolar region. The fig below indicates that formants structure is like nasals and lateral but formant frequencies follow the different trends. F1, F2 and F3 of /ɾ/ are 522.40695 Hz, 1696.812583 Hz and 2875.21392 Hz respectively. F1 is higher than laterals but F2 and F3 are lower than laterals. It can be observed that increase in F1 causes decrease in F2 and F3.

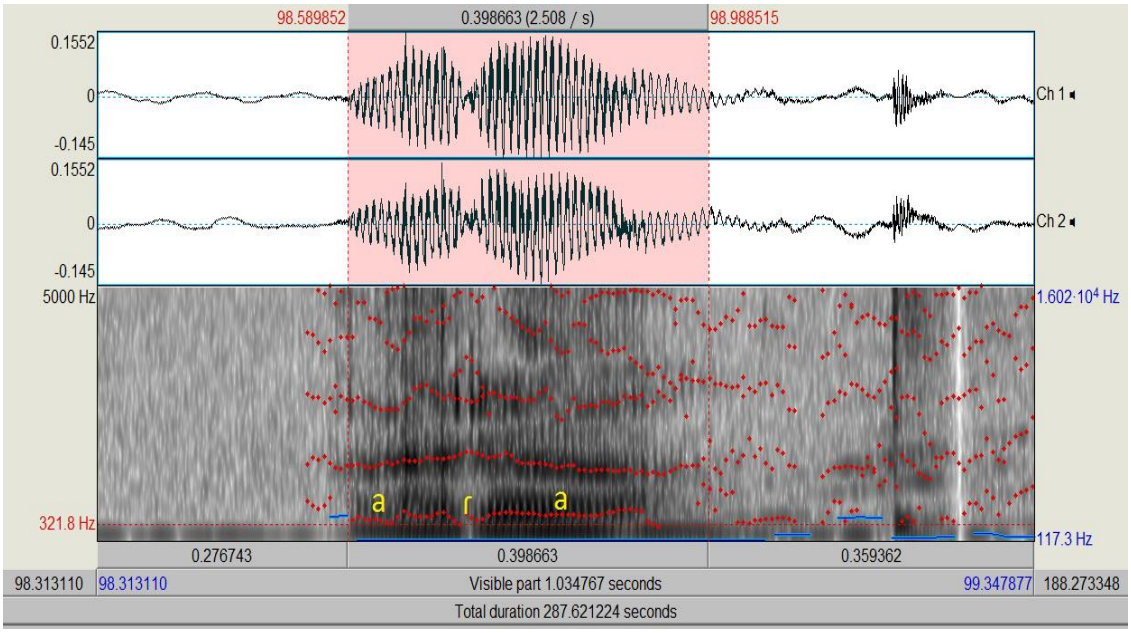

Fig. 11 Spectrogram of /ɾ/

Glides

There are two glides in Dawoodi language, bilabial /w/ and palatal /j/. Both glides are voiced with no voiceless part. The table below shows the formant frequencies of the glides.

Table 13
Formant frequencies of glides

Place of articulation	Glides	F1	F2	F3
Bilabial	w	398.43937	1161.85667	2936.7856
Palatal	j	387.30090	2321.59678	3044.51293

It is observed that F1 is higher in /w/ but F2 and F3 are lower than /j/. Therefore, it proves the idea that increase in F1 decreases the F2 and F3 as discussed above. Fig 1 and 2 show the spectral cues of /w/ and /j/ respectively, which show that formants are like vowels but fainter.

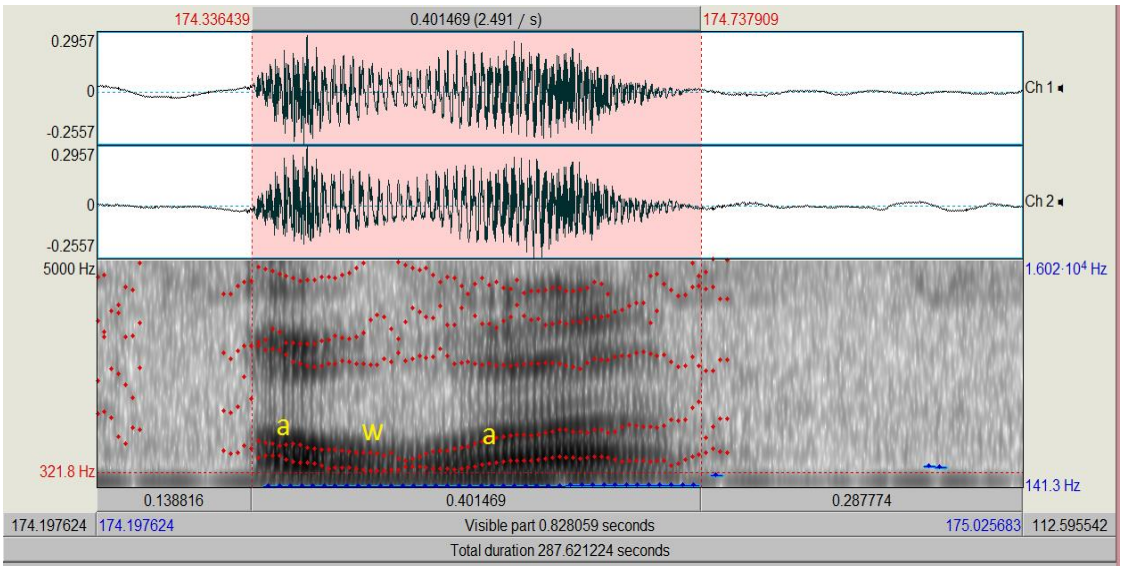

Fig. 12 Spectrogram of /w/

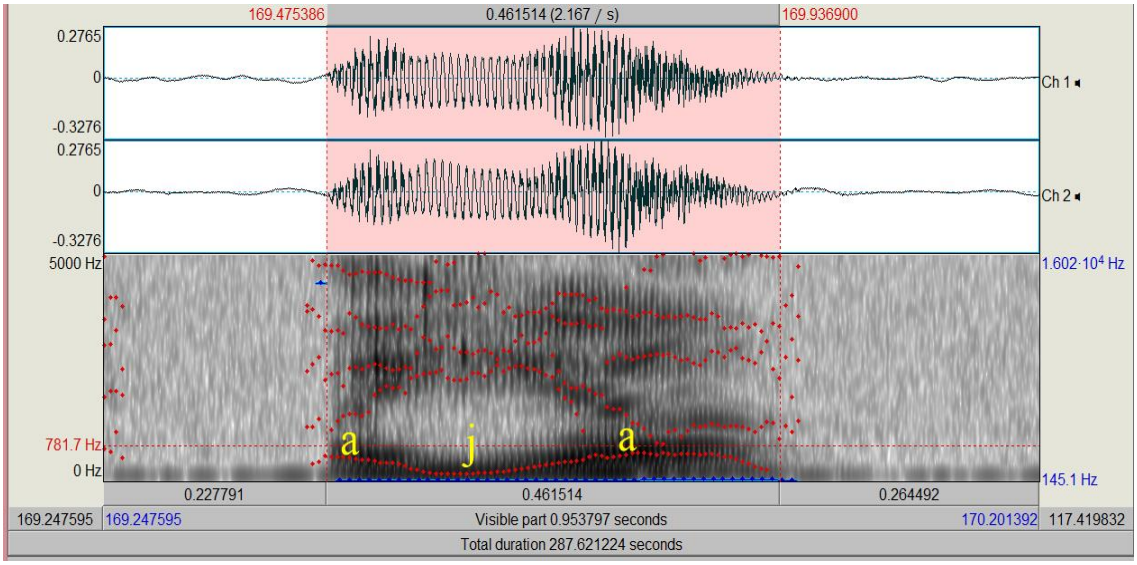

Fig. 13 Spectrogram of /j/

Palatography

Palatography is a process to figure out the speech articulators involved in the production of different sounds. Researcher has done the palatography in order to clarify the place of articulation of some consonants. In this section, palatography of Dawoodi consonants will be discussed.

Results and Discussion

Few Dawoodi consonants are difficult to recognize in terms of place of articulation including /ʈ ɖ t d ʃ/. It involves dental and alveolar stops along with post alveolar fricatives.

It is observed that for the production of /ʈ ɖ/ and tongue position includes tip of the tongue which touches the upper teeth. /t d/ are alveolar as active articulator tongue touches the alveolar ridge. In the articulation of /ʃ/, tongue moves towards palate and it involves half palate and half-alveolar ridge. It reveals that /ʈ ɖ/ are dental, /t d/ are alveolar and /ʃ/ is post alveolar.

Fig. 14 Palatography of /d̪/.

Dawoodi Consonants

- There are 36 consonants segments in Dawoodi, which involve stops, fricatives, affricates, nasal, lateral, tap and glides.
- All consonants have their minimal pairs, which show their meaningfulness.
- All the consonants exist at word initial position except velar nasal. Some consonants exit word final position
- Dawoodi stops and affricates have three way voicing contrast (voiced, voiceless and aspirated voiceless) whereas fricatives have two way voicing contrast (voiced and voiceless).
- VOT, closure duration and burst are the major acoustic cues of Dawoodi stops. Stops are clearly distinguished based on their acoustic cues.
- Friction duration along with V1 and V2 duration are significant cues of fricatives. Friction is higher in Voiceless fricatives and duration of V2 is higher than V1. Turbulence noise is strong in strident.
- Affricates are seven in number. Closure duration, friction duration and total duration are the major cues. Total duration is higher in aspirated voiceless and lower in voiced affricates.
- Nasal, lateral, tap and glides are measure in terms of formant frequencies. They have vowel like formant structures but fainter than vowel.
- Palatography is significant source to clarify the articulation of consonants.

Conclusion

Dawoodi is an Indo-Aryan language, spoken in Hunza and Nagar in Gilgit Baltistan. It is an endangered language having very limited number of speakers. The present study attempted to figure out the acoustic properties of consonants and vowels of Dawoodi language and develop the phonemic inventory based on those acoustic cues.

Consonants are analyzed phonemically and acoustically. Phonemic analysis presents the consonant inventory; minimal pairs, voicing contrast and word level distribution, whereas acoustic analysis presents the acoustic properties of different consonants. It shows that Dawoodi has large-sized consonant inventory having 36 segments articulated from 8 different places of articulation including bilabial, dental, alveolar, post alveolar, retroflex, palatal, velar and glottal. In terms of manner of articulation, consonants are divided into 7 different categories including stops, fricatives, affricates, nasal, lateral, tap and glides. Minimal pairs of all consonants were drawn to determine the meaningfulness of phonemes. Voicing contrast reveals that stops and some affricates (except alveolar /ts/) have three way voicing contrast including voiceless, voiced and aspirated voiceless. Alveolar and velar fricatives have two-way series, voiced and voiceless, whereas post alveolar, retroflex and palatal fricatives have no voiced and glottal fricative has no voiceless counterpart. Word level distribution shows that all consonants do not occur at all three positions of the word. Moreover, palatography is also carried out to clarify the place of articulation of certain sounds.

There are twelve Dawoodi stops having VOT, closure duration and burst as significant acoustic cues. VOT is higher in aspirated voiceless stops and lower in voiced stops, whereas closure duration is higher in unaspirated voiceless stops and lower in voiced stops. Burst is falling in bilabial, rising in dental and alveolar whereas, compact in velar stops. Dawoodi stops show the same trends as other Indo Aryan languages have like Hindko (Rashid, 2015).

There are eight fricatives having friction duration, V1 duration, and V2 duration as significant acoustic cues. Friction duration is higher in voiceless fricatives and lower in voiced fricatives. Duration of V1 is lower than V2 in all fricatives. Strident have higher turbulence noise than non-strident.

Dawoodi language has seven affricates, which are measured in terms of friction duration, closure duration and total duration. Friction duration is higher than closure duration in majority of the fricatives. Total duration is higher in aspirated voiceless and lower in voiced affricates. Nasals, lateral, taps and glides are measured in terms of formant frequencies. They have vowels like formant structures but dimmer than vowels.

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