

Acoustic Investigation of /l, j, v/ as Approximants in Urdu

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Abstract

This presented research work aims to investigate the acoustic properties of /l, j, and v/ in Urdu as approximants. For the acoustic analysis of /l, j, and v/, data has been recorded from 4 native speakers of Urdu (2 males and 2 females) and total 280 utterances of approximants have been recorded at three positions of word i.e word initial, middle and final. Two experiments have been conducted using PRAAT to investigate the acoustic properties of approximants in Urdu; first experiment is based on the spectrogram analysis of approximants and second experiment analyzes the periodicity level of these approximants. The second experiment is conducted by calculating the median of Harmonicity to Noise Ratio (HNR) values of these sounds. The analysis indicates that approximants in Urdu also behave like fricatives. Moreover, this research also explores the controversial issue about the existence of aspirated approximants i.e. /l^h, j^h, v^h/. Results indicate that /j^h/ is no more used by Urdu speakers. Only two aspirated approximants exists in Urdu i.e. /l^h, v^h/.

Keywords: Urdu approximants, fricatives, acoustic measures, median, HNR

1. Introduction

The term “approximant” was first coined by Ladefoged and he defined it as approximants belong to the two phonetic classes; one is resonant oral and second is consonant [1]. He also claims that approximant is an “approach of one articulator towards another but without the vocal tract being narrowed to such an extent that a turbulent airstream is produced” [2]. The second definition is also used by IPA as standard. Approximants have vocal tract which is not as much closed as it is for the consonants and not as

much wide as it is for the vowel but the vocal tract of approximant is in the middle of vowel and consonants. That’s why approximants have both the properties of vowels and consonants.

Trask [3] on the other hand placed approximants in between vowels and fricatives because of the constriction of the airflow and he claims that approximants produce frication noise. However, researchers sometimes disagree and try to find out which segments come under the approximant category [3].

The aim of this research is also to investigate the acoustic properties of /l, j, v, l^h and v^h / as approximants in Urdu language. These sounds are selected in this research because approximants in Urdu do not always behave like semi-vowels. They also appear as fricative in some cases. The motivation behind this research is to find out the contexts where approximants behave like semi-vowels and where approximants turn themselves into fricatives.

The paper is organized as follows: Section 2 overviews different features of approximants that have been researched in different languages, the procedure for carrying out the research is discussed in section 3, results and data analysis of Urdu approximants is given in Section 4. Section 5 illustrates the research findings and finally, conclusion and dimensions for the future work are presented in Section 6.

2. Literature review

IPA [4] categorizes approximants as laterals [l, ɭ, ʎ, ʟ], non-laterals (or centrals) [v, ɹ, ɻ, β] and semi-vowels [j, ɰ, w, ɥ]. [v, β] are “Spirant approximants” or approximant-like versions of voiced fricatives. A special openness diacritic [-] is used to indicate the approximant like version of fricative. Spirant approximant [v] is found in Dutch [3] and it is assumed that the approximant behave as a fricative when it comes at onset and coda position. /j/ with [-] is also

used in Spanish to show the noise or turbulence in the /j/ in emphatic speech [2].

Acoustic measures have been used to analyze the linguistic properties of American English semivowels [5]. Different features such as sonority, consonantal, high, front and retroflex were analyzed and used to distinguish the /l, w, j, r/ from one another. The corpus was consisted of 233 polysyllabic words and collected from 4 speakers (2 males and 2 females). The sonorant property differentiates semivowels from other consonants and retroflex property separates /r/ from /l, j, w/. Formants values differs for each approximant as F3 is weaker for /w, l, r/ and stronger for /j/. F1 differentiates glides /w, j/ from the liquids /l, r/ and F2 value separates /w/ from other semi-vowels as it falls below 1000Hz than others.

Korean language has three approximants [w, j, l] [6]. At word initial position, [l] is deleted when it is followed by [i] or change to [n]. [l] is produced as [r] at the word initial position of loan words and some Korean names. [w] and [j] are glides and mostly come at prevocalic position in Korean language. [w] phoneme shows same vocal tract like [u] vowel when it comes before [ɪ, e, a, ə] and [j] shows the same vocal tract as of [i] when it comes before the vowels [e, a, u, ə, ε, o]. The basic difference among Korean stops, glides and vowels transitory pattern is the duration. The transitory duration of stops is shorter, vowels have longest transitory pattern whereas glides have intermediate transitory duration. F1 and F2 frequencies of [w] are lower than [u], F1 of [j] is lower and F2 is higher as compared to [i]. Korean [r] has very short duration but in this duration, closure and release time period is present. In Korean language, the formant values of approximants are higher in female speakers as compared to the male speakers. Different /w/ variants of Korean have been investigated in [7]. Two variants of /w/ have been explored due to F2 transitions; high back glide [w] with lower F2 and high front glide [ɰ] with higher F2. /w/ is usually fully realized as [w] before [a] and realized as the [ɰ] before [e] but not before [a] for both males and females.

Glides or semi-vowels in Sindhi language have some acoustic vowel characteristics like; formant structure and periodic wave forms [8]. In Sindhi language, Glides [w] and [y] are voiced phonemes and voiced region can also be seen acoustically. Glides show sharp transitory segment. In Sindhi language, /w/ shows periodic signal activity and voicing at the low region of the glide. It is bilabial, F1 moves downward when it approaches to the glide and moves upward when it moves away from the glide. On the other hand, F2 remains unchanged. /y/ is palato-alveolar glide in Sindhi language. It shows energy at lower region of the glide and periodic signals in the spectrogram. It also

shows sharp transitory formant transition. F2 goes upwards when it approaches to the glide and moves downward when it goes away from the glide. On the other hand, F1 motion is vice versa to the F2 motion.

Allophonic variation of /v/ and /w/ has been studied for Hindi in [9]. There is only one grapheme in Devanagari for these two phones. To find out the answers to the queries, 154 words were selected with possible prosodic positions. The speech thus analyzed through the use of speech form editor and lip movement has also been noted for some cases. Through the spectrogram analysis, it has found that /w/ shows lower second formant with lack of friction. Moreover, moraic structure is also considered to describe the syllable structure in these allophones.

Different parameters have been used to analyze the approximants for different languages. However, in case of Urdu approximants very little or unpublished work has been found. Some Urdu approximants have been studied through acoustic analysis but the major challenge was to finalize a proper method that can justify the presence of these approximants in Urdu. So the aim of this research is to explore the existence of /l, j, v, l^h/ and /v^h/ as approximants in Urdu.

3. Methodology

Three Urdu consonant /l, j, v/ have been studied acoustically. These consonants have been selected because of their vowel like formant patterns. Aspirated sounds /l^h/ and /v^h/ have also been studied to find out their existence in Urdu language. In order to analyze the acoustic properties of these consonants, speech data is recorded from 4 speakers (2 males and 2 females). For this study, the data has been collected from only 4 speakers as the time was required to find out the appropriate method to study the Urdu approximants and also less work was found on it.

Data is recorded in an anechoic chamber at the sampling rate of 8 kHz. PRAAT software is used to record and analyze the data. These sounds have been studied at three word positions; initial, middle and final. The selected numbers of utterances for /l, j, v/ are given in Table 1.

Table 1 No of utterances for /l, j, v/ at three positions of word

Phonemes	No. of Utterances		
	Initial	Middle	Final
/l/	10	10	10
/j/	10	10	-
/v/	10	10	-

The utterances have been embedded into the carrier phrase e.g.

1. میں نے ... کہا۔
2. /mã: ne: kəha: /
3. I have said

The above mentioned 70 utterances have been recorded by each speaker so total of 280 utterances have been recorded and analyzed to find out the results. Some instances of /v/ at final position have also been recorded and analyzed. The words were /عضو / /uzv/ /body part / and /جزو / /dʒuzv/ /portion or part/. However, analysis of these utterances indicates that speakers do not pronounce /v/ sound at the end of words.

In Urdu [10] there is direct relationship of word orthography and its pronunciation but still there are some words in Urdu which are not pronounced as they were written specifically in case of /l^h and v^h/. To study the acoustic property of the aspirated /l^h and v^h/, words have been selected from Urdu Lughat [11] and Oxford dictionary [12]. In both dictionaries, there was no instance of /j^h/ and only one instance of /v^h/ has been found. So the selected words for /l^h/ was /دولہا / /d̪u:l^ha: / /Groom/ and /چولہا / /tʃu:l^ha: / /Stove/. For /v^h/ sound, the selected word was /وہیل / /v^he:l / /Whale/. Alternative versions of these words were also found in dictionary; /دولہا / /d̪ulha: / /Groom/, /چولہا / /tʃulha: / /Stove/ and /وہیل / /vhe:l / /Whale/. However, for the recording purposes standard words with /ھ/ were given to the speakers to investigate whether speakers can articulate aspirated versions of approximants or not.

3.1. Acoustic analysis: experiment 1

Five Urdu consonants /l, j, v, l^h and v^h/ are investigated acoustically in this paper to find out their occurrences as approximants or fricatives. All of the selected consonants are analyzed at three word positions; initial, middle and final. Along with the study of formant like patterns or frication noise in sounds, other acoustic cues durations and formant transitions are also used to differentiate among these sounds. See Section 4 Table 2 and 3 for the results of acoustic analysis.

3.2. HNR analysis: experiment 2

The selected sounds are also tested through calculating the median of HNR values of /l, j and v/ utterances. HNR measures the replacement of harmonic structure in spectrogram by the frication noise [13]. The method for harmonicity median is described in [14] that measures the acoustic periodicity. In this research, HNR values have been

calculated using PRAAT. For calculating the HNR median, the number of frames of each sound utterance and their values were extracted from PRAAT query after analyzing the periodicity. Afterward, the values are calculated to find out median of the sound. See Appendix A for the median values.

4. Results and data analysis

This session is subdivided into two sub-sections i.e. experiment 1 results and experiment 2 results along with their analysis.

4.1. Experiment 1 results and data analysis

Table 2 Duration values of /l, j, v/

Urdu phonemes	Duration at word initially with pause	Duration at word medially	Duration at word finally with pause
/l/	105ms	78ms	118ms
/j/	93ms	65ms	-
/v/	70ms	56ms	-

Table 3 Formant values of /l, j, v/

Urdu phonemes	Formant values word initial		Formant values word medial		Formant values word final	
	F1	F2	F1	F2	F1	F2
/l/	292	1584	325	1584	295	1592
/j/	311	1830	306	1867	-	-
/v/	290	1212	324	1289	-	-

Acoustically, /l/ sound takes formants and exists at all three word positions; initial, middle and final. When /l/ occurs at word initial position with pause, its duration increases up to 27ms than its word medial position version. No transition is found in succeeded vowel and formants remain stable but lighter than the succeeded vowel. Formant values for /l/ at three positions are given in Table 3. At word medial position, the duration of /l/ decreases that is described in Table 2. Formants become lighter at word medial position. At word final level with pause, /l/ duration increases up to 40ms than its word middle position. /l/ forms light formants but sometimes takes light frication with formants and voicing at the base level. Figure 1 presents /l/ at middle position.

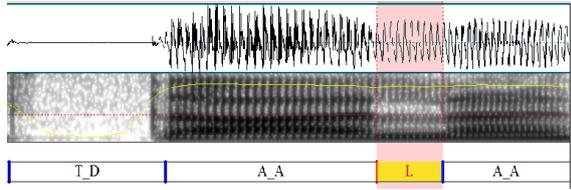


Figure 1: /l/ at middle position

In Urdu, /j/ occurs at only two positions; word initially and medially. /j/ behaves differently in different contexts. At word initial with pause position, /j/ behaves in three ways (i) vowel like (ii) fricative like and (iii) both vowel and fricative like. The average duration of /j/ increases at word initial level up to 28ms. After acoustic analysis, it has been observed that the dual characteristic of /j/ is only the part of speaker (Sp) utterances. It is also found out that its duration value is more than the other values and reaches up to 132ms. Figure 2 presents the dual property of /j/ at initial position with preceded pause.

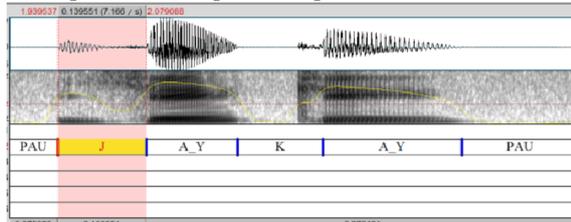


Figure 2 Dual property of /j/

It is difficult to analyze when /j/ comes medially, it sometimes takes frication and sometimes takes formants. This phenomenon is tested by experiment 2 and described in detail in section 4.2. When /j/ comes between two vowels, it gets merged with the vowel. However, in this context intensity helps a lot as a slight decrease in intensity indicates the presence of /j/ e.g. in /کجا/ /kija:/ /Did/ or /آیا/ /a:ja:/ /Come/. Table 3 indicates that /j/ has higher F2 values than other sounds.

When /v/ comes at initial position, its duration increases up to 14 ms than its middle position and it can take the property of a fricative or semi-vowel. /v/ forms light formants and sometimes it has only frication. At middle position, F2 of the preceding vowel falls whereas F3 remains same. This behavior of medial /v/ has also found across the speakers which might be an indication of occurrence of /v/ as retroflex in Urdu. /v/ at final position has been analyzed and found out that speakers have not pronounced /v/ at this position. The F2 value of /v/ is also significant that is lower than all other sounds and differentiates its property from others.

The data from the speakers has been analyzed and found out that /l^h/ is not pronounced in word /دولہا/

/دولہا:/ /Groom/. Instead of pronouncing /l^h/, speakers have pronounced /l/ and /h/ separately as /دولہا:/ /دولہا/. Other selected aspirated word was /وہیل:/ /Whale/ and it is observed that speakers has pronounced it as /وہیل:/ /Whale/ without the aspirated sound. The speakers have changed the aspirated /v^h/ into un-aspirated /v/. In Urdu, /ہ/ /do chasmi hey/ is used to represent the aspiration of a sound [10]. However, it is observed that in Urdu Lughat [11] and Oxford dictionary [12] words like /چولہا، دولہا، چولہا/ are also written as /چولہا، دولہا، وپیل، / . The alternative orthographies of such words shows that /l^h/ is gradually replacing with /l+h/ sounds and /v^h/ with its un-aspirated version /v/.

4.2. Experiment 2 results and data analysis

The findings from acoustic analysis are then tested by experiment 2 and try to answer the expected queries. Different behaviors of /l, j, and v/ have been tested in all selected positions and generate a table to show the occurrence of these sounds as approximant or fricative in percentages.

Table 4 Acoustic behavior of /l, j, v/ across speakers

No. of Sp	Positions	Approximant (%)	Fricative (%)	Mixed (%)
Sp1 (F)	/l/ initial	70	30	-
	/l/ medial	90	10	-
	/l/ final	100	-	-
	/j/ initial	20	20	60
	/j/medial	50	50	-
	/v/ initial	60	40	-
Sp2 (F)	/l/ medial	70	30	-
	/l/ final	100	-	-
	/j/ initial	100	-	-
	/j/medial	100	-	-
	/v/ initial	60	40	-
	/v/ medial	90	10	-
Sp3 (M)	/l/ initial	100	-	-
	/l/ medial	80	20	-
	/l/ final	100	-	-
	/j/ initial	100	-	-
	/j/medial	100	-	-
	/v/ initial	80	-	20
	/v/ medial	90	10	-
	/v/ final	100	-	-
Sp4 (M)	/l/ initial	90	10	-
	/l/ medial	100	-	-
	/l/ final	80	20	-
	/j/ initial	60	40	-
	/j/medial	100	-	-
	/v/ initial	50	50	-
/v/ medial	100	-	-	

Table 4 describes the percentages for approximant, fricative and mix property that have been discussed for /j/ sound. The results have been given for each speaker in which the first 2 are females and last 2 are males.

/l/ at initial position is approximant in all speakers, only in speaker1 it is 30% fricative as it sometimes takes frication at start which causes less periodicity in /l/. At medial position, there were 2 utterances of speaker 3 and one utterance of speaker1 in which /l/ was found fricative. At final position, only 2 utterances of speaker 4 were found in which the /l/ was fricative.

In speaker 1, different behavior of /j/ has been observed at initial level. At this level, /j/ had dual behavior of approximant and fricative which is tested by the experiment and found out that there were 6 utterances of Sp1 in which /j/ had the dual property. However, it was observed that this feature was only the part of Sp1 utterances and Sp 1 was taking this feature with preceded pause in stress syllable. In Sp3 /j/ is 100% approximant. At medial position, there is equal tendency of approximant and fricative in Sp1 but in other speakers /j/ is 100% approximant. So, only sp1 is creating a slight disagreement with other speakers as it is showing very independent behavior.

There is tendency of /v/ to occur as either fricative or approximant at word initial position. There were 2 utterances in Sp3 that shown dual property (approximant and fricative) in /v/ at word initial position. At word medial position, /v/ is 30% fricative in Sp1 only and for other speakers' utterances it is more approximant like.

Through the experiment 2, median of HNR values have been calculated for each utterance. After the experiment conducted for all 4, it was observed that the threshold for the median values of HNR were different for males and females. For females, the value for voiceless fricatives was less than 3dB and the value for voiced fricative was reached up to 17dB. So the value more than 17dB was indicating that the consonant is more vowel like as the vowel values were starting from this range. However, the threshold for males was totally different. The value for voiced fricative was starting from 3dB and the vowels values were starting from 10dB. So, the value for a consonant at 10dB or above was indicating the occurrence of consonant as approximant.

Figure 3 describes the /l/ initial median values of 10 utterances for each speaker. The different line colors show different speakers. The graph shows a gradual increase in Sp3 behavior that is above 10dB indicating 100% approximant behavior but the behavior in Sp4 is very abrupt going from voiced fricative to approximant and reaches up to highest range of 20dB. The graph lines for Sp1 and 2 show some utterances below 20dB as fricatives.

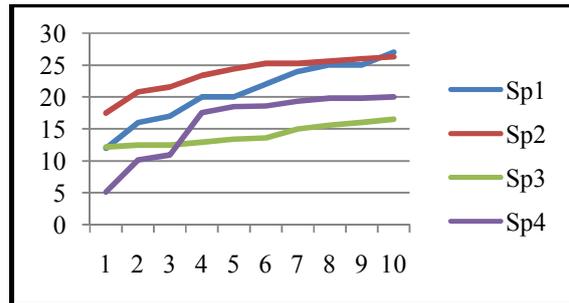


Figure 3 Median graph for /l/ initial position

Figure 4 describes median values of /l/ at medial position. The graph describes 10 utterances for each speaker. It represents some utterances of Sp1 and Sp3 which have fricative property. It is observed through the analysis that /l/ takes fricative property in such cases due to the presence of other fricatives in its surrounding.

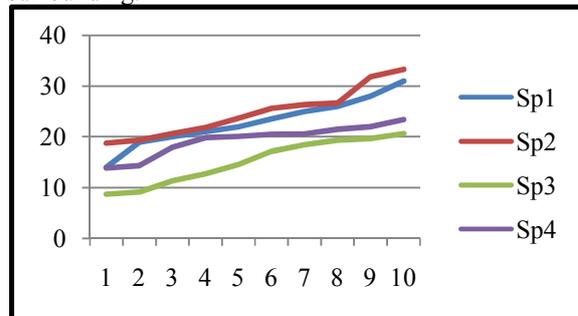


Figure 4 Median graph for /l/ medial position

Figure 5 describes the median values for /l/ at word final position. Graph presents that the lines of Sp3 and 4 are merging at the end as they are sharing same values. The figure indicates that only in Sp4, /l/ has fricative part and in all others the /l/ is 100% approximant. Only two utterances of Sp4 are fricative like because they occurred with following pause in the data which is actually the main cause of less periodicity in these two utterances. The lines show very smooth transition in the graph as the reason might be the values are less fricative.

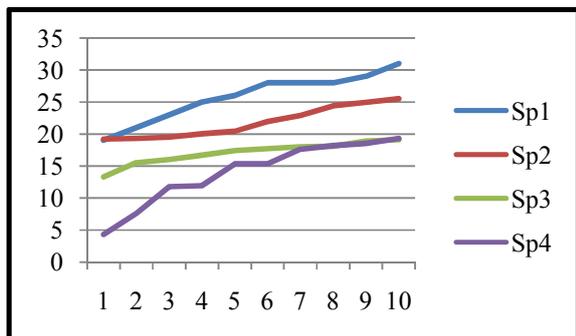


Figure 5 Median graph for /l/ final position

Figure 6 represents the median values for /j/ at initial position. The figure represents only 3 speakers excluding Sp1. The reason is clear from the above described table that /j/ at initial position in Sp1 was showing dual behavior of approximant and a fricative at the same time. It is significant that in Sp3 the graph line is very gradual going above 10dB showing 100% approximant behavior. According to the graph, some utterances of /j/ have fricative like property which is context dependent as in some cases /j/ differentiated itself from high vowels /i:, e: and u:/ by taking fricative property.

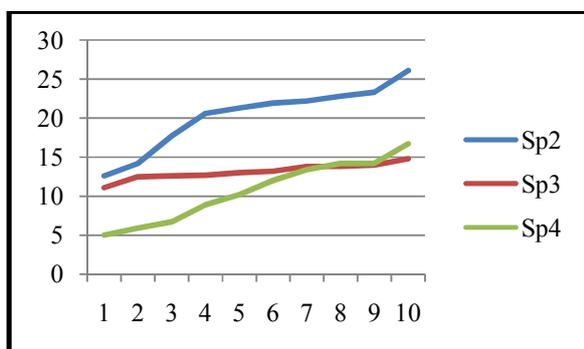


Figure 6 Median graph for /j/ initial position

Figure 7 describes median values for /j/ at medial position. The three graph lines for Sp2, 3 and 4 show behavior of /j/ as approximant at medial position. The graph shows that the values for Sp2 and 4 are significantly high than the other ones. The impact of stress has also been seen in Sp4 utterances, as the values of median are very high due to stress. Sp 1 again shows a slight discrepancy than others in the graph as it takes both behaviors with same ratio.

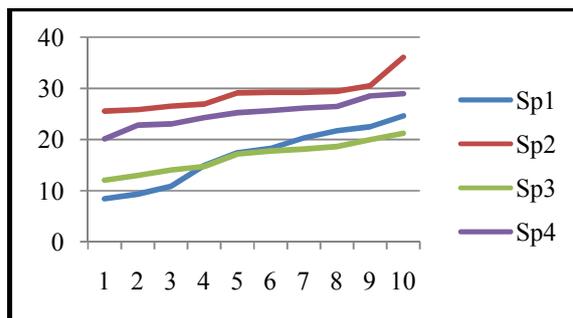


Figure 7 Median graph for /j/ medial position

Figure 8 illustrates the median values of /v/ at initial position. The graph line for Sp3 has stopped at 8th utterance because of the reason that 2 utterances of the Sp3 were having the mix property like /j/ initial. But except those 2, the behavior of /v/ is approximant like in Sp3. /v/ at initial position is both fricative and approximant in other speakers. The fricative behavior of /v/ utterances is also due to the impact of neighboring fricatives on /v/ sound.

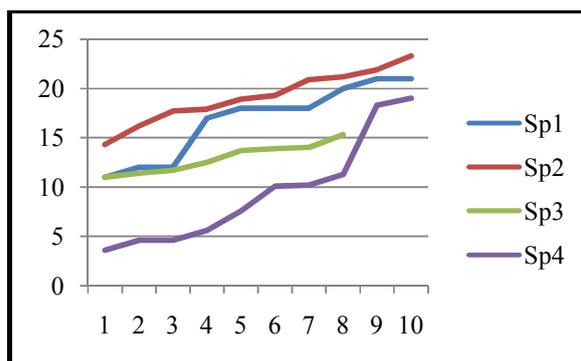


Figure 8 Median graph for /v/ initial position

Figure 9 describes /v/ at medial position. A sharp decrease at utterance 1 below 0 for Sp 2 is due to the devoiced fricative value of /v/ at medial position. Except the 1st utterance of Sp2, other values show approximant behavior of /v/. Similarly, Sp1 and 3 has some fricative values but Sp4 shows more gradual behavior above 10dB of /v/ medial as approximant. The median values at each position are also given in Appendix A.

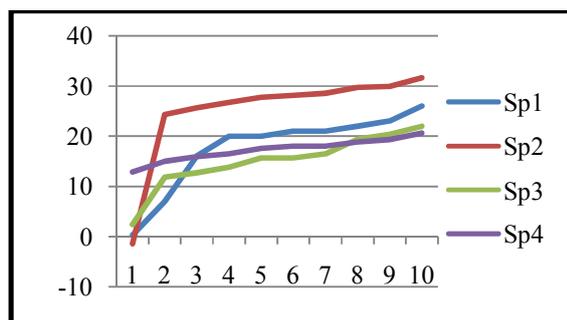


Figure 9 Median graph for /v/ medial position

5. Research Findings

Different behaviors have been observed through the acoustic and HNR analysis of /l, j and v/ in Urdu across speakers. Some features were very speaker specific. The dual property of /j/ at initial level has been observed in only Sp1. It is observed that this property in Sp1 occurs in /j/ initial when it comes with preceded pause specifically when it is stressed. It is also observed when /j/ comes with high vowels like /i:/, /e:/ or /u:/, it takes acoustic property of fricative to differentiate itself from high vowels. Similarly, when /j/ comes with /a:/ sound in unstressed context it becomes approximant. It is also observed that sometimes /j/ take frication because of its neighboring fricative consonant.

It is observed that the variations in the behavior of /l, j and v/ are speaker dependent. It is observed that the speaker 4 is using the fricative quality in case of unstressed context and in stressed context; it is using more approximant like property. The variation of /l/ as fricative has also been observed in speakers. /l/ takes frication when it is followed by a pause, which reduces the periodicity level in /l/. It is also observed that /l/ changes its acoustic property or lose formants when it comes with any fricative sound i.e. /h, x, s/ etc.

The analysis of /v/ reports that /v/ behaves like approximant when it comes at word medial position. However, there are some exceptions to this generalization as in the first utterances of Sp2 and 3; /v/ became voiceless fricative due to neighboring /h/ sound and /r/ respectively indicating neighboring fricatives can influence target sound.

6. Conclusion and future dimensions

/l, l^h, j, v and v^h/ sounds of Urdu have been investigated in this study to find out their acoustic properties as approximants. Two types of experiments have been conducted which report that /l, j and v/ can exist in Urdu both as an approximant and a fricative,

although the percentage of approximant behavior is more than the fricative behavior. Analysis also indicates that different variations in these sounds are speaker dependent. Moreover, acoustic analysis indicates that /l/ shows longest duration at final position than others and /v/ shows lowest F2 values than others. Aspirated version of /l/ and /v/ is also studied in this research. Results tells that /l^h/ is now pronounced as /l and h/ and /v^h/ is mostly changed into its un-aspirated version by the speakers. There are other sounds in Urdu inventory like /r/ and /r̥/ and their aspirated versions which are claimed to have approximant like behavior. In future, acoustic properties of these sounds would be analyzed using scientific methods.

7. References

- [1] P. Ladefoged, *A Course in Phonetics*, 4th ed., Bill Hoffman, Ed. California, Los Angeles, USA: Earl McPeck, 1975.
- [2] E. Martinez-Celdran, "Problems in the classification of approximants," *Journal of the International Phonetic*, vol. 34, no. 2, pp. 201-210, Dec 2004.
- [3] I. E. Colombo, *On the Phonetic Status of Labial Approximants in Dutch*. University of Amsterdam, 2015.
- [4] International Phonetic Association, *Handbook of the International Phonetic Association: A guide to the use of the International Phonetic Alphabet*. Cambridge, United Kingdom: Cambridge University Press, 1999.
- [5] C. Y and E. Wilso, "Acoustic measures for linguistic features distinguishing the semivowels /w j r l/ in American English," *The Journal of Acoustical Society of America*, vol.92, no.2, pp. 736-757, August 1992.
- [6] M. C. Kim and A. J. Lotto, "Acoustic measurements of Korean approximants," *The Korean language in America*, vol.9, pp. 72-77, 2004.
- [7] M. Oh, "/W/ Variants in Korean," *Journal of the Korean society of speech sciences*, vol. 2, no. 3, pp. 65-73, 2010.
- [8] A. Keerio, L. D. Dhomeja, A. A. Shaikh, and Y. A. Malkani, "Coparative Analysis of Vowels, diphthongs and Glides of Sindhi," *Signal and Image Processing*, vol. 2, no. 4, December 2011.
- [9] J. Pierrehumbert and R. Nair, "Implication of Hindi Prosodic Structure," in *Current Trends in Phonology: Models and methods (= Proceedings of the Royaumont meeting 1995)*, University of Salford Press, pp. 549-584.
- [10] S. Hussain, "Letter-to-sound conversion for Urdu text-to-speech system," in *Association of Computational Linguistics*, Geneva, Switzerland, 2004, pp. 74-79.
- [11] *Urdu Lughat: Tarixi Usul Per*, 1st ed. Karachi, Pakistan: Muheet Urdu Press, 2013, vol. 3.

- [12] *Oxford Urdu-English Dictionary*, 1st ed. Karachi, Pakistan: Oxford University Press, 2013.
- [13] Z. Bárkányi and Z. Kiss, "Is /v/ different?," in *Proc. Twenty years of theoretical linguistics in Budapest 25.*, Budapest, 2010, pp. 1-5.
- [14] S. Hamann and A. Sennema, "Acoustic differences between German and Dutch labiodentals," in *ZAS Papers in Linguistics 42*, Berlin, 2005, pp. 33-41.

Appendix A

Table 1 Median values for /l/ initial position

Sp1	Sp2	Sp3	Sp4
12	17.5	12.19	5.1
16	20.8	12.5	10.1
17	21.6	12.5	10.9
20	23.4	12.9	17.5
20	24.4	13.4	18.5
22	25.3	13.6	18.6
24	25.3	15	19.3
25	25.6	15.6	19.8
25	26	16	19.8
27	26.3	16.5	20

Table 2 Median values for /l/ medial position

Sp1	Sp2	Sp3	Sp4
14	18.7	8.7	13.8
19	19.3	9.1	14.3
20	20.6	11.3	17.9
21	21.8	12.7	19.8
22	23.6	14.5	20.1
23.5	25.6	17.1	20.5
25	26.3	18.4	20.6
26	26.6	19.3	21.5
28	31.8	19.6	22
31	33.3	20.6	23.4

Table 4 Median values for /l/ final position

Sp1	Sp2	Sp3	Sp4
19	19.2	13.3	4.3
21	19.3	15.5	7.6
23	19.5	16	11.8
25	20	16.7	11.9
26	20.4	17.4	15.3
28	21.9	17.7	15.3
28	22.9	18	17.6
28	24.4	18.1	18.2
29	24.9	18.9	18.5
31	25.5	19.1	19.3

Table 4 Median values for /j/ initial position

Sp2	Sp3	Sp4
12.6	11.1	5
14.2	12.5	5.9
17.7	12.6	6.7
20.6	12.7	8.9
21.3	13	10.2
21.9	13.2	12
22.2	13.8	13.4
22.8	13.8	14.2
23.3	14	14.2
26.1	14.8	16.7

Table 5 Median values for /j/ medial position

Sp1	Sp2	Sp3	Sp4
8.4	25.5	12	20.1
9.3	25.8	12.9	22.8
10.8	26.5	14	23
14.9	26.9	14.7	24.2
17.4	29.1	17.1	25.2
18.2	29.2	17.7	25.6
20.3	29.2	18.1	26.1
21.7	29.4	18.6	26.4
22.5	30.5	19.9	28.5
24.6	36	21.2	28.9

Table 6 Median values for /v/ initial position

Sp1	Sp2	Sp3	Sp4
11	14.3	11	3.6
12	16.2	11.4	4.6
12	17.7	11.7	4.6
17	17.9	12.5	5.6
18	18.9	13.7	7.6
18	19.3	13.9	10.1
18	20.9	14	10.2
20	21.2	15.3	11.3
21	21.9	-	18.3
21	23.3	-	19

Table 6 Median values for /v/ initial position

Sp1	Sp2	Sp3	Sp4
0.3	-1.4	2.4	12.9
7	24.3	11.8	15
16	25.6	12.7	15.9
20	26.7	13.8	16.5
20	27.7	15.7	17.6
21	28.1	15.7	18
21	28.5	16.5	18
22	29.7	19.4	18.8
23	29.9	20.4	19.3
26	31.6	22	20.6