ASPIRATED APPROXIMENTS IN URDU

SULEMAN MAZHAR

ABSTRACT

Urdu is a South Asian language. Like other South Asian languages, its inventory has many aspirated sounds. Aspirated approximants are rare in world languages and their existence in Urdu is therefore controversial. This paper investigates the existence of aspirated approximants in Urdu and concludes that they are not found in Urdu now.

1. INTRODUCTION

Aspirated stops are common in South Asian languages. Clark and Yallop (1990, pp91) have reported voiced aspirated plosives in Hindi and Gujrati. But aspirated approximants and fricatives are rare in the inventory of world languages. Clark and Yallop (1990, pp91) report a voiceless aspirated fricative /ʃ/ in Burmese. Masica also reports aspirated approximants /lʰ/, /wʰ/, and /jʰ/ in Marathi, a language spoken in South Asia (1991, pp. 104).

Urdu is another South Asian language that is reported to have aspirated approximants. But this claim is controversial to say the least. This paper reports the results of investigation carried out for existence of aspirated approximants in Urdu. F1/F2 intensity ratio was analyzed as an acoustic cue of aspirated approximants. The results indicate no acoustic evidence of the aspirated approximants.

2. PROBLEM STATEMENT

The paper investigates the existence of aspirated approximants in Urdu language. Approximants considered are /j/, /l/, /w/, /r/ (trill) and /ɽ/ (retroflex).

3. LITERATURE REVIEW

Urdu distinguishes between aspirated and non-aspirated consonants. Aspirated sounds are known as /məhaprɑn/ مہاپران (heavy sounds) and non-aspirated as /əlpprɑn/ الپ پران (light sounds) (Bukhari, 1988. pp. 79).

Following are Urdu's evident aspirated sounds

ڈھ دھ چھ جھ کھ گھ ٹھ تھ پھ بھ

/dʰ/ /ɖʰ/ /ʃtʰ/ /dʒʰ/ /kʰ/ /gʰ/ /tʰ/ /ʈʰ/ /pʰ/ /bʰ/

Following controversial aspirated continuants are also reported in Urdu.

ڑھ رھ لھ نھ مھ

/ɽʰ/ /rʰ/ /lʰ/ /nʰ/ /mʰ/

Literature on Urdu phonology throws very little light on occurrence or distribution of aspirated approximants in the inventory of Urdu. There is controversy on their very existence. Some authors believe that they exist in the language but others say that they might have existed in old Urdu but nowadays their use has vanished.

Khan points out existence of aspirated approximants /lʰ/, /ɽh/ and /rʰ/ in Urdu. He mentions some words, which are believed to have aspirated /l/, /r/ and /ɽ/. According to him following words /sərʰɑnɑ/ (pillow), /bɑrʰvĩ/ (twelfth) contain aspirated /r/ (1997, pp. 102). He also points out that /ɽ/ is aspirated in the following words /sɑɽʰɪ/ (an Indian dress for ladies), /buɽʰɑ/ (old man) (1997, pp. 104). Likewise he gives /kolʰu/(oil expeller), /kʊlʰɑɽɪ/ (axe) for aspirated /l/ (1997, pp. 112). As far as aspirated /j/ and /w/ are concerned, he believes that they are not found in present day Urdu but they might have existed in older versions of Urdu as Insha has included them in Urdu inventory. Khan argues that words like /vəhɑ̃/(there), /sehɑrɑ/ (support) and /jəhɑ̃/ (here) were spoken as /vʰa/, /sʰɑrɑ/ and /jʰɑ̃/ in old Urdu because they

are also transcribed as /vɑ/ and /jã/(1997, pp126).

Urdu has several dialects and one of them is Dakkani, which is spoken in Hydrabad Dakkan, India. Qadri gives a good discussion of Dakkani dialect of Urdu in his book. He has included aspirated lateral, flap and trill in Dakkani Urdu (1930, pp. 64). He also includes aspirated labio-dental fricative /v/ in Urdu inventory. He has given words /lʰær/ (wave), /lʰəvɑ/ (iron) for aspirated lateral /lʰ/(1930, pp. 91). According to Qadri trill is not found independently in Urdu and has no separate symbol. It exists in words like /pərʰezgɑrɪ/ (piety), /rʰəmət/ (blessing) (1930, pp. 92). Likewise /ɽʰ/ is found in /pəɽʰ/ (read), and /gərʰ/ (fort) according to Qadri (1930, pp. 94).

Haqi has pointed out aspirated /lʰ/ (1995, pp. 826), /rʰ/ (1995, pp. 586) and /ɽʰ/ (1995, pp. 587) In his dictionary and has given a list of words in which they occur. He also gives three words in which /lʰ/ comes at initial position. These are /lʰəsən/ (garlic), /lʰəsuɽɑ/ and /lʰəs.sɪ/. But he regards these as nonstandard pronunciations.

It is reported that /r/, /ɽl/ and /l/ are aspirated before /h/ written as (ھ) called /ɖɑu ʃtəʃmi hɑ/ (two eye /hɑ/) and are not aspirated before /h/ written as (ہ) called /jək ʃtəʃmi hɑ/ (single eye /hɑ/) in writing (Haqi, 1995, pp. 963). But unfortunately this practice is not consistent in the literature. Many books do not care for this convention and use both versions of /hɑ/ interchangeably.

Qadri observes the existence of aspirated voiced labio-dental fricative /vʰ/ in words like /vʰɑ̃/ (there) and /vʰɪ̃/ (there). But he does not include /w/ and /wʰ/ in Urdu inventory. Khan also holds the opinion that /w/ does not exist in Urdu (1997, pp115). However /wʰ/ was also considered in the analysis done for aspirated approximants because English word /wʰæl/ (whale fish) is commonly use in Urdu. Its aspirated nature is not sure and is reported to change to labio-dental fricative when used in Urdu. Some people do not accept it as pure Urdu word but since it is in common use both in writing and speech, therefore its status, as an Urdu word cannot be ignored.

Due to such uncertainties about aspirated approximants in Urdu, few rules are found that explain distribution of aspirated approximants in Urdu. Khan, however, points out some language constraints on the occurrence of aspirated approximants, which are: -

1. Aspirated trill /rʰ/ does not exist word finally and word initially. It exists word medially (Khan, 1997, pp.102). But no rule is given that defines its appearance word medially as compared with non-aspirated trill /r/.

2. Aspirated flap /ɽʰ/ does not exist word initially. It is frequently found word finally and medially (Khan, 1997, pp.102). But again no rule is defined to govern its distribution versus non-aspirated flap /ɽ/.

3. Aspirated lateral /lʰ/ exists only word medially (Khan, 1997, pp112). But now this use is also vanishing e.g. /du.lʰən/ (bride) is spoken as /dʊl.hən/ by majority of speakers.

4. Khan denies existence of /w/ and /wʰ/in Urdu (1997, pp.115). He also denies the existence of aspirated approximant /jʰ/ (1997,pp.126).

Qadri gives some rules for appearance of aspirated approximants, which are: -

1. Word finally /l/ changes to /lʰ/ when followed by a syllable beginning with an /h/ e.g. /kəl#hi/ > /kəlʰi/ (only yesterday). Secondly whenever /l/ occurs in distribution /V_h/ where V is a vowel, it changes to aspirated /lʰ/ e.g. /ləhr/ > /lʰær/ (wave) and /lohɑ/ > /lʰəvɑ/ (iron) (1930, pp. 91).
2. Similarly trill /r/ is pronounced /rʰ/ when /r/ occurs in V_h distribution. Here original /h/ is disappeared and l is aspirated e.g. /rəhnɑ/ > /rʰənɑ/ (to stay) (1930, pp. 92).

3. Aspirated retroflex flap /ɽʰ/ is found word medially. In final position it is changed to non-aspirated counterpart e.g. /pəɽʰ/ >

/pəɽ/ (read) although it is written with ے. It does not occur word initially (1930, pp. 94).

Obviously these rules also do not explain fully the occurrence of aspirated approximants.

As far as the acoustic cue for aspirated approximants is concerned, it is reported that F1/F2 intensity ratio for aspirated approximants is greater than F1/F2 intensity ratio of non-aspirated counterparts. Intensity of high frequencies decreases due to aspiration. However the ratio of F1/F2 intensity for aspirated approximants in Urdu is not known.

4. METHODOLOGY

4.1 Speakers

In order to investigate the existence of aspirated approximants in Urdu, four native speakers of Urdu were recorded. Urdu has many dialects and great variation exists from one dialect to another. Hence the scope of this experiment was restricted to those Urdu speakers who belonged to Punjabi family. Selected speakers are natives of Lahore, Pakistan. They understand Punjabi spoken in Lahore and use Urdu as their major communication language. They belong to the age group of 18 to 23 years and are students of FAST.

4.2 Data

Twenty-six total words were chosen for the experiment. Word distribution for each approximant was as follows:

TABLE 1 Distribution of Data

Number of Words	Approximants
5	/r/ or /r^h/
7	/ɽ/ Or /$ɽ^h$/
7	/l/ or /l^h/
4	/w/ or /v/ or /w^h/ or / v^h/
3	/j/ or /j^h/
Total Words: 26	

Each group of words for an approximant was further divided into following groups.

1. Approximant appearing word initially.
2. Approximant appearing word finally.
3. Approximant appearing word medially.

It was tried that at least two words belonging to each group are taken such that one word contain aspirated approximant while other contains its non-aspirated version. These words were recorded 4 times each and a total of 104 utterances of these words for each speaker (a total of 416 utterances for four speakers) were analyzed.

The carrier phrase chosen was /mæ̃ ne ____ kəhɑ/.

4.3 Software

All these recordings were done and analyzed using Praat and Speech Analyzer software.

4.4 Features Analyzed

F1/F2 intensity ratio of approximants in all words was measured and analyzed. This analysis was in accordance with the observation stated in literature overview.

In case of /ɽ/ duration of shwa /ə/ was also noted. Appearance of shwa /ə/ was an unexpected phenomena in all /ɽ/-containing words.

5. RESULTS

5.1 Aspirated Trill

For analysis and investigation of aspirated trill in Urdu, words in table 3 (Word no.8-12) were used. Average F1: F2 intensity ratio ranged from 1.3-2. Analysis of spectrogram showed that in 90% data /r^h/ > /r/. Only /sə.r^hɑ.nɐ/ was pronounced as /sə.rə.hɑ.nɐ/ by two speakers.

5.2 Aspirated Flap

Words.13 –19 in table3 were used for examining aspirated flap in Urdu. Average F1:F2 ratios ranged between 1.33-1.7. In more than 80% samples of suspected /ɽʰ/ these ratios were consistent with F1:F2 ratios of those words which contain /ɽ/. These results are shown in appendix B.1. Variation of F1:F2 intensity ratio from speaker to speaker does not exceed 0.35 and this difference was due to difference in speaking habits.

Spectrograms of /ɽ/ in most of the cases (more than 90%) reported existence of shwa (ə) just after /ɽ/. This shwa was especially prominent in word final /ɽ/, irrespective of whether it was transcribed as /ɽ/ or /ɽʰ/ in the text.

Spectrogram of /bu.ɽʰɑ/showed following results:

1. /bu.ɽʰɑ/ > /bu.ɽɑ/
2. /bu.ɽʰɑ/ > /bu.ɽəh/
3. /bu.ɽʰɑ/ > /bu.ɽə.hɑ/

Case 1 was the most frequently occurring event.

Spectrogram of /gʊɽ/ resulted in shwa(^) at the end of /ɽ/.

Spectrogram of /gəɽʰ/ showed following results

1. /ɽʰ/ > /ɽə/ (95% samples)
2. /ɽʰ/ > /ɽəh/ (Few samples)

Likewise other words exhibited that /ɽʰ/ > /ɽə/.

In some cases where vowel followed /ɽʰ/, shwa was absent i.e. /ɽʰV/ > /ɽəV/ > /ɽV/.

5.3 Aspirated Lateral

Words.1–7 in the table.3 were used for examining aspirated lateral occurrence. Two speakers (speaker 3 and 4) did not pronounc /lʰ/ in any word i.e. /lʰ/ > /l/. Remaining two speakers pronounced /l/ and /h/ separately in more than 80% words when /lʰ/ occurred word medially i.e. /lʰ/ > /l.h/.

Word initially, /lʰ/ was never spoken. Speaker 3 and 4 pronounced /lʰəs.sən/ as /ləs.sən/ and /lʰə.su.ɽɑ/ as /lə.su.ɽɑ/. First two speakers pronounced these words as /ləh.sən/ and /ləh.su.ɽɑ/.

Average ratio of F1/F2 intensity varied with from word to word. It was 2.2 for word initial /l/, 2 for geminated /l/ and 1.6 for other words. In most of the cases, result was /lʰ/ > /ləh/ or /lʰ/ > /lə/.

5.4 Aspirated w

Words 20-23 in table.3 were chosen to investigate existence of aspirated /w/. None of the speakers pronounced /wʰ/ or /w/. /w/ was changed to /v/, labio-dental voiced fricative. Even “whale” which is derived from English, and is spoken with /wʰ/ in English, was pronounced /vel/ or /vehl/ or /vəhel/. Moreover aspiration from /vʰ/ was deleted at the word final position. Medially /vʰV/ was changed to /vV/ where V was a vowel.

5.5 Aspirated j

Words 24-27 were checked for aspirated j. But none of the speaker pronounced aspirated /jʰ/. /j/ was always followed by some vowel depending upon its context and /h/ vanished in majority of the samples. F1/F2 ratio was consistent for the each speaker.

6. DISCUSSION

From the above results it can be deduced that aspirated approximants are not a part of Urdu dialect spoken in Lahore today since majority of the data shows absence of these approximants.

Amongst five approximants two are surely absent from Urdu since none of the speaker pronounced them. They are /wʰ/ and /jʰ/. As far as /ɽ/, /r/ and /l/ is concerned, majority of data denies any existence of their aspirated counterparts. In few cases higher F1:F2 ratio was observed. But the difference of ratio was less then 1. In all these cases approximant was separated from /h/ by a small duration shwa (ə).

Literature review and spectrogram analysis show that aspirated /r/, /ɽ/ and /l/ might have existed in Urdu in past but now they are not used. Masica (1991, pp. 103) Reports that there is a natural tendency for aspirates to evolve into fricatives, especially voiceless stops, but in Indo-Aryan languages it is resisted. On the basis of Masica's observation it is proposed that this phenomenon has occurred with Urdu in case of aspirated approximants. Urdu has retained aspirated stops but has lost aspirated /r/, /ɽ/ and /l/.

One reason for this can be connected to articulation of the approximants. Aspiration is best possible in stops since stopped air during closure allows aspirated release easier. In case of approximants, more lung effort is required to sustain this air pressure because approximants are more sonorant than stops. Hence probably due to its articulatory difficulty, use of aspirated approximants has vanished. Another reason for these changes can be wrong orthography of two possible forms of /h/ (Bukhari, 1990, pp. 83).

From data analysis it is concluded that aspiration and continuant tiers repel each other at the same time slot X. Hence one of them is deleted. In Urdu aspiration is secondary feature as compared with continuant feature. Hence aspiration is deleted in Urdu. In some rare cases aspiration was replaced by adding new time slot X (carrying /h/ features) next to the aspirated approximant time slot.

For example, data on /r/ shows that word medial /r^{h}V/ changed to /r.hV/ or /rV/ and word medial /r^{h}. C/ changed to /r. C/ where V was a vowel and C was a fricative. Reason is same as explained above. It is noteworthy that Urdu does not allow /r^{h}/ word initially and finally. Perhaps this rule also forced the replacement of syllable initial or syllable final /r^{h}/ with /r/. Word initially and finally, Urdu does not license /r/.

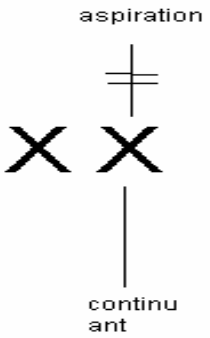
Data on /ɽ/ showed that in all cases /ɽ^{h}/ > /ɽə/. Aspiration was vanished or replaced with /h/, appearing as onset in the next syllable or coda in the same syllable. Word initially /ɽ^{h}/ is not licensed by Urdu. Another important result was appearance of shwa (ə) with /ɽ/. It appears that ə is a part of /ɽ/. There is no connection between aspiration of /ɽ/ and /ə/. Shwa /ə/ is merely a result of retroflex movement of tongue. This argument is supported by the results obtained for word /gʊɽ/ in which /gʊɽ/ > /gʊɽə/.

/l/ also showed same behaviour. Medially it always changed as follows: /l^{h}/ > /l.h/ or /l/. Both forms are used equally. e.g. /əl.l^{h}əɽ/ was pronounced as /əll.həɽ/ by two speakers. Other two speakers pronounced it as /əl.ləɽ/. Word initially or finally it is not licensed.

7. CONCLUSIONS

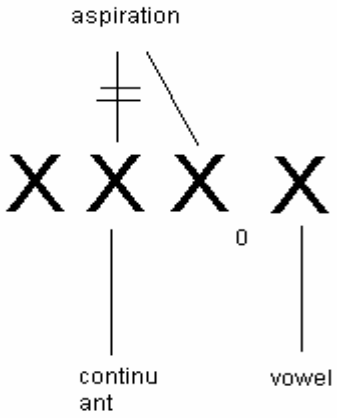
1. In Urdu aspirated approximants are usually those which are written with /ɖ̤ɑu ʃtəʃmi hɑ/ (two eye /hɑ/).
2. No Urdu aspirated approximant occurs word initially.
3. All Urdu aspirated approximants except /ɽ^{h}/ do not occur word finally. /ɽ^{h}/ Is also changed to /ɽ/.
4. Aspirated approximants might have occurred medially in old Urdu but now they have changed to their non-aspirated counterparts. Possible reason is that aspiration requires instantaneous airflow, which is difficult to produce with already semi open oral configuration in approximants.
5. Aspiration and Continuant tiers at a time slot X repel each other. As a result a secondary tier (in Urdu it is aspiration) is normally deleted or split to next timeslot X. In Urdu, following rules govern this de-aspiration. Most of the speakers de-aspirate words using rule R1. Preceding time slot X can be any vowel or consonant in R1.

(R1)



6. Some speakers changed /A^{h}/ to /A.h/ (where A was an approximant) using R2 but it was in rare cases e.g. /sə.r^{h}ɑ.ne/ changed to /sər.hɑ.ne/ using R2 by two speakers. Preceding time slot X can be any vowel or consonant.

(R2)



7. Appearance of shwa has no relation with aspirations since it appears in both /gʊɽ/ and /gəɽ^{h}/ and seems to be a part of /ɽ/.

8. Aspirated /j/ and /w/ have rare references in old Urdu. No acoustic evidence of their existence in Urdu was found. Perhaps they have also changed to non-aspirated versions following R1 and R2.

8. REFERENCES

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10. APPENDICES

Appendix A

TABLE A.1 Experimental Data

Words (English transcription)	Urdu Word	Reference No:
Words for /l/		
1. /lʰəs.sən/	لھسن	(Haqi, S. 1995. pp. 826)
2. /lʰə.su.ɽɑ/	لھسوڑا	(Haqi, S. 1995. pp. 826)
3. /ʃtu.lʰɑ/	چولھا	(Khan, M. 1997. pp. 102)
4. /kolʰu/	کولھو	(Khan, M. 1997.pp.102)
5. /əl.lʰəɽ/	الھڑ	(Qureshi, B. 1992)**
6. /gɪl.lʰəɽ/	گلھڑ	(Qureshi B. 1992) **
7. /kɑlɑ/	کالا	(Qureshi B. 1992) **
Words for /r/		
8. /rəhət/	رہٹ	(Haqi, S. 1995) **
9. /bɑrʰvĩi/	بارھویں	(Qureshi B. 1992) **
10. /sə.rʰɑnɑ/	سرھانا	(Qureshi B. 1992) **
11. /bɑrɑ/	بارہ	(Haqi S. 1995) **

12. /gərəm/	گرم	(Haqi S. 1995) **
Words for /ɽ/		
13. /bu.ɽʰɑ/	بوڑھا	(Khan, 1997, pp. 112)
14. /sɑ.ɽʰi/	ساڑھی	(Khan, 1997, pp.112)
15. /bəɽʰ.t̪i/	بڑھتی	(Haqi, 1995)**
16. /bəɽʰ.jɑ/	بڑھیا	(Khan, 1997, pp. 112)
17. /dɑɽʰ/ or /d̪ɑɽʰ/	ڈاڑھ / داڑھ	(Khan, 1997, pp. 112)
18. /gəɽʰ/	گڑھ	(Khan, 1997, pp. 112)
19. /gʊɽ/	گڑ	(Haqi, 1995)**
Words for /w/ or /v/		
20. /wohi/	وہی	(Nayyar, 1989)**
21. /vəhɑb/ or /wəhəb/	وہاب	(Nayyar, 1989)**
22. /vʰel/	وھیل	*
23. /mevɑ/	میوہ	(Haqi, 1995)**
Words for /j/		
24. /jeh/	یہ	(Haqi, 1995)**

25. /jəhi/	یہی	(Haqi, 1995)**
26. /rəvəɪjəh/	رویہ	(Haqi, 1995)**

*This word has entered from English and is an English approximant. For that reason it was tested.
**These references have been given from dictionaries and can easily be found in alphabetical order from the sources. Therefore their pages are not mentioned.

Appendix B
Results

TABLE B.1 Results for /ɽ/

Features	Speaker 1	Speaker2	Speaker 3	Speaker4
/bu.ɽʰɑ/ > Spoken Word	/bu.ɽɑ/ or /bu.ɽəh/ (2 samples)	/bu.ɽə.hɑ/	/bu.ɽɑ/	/bu.ɽɑ/
Duration of shwa / following vowel (seconds)	0.25	0.06	0.12	0.2
F1/F2	500/1300	550/1300	550/1300	450/1300
F1 (db)/F2 (db)	60/42	43/27	40/30	47/36
/sɑ.ɽʰi/ > Spoken Word	/sɑ.ɽi/	/sɑ.ɽi/ or /sɑ.ɽih/ (1 sample)	/sɑ.ɽi/	/sɑ.ɽi/
Duration of shwa / following vowel (seconds)	0.25	0.12	0.12	0.18
F1/F2	500/1800	550/1800	600/1800	500/1700
F1 (db)/F2 (db)	61/42	42/26	36/24	43/30
/bəɽʰ.jɑ/ > Spoken Word	/bəɽə.jɑ/	/bəɽəɪjɑ/	/bəɽɪjɑ/	/bəɽəɪjɑ/
Duration of shwa / following vowel (seconds)	0.03	0.03	0.03	0.03
F1/F2	500/1800	500/1800	500/1800	500/1700
F1 (db)/F2 (db)	56/36	43/26	34/20	45/35
/bəɽʰ.t̪i/ >	/bəɽə.hə.t̪i/	/bəɽə.hə.t̪i/	/bəɽə.ht̪i/	/bəɽə.t̪i/

Spoken Word				
Duration of shwa / following vowel (seconds)	0.05	0.02	0.02	0.06
F1/F2	500/1800	500/1500	500/1500	500/1500
F1 (db)/F2 (db)	60/40	39/26	34/20	47/36
/dɑɽʰ/ or /d̪ɑɽʰ/ > Spoken Word	/d̪ɑ.ɽə/	/d̪ɑ.ɽə/	/d̪ɑ.ɽə/	/d̪ɑ.ɽə/
Duration of shwa / following vowel (seconds)	0.03	0.04	0.06	0.06
F1/F2	500/1700	500/1700	500/1600	500/1600
F1 (db)/F2 (db)	60/43	44/25	35/24	45/35
/gʊɽ/ > Spoken Word	/gʊɽə/	/gʊɽə/	/gʊɽə/	/gʊɽə/
Duration of shwa / following vowel (seconds)	0.05	0.05	0.06	0.06
F1/F2	500/1300	500/1300	500/1300	500/1500
F1 (db)/F2 (db)	64/45	42/26	40/30	48/37
/gəɽʰ/ > Spoken Word	/gəɽə/	/gəɽə/	/gəɽə/	/gəɽə/
Duration of shwa / following vowel (seconds)	0.05	0.06	0.06	0.07
F1/F2	550/1400	500/1300	550/1400	450/1350
F1 (db)/F2 (db)	63/43	42/26	40/30	47/38

TABLE B.2 Results for /l/

Features	Speaker 1	Speaker 2	Speaker 3	Speaker 4
/lʰəs.sən/ > Spoken Word	/ləh.sən/	/læh.sən/	/ləs.sən/	/ləs.sən/
F1/F2	400/1700	400/1800	600/1500	400/1500
F1 (db)/F2 (db)	60/30	46/19	42/23	39/21
/lʰə.su.ɽɑ/ > Spoken Word	/ləh.su.ɽɑ/	/lə.su.ɽɑ/	/lə.su.ɽɑ/	/lə.su.ɽɑ/
F1/F2	400/1700	450/1700	600/1500	400/1500
F1 (db)/F2 (db)	58/27	42/17	42/16	40/18
/ʃtu.lʰɑ/ > Spoken Word	/ʃtu.lə.hɑ/ or */ʃtu.lʰɑ/	/ʃtʊl.hɑ/	/ʃtu.lɑ/	ʃtu.lɑ/
F1/F2	400/1300	400/1300	500/1300	450/1300
F1 (db)/F2 (db)	65/36	43/24	42/25	47/30
/kolʰu/ > Spoken Word	/ko.lə.hu/ or /kol.hu/	/ko.lə.hu/ or /kol.hu/	/kolu/	/kolu/
F1/F2	500/1500	450/1300	500/1400	500/1300
F1 (db)/F2 (db)	66/40	45/26	43/24	48/30
/əl.lʰəɽ/ > Spoken Word	/əll.həɽ/	/əll.həɽ/	/əl.ləɽ/	/əl.ləɽ/

F1/F2	500/1700	500/1600	400/1400	500/1500
F1 (db)/F2 (db)	65/32	42/17	40/17	48/27
/gɪl.l^{h}əɽ/ > Spoken Word	/gəll.həɽ/	/gɪll.həɽ/	/gəl.ləɽ/	/gəl.ləɽ/
F1/F2	450:1750	400:1700	400:1600	400/1600
F1 (db)/F2 (db)	70/38	43/22	41/21	48/23
/kala/ > Spoken Word	/kala/	/kala/	/kala/	/kala/
F1/F2	450/1300	600/1300	500/1200	450/1300
F1 (db)/F2 (db)	60/40	40/26	38/22	46/28

TABLE B.3 Results for /r/

Features	Speaker 1	Speaker 2	Speaker 3	Speaker 4
/rəhət/ > Spoken Word	/rəhət/	/rehət/	/rəhət/	/rəhət/
F1/F2	400/1800	425/1600	500/1400	425/1650
F1 (db)/F2 (db)	46/27	41/22	34/21	42/28
/bar^{h}vĩ/ > Spoken Word	/barvĩ/	/barvĩ/	/barvĩ/	/barvĩ/
F1/F2	525/1500	550/1550	500/1400	450/1500
F1 (db)/F2 (db)	64/46	43/21	34/22	41/25
/sə.r^{h}a.ne/ > Spoken Word	/sər.ha.ne/	/sər.ha.ne/	/sə.ra.ne/	/sə.ra.ne/
F1/F2	550/1550	550/1525	500/1300	450/1450
F1 (db)/F2 (db)	63/43	41/23	32/18	46/37
/bara/ > Spoken Word	/bara/	/bara/	/bara/	/bara/
F1/F2	425/1350	700/1400	500/1400	500/1350
F1 (db)/F2 (db)	56/42	40/30	35/27	40/31
/gərəm/ > Spoken Word	/gərəm/	/gərəm/	/gərəm/	/gərəm/
F1/F2	550/1500	450/1550	400/1400	475/1400
F1 (db)/F2 (db)	60/42	40/28	34/22	35/23

TABLE B.4 Results for /j/

Features	Speaker 1 Ratio	Speaker 2 Ratio	Speaker 3 Ratio	Speaker 4 Ratio
/jeh/ > Spoken Word	/je/	/je/	/je/	/jeh/
F1/F2	400/2400	275/2450	400/2500	325/2000
F1 (db)/F2 (db)	60/30	42/10	34/5	42/17
/jəhi/ > Spoken Word	/jehi/	/jehi/	/jehi/	/jəhi/
F1/F2	400/2350	275/2450	300/2500	350/2000
F1 (db)/F2 (db)	63/29	40/9	36/8	45/17
/rəvəɪjəh/ > Spoken Word	/rəvəɪjɑ/	/rəvəɪjɑ/	/rəvəɪjɑ/	/rəvəɪjɑ/
F1/F2	350/2350	450/2350	250/2400	325/2100
F1 (db)/F2 (db)	37/19	39/8	39/17	44/27

Note

1. F1: F2 for /w/ is not given since in all cases /w/>/v/. /v/ is fricative and contains noise instead of formants in its spectrum.
2. Addition of extra row for vowel duration for /ɽ/ was due to the fact that /ɽ/ was always followed by shwa /ə/ when it occurred word finally. Others approximants did not result in shwa /ə/ when they were located word finally.

Appendix C Spectrograms

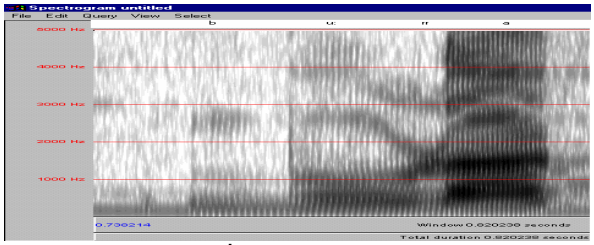

Figure C.1: /bu..ɽʰɑ/ > /bu..ɽɑ/

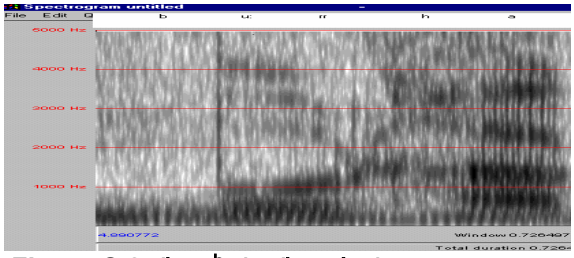

Figure C.2: /bu.ɽʰɑ/ > /bu.ɽ.hɑ/

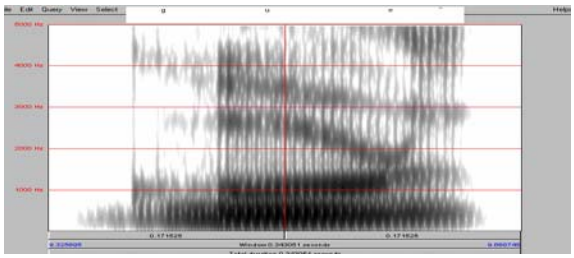

Figure C.3: /gʊɽ/ > /gʊɽə/

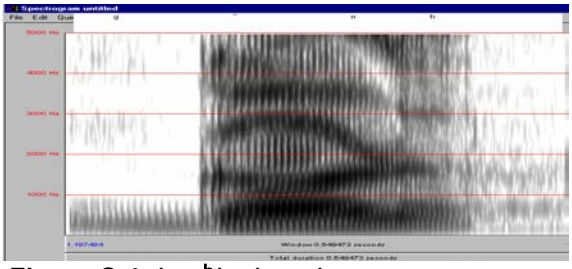

Figure C.4: /gəɽʰ/ > /gəɽə/

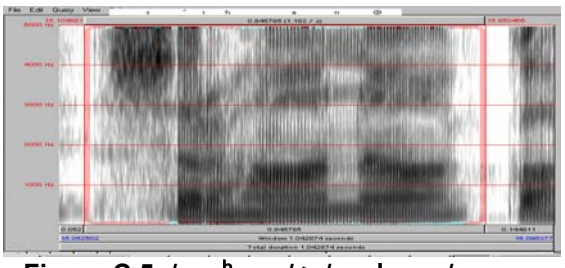

Figure C.5: /sə.rʰɑ.ne/ > /sər.hɑ.ne/

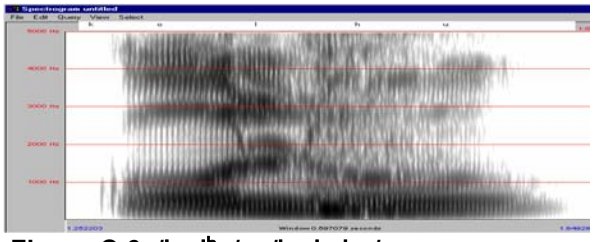

Figure C.6: /ko.lʰu/ > /ko.lə.hu/

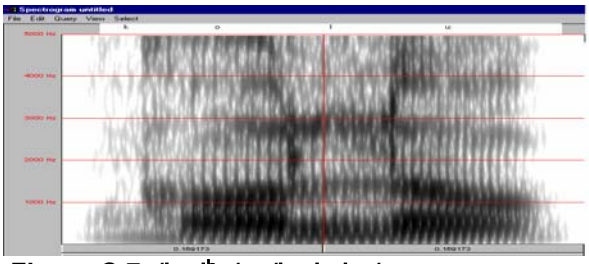

Figure C.7: /ko.lʰu/ > /ko.lə.hu/

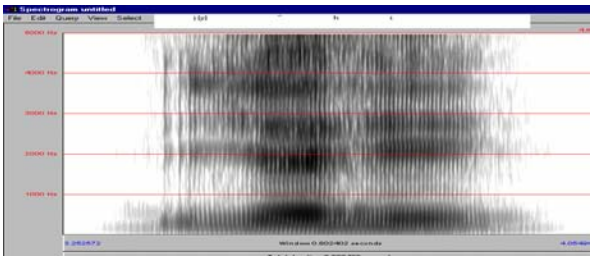

Figure C.8a: /jəhi/ > /jehi/

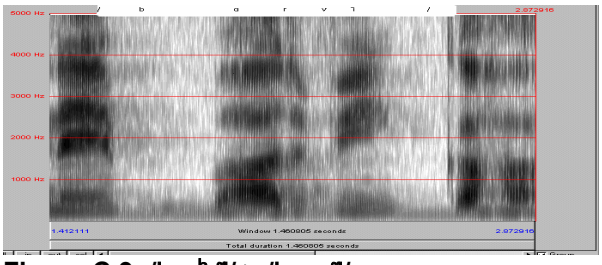

Figure C.9: /bɑrʰvĩ/ > /bɑr.vĩ/

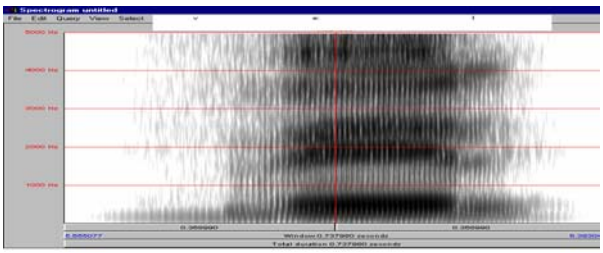

Figure C.10: /vʰæl/ > /vel/