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Identification of Diphthongs in Urdu and their Acoustic Properties

***Abstract**: There is a large inventory of vowels in Urdu and therefore the phonetic existence of diphthongs is very likely. This paper illustrates a survey to identify the diphthongs in Urdu. After the identification, their phonemic and acoustic properties are discussed. Furthermore the formation of diphthongs (their phonetic to phonemic conversion) is discussed using examples.*

***Keywords:** Syllables, Onglide, Offglide, Glides, Rising Diphthongs, Falling Diphthongs*

1. INTRODUCTION

In simple vowels, or monophthongs, the tongue body has a relatively stable position throughout. But there are other vowels where the tongue body does not stay in one place, even in the most abstract diagrams with artificial slices. Complex vowels, which are characterized by movement, are called diphthongs (http://www.umanitoba.ca/faculties/arts/liguistics/russell/138/sec3/diphth.htm). Here "di" means two and "phthong" means a voiced sound. Diphthongs are made up of two vowel sounds.

Diphthongs have a dynamic characteristic of change in vocal tract configuration. As the articulatory configuration changes, so does the acoustic pattern. This change is gradual.

If the first vowel of the diphthong is prominent, it is called a falling diphthong, and if the second vowel of the diphthong is prominent, it is called a rising diphthong.

2. LITERATURE REVIEW

According to Kent and Read, 92, there are three parts to the diphthong: the first vowel (starting position, and often referred to as the onglide), the transition period, and the second vowel (the final position, or the direction of movement, and often referred to as the offglide).

However Clark and Yallop, 95 state that distinct positions of onglide, transition and offglide may not be visible in the acoustic analysis of the diphthongs. Alternatively diphthongs may be defined as complex articulation combining pure vowels. The timing of articulation movement between two endpoints of pure vowels can be variable. In this case then onglide refers to a relatively brief onset leading into a dominant vowel quality. Offglide refers to similar effect at the end of the vowel, moving away from the dominant vowel quality. The term diphthong is then reserved for a glide between two vowel qualities, neither of which dominates (Clark and Yallop, 1995).

According to Ladefoged, 93, the first part of a diphthong is usually more prominent than the last and such are called falling diphthongs. In fact, the last part is often so brief and transitory that it is difficult to determine its exact quality (Ladefoged, 93). Some phoneticians use the term nucleus to refer to the onglide position due to its prominence over the offglide position (Kent and Read, 1992).

The majority of languages of the world do not use diphthongs in their phonological inventory (Laver, 1994). Generally speaking, if a language distinguishes more than about ten vowels, then it may be exploiting diphthongal combinations (Clark and Yallop, 95).

Phonology books on Urdu by Dr. Sohail Bokhari, and Dr. Mehboob Alam state that phonemically, no diphthongs exist in Urdu. Their phonetic existence however remains undocumented. Since Urdu has 7 long vowels, 4 short vowels and 6 nasalized long vowels (Mannan, e.t.a.l, 2002). Therefore there are chances of the language exploiting diphthongs. This paper describes the identification of diphthongs in Urdu and their analysis.

3. METHODOLOGY

3.1 Subjects

25 native speakers of Urdu were used as subjects for the survey to identify the existence of diphthongs. They were trained to identify syllables of Urdu. This was performed by giving them examples of words from Urdu and telling them the syllable count in them. A list of sample data was recorded which contained words of variable syllable count. Words, which possibly contained diphthongs were mixed in this list and recorded. Once the subjects were able to identify the syllables, they were given this recorded data for identifying syllables. They listened to the recorded words and the syllable count they told was recorded down.

For the purpose of acoustic analysis of diphthongs, 5 native male speakers of Urdu were asked to speak the words possibly carrying diphthongs and their speech was recorded. The cardinal vowels of these 5 speakers were also analyzed so that they could be compared to the diphthongs.

3.2 Data Recordings and Analysis

Recording of the word list was done on Praat 3.9.35, a speech-processing tool designed for Windows users. The recorded wave file was used for acoustic analysis in WinSnoori 1.3, also a speech-processing tool. The equipment consisted of a high fidelity (Hi-Fi) microphone, a Teac integrated stereo amplifier and two high quality speakers with 8-ohm impedance.

3.3 Procedure

A list of words, possibly containing diphthongs, was prepared. These words were mixed with other words carrying no diphthongs and a list of mix words was recorded. Individually the subjects were asked to identify

the number of syllables. After this the results were collected in Table 1 shown in the Results section. If the speakers considered the possible diphthong as a single syllable, then it was considered as a diphthong by them, otherwise it was not.

For the acoustic analysis, 5 speakers were given flash cards and their speech was recorded. They were asked to speak the word containing diphthongs occurring in a carrier phrase and their speech was recorded. As the word occurred in the same carrier phrase, the context for each diphthong remained the same. This recording resulted in a stressed diphthong being recorded.

In order to plot the diphthongs in a chart, speech containing the cardinal vowels was also recorded of these 5 native speakers. Data was randomized and recorded three times. The average formant values of the cardinal vowels spoken by these speakers were then plotted in Figure 1.

4. RESULTS

The results of the survey of 25 subjects are recorded in the Table 1. The 2nd column shows the possible diphthong in Urdu. The 3rd column shows the occurrence of the diphthong in the words of Urdu language. The 4th column shows the result of the survey. If more than 50% of the people (i.e., 13 or more) think that it is a diphthong, and then it is added into the list of diphthongs in Urdu, otherwise not. (The detail of the survey is shown in Appendix A: Table 4). Out of these 13, 4 were nasal diphthongs. The 9 non-nasals are plotted in Figure 1. The values can be read from Table 2. (Table 2 contains the formant values of all 13 diphthongs). The duration of the first vowel and second vowel was also recorded to find if Urdu has falling diphthongs or rising ones. The readings are shown in Table 3. The formant values: F1, F2, and F3 are shown in Tables 5-17 of the Appendix A. Table 18 shows the formant values of the cardinal vowels.

Table 1 Result of Survey of 25 Native Urdu Speakers (Refer to Appendix A for detailed data)

Sr. #	Diphthong	Occurrence	Result	Vote Count
1	ɪu˜	kɪu˜	√	24
2	əe	nəe	√	23
3	əɪ	nəɪ	√	23
4	ɑo	ao	√	21
5	ɑi	ɑi	√	21
6	ɑe	ɑe	√	21
7	eɑ	geɑ	√	19
8	oi	koi	√	18
9	ɑẽ	lɑẽ	√	17
10.	oe	k^hoe	√	17
11.	əi˜	gəi˜	√	16
12.	ɪɑ	pɪɑ	√	15
13.	ɑu˜	dʒɑu˜	√	13
14.	ʊe	hʊe	×	12
15.	ʊɑ	hʊɑ	×	12
16.	ʊə	mʊə̯t əl	×	12
17.	ɪe	pɪe	×	8
18.	ɪẽ	pɪẽ	×	6
19.	ɪɑ˜	mɪɑ˜	×	5
20.	oẽ	roẽ	×	5
21.	ɪo˜	mo̯t ɪo˜	×	4
22.	uɑ˜	d^huɑ˜	×	4

5. DISCUSSION

It was interesting to note the speaker variation in the data collected. Consider Table 4 in the Appendix A. There were some native speakers of Urdu who considered only one word to contain a diphthong such as Native Speaker number 22. While there were other subjects who identified a lot of diphthongs such as native speaker number 4 who considered 18 out of 22 diphthongs. This shows that the perceptual identification of diphthongs is speaker-dependent to a great extent.

There are other diphthongs for which 12 subjects voted. e.g. "ʊɑ" in "hʊɑ", and "ʊe" in "hʊe". The former means "happened" and the latter refers to the "plural aspect of happened". It was possible that if some more native speakers were consulted, the majority would consider these to be diphthongs. Possibly, if we would have taken different set of subjects then our results may be quite different due to this speaker variation. We may have found more or less diphthongs than the present result or, possibly a different set of diphthongs.

Figure 1 shows the start position of the diphthong, its direction of movement and its final position. The diphthongs often do not begin and end with the same quality as that of cardinal vowels. Each diphthong is represented in the F1-F2 (Figure 1) by a trajectory that begins with the formant frequencies of the onglide and ends with the formant frequencies of the offglide.

One of the interesting cases is that of "oe". (See Figure 1 "oe" is shown by line 7.) It starts from a position, which is closer to vowel "ʊ" instead of "o". The F2 (second formant) of "o" is low (at 850), while F2 of "ʊ" is high (around 1050). The onglide of diphthong "oe" maps on the short vowel "ʊ" having F2 very close to that of "ʊ". Same is the case with "oi". The onglide of this diphthong also maps on the short vowel "ʊ" instead of "o" (considering the F2 of both vowels). In both these cases, we perceive it as "o" but the formant values are close to that of "ʊ".

Table 2 Diphthongs in Urdu, their Formats and Duration

Sr. #	Diphthong	Duration in ms	Start F1	Start F2	End F1	End F2
1.	Oe	178	430	1032	360	1835
2.	ɑẽ	213	530	1461	391	2248
3.	ɑe	208	740	1456	366	2070
4.	ɪu˜	162	318	2085	351	755
5.	əɑ	196	353	2103	446	1536
6.	ɑi	198	737	1489	334	2256
7.	əi	184	469	1734	283	2328
8.	əe	188	477	1691	375	2119
9.	əẽ	209	422	1843	311	2345
10.	oi	186	415	1036	313	2181
11.	ɪɑ	206	322	2137	430	1504
12.	ɑu˜	221	429	1765	343	670
13.	ɑo	209	728	1356	396	955

onglide and offglide to the durations of the underlying vowels. The diphthong "oi" was analyzed and the duration values are shown. It shows that 39% of the time is taken in the onglide and about 61% of the time is taken in the offglide. The last three columns of Table 3 show that 'o' loses its timing slot and becomes 'ʊ'.

Phonology books on Urdu by Dr. Sohail Bokhari, and Dr. Mehboob Alam state that phonemically, no diphthongs exist in Urdu. No minimal pairs can be used to account for the phonemic existence of the diphthongs, since the process of deletion results in the formation of diphthongs.

Due to urge of humans to be lazy and articulate minimally in order to produce speech, there may be a difference in the phonemic transcription and the underlying phonetic transcription. There are many of rules of phonology, which are responsible for this change from the phonemic transcription to the phonetic transcription.

Sometimes the underlying syllables, which exist in the writing style or the syllable in the mind of a speaker, differ from the surface form of syllables or the syllables that are spoken.

Speaker	#	Duration for "oi"			Duration of Pure Vowels		
		Onglide	Offglide	Total	"ʊ"	"i"	"ʊ"+ "i"
Speaker 1	1	98	122	220	148	239	387
	2	91	95	186	120	241	361
	3	86	118	204	134	250	384
Speaker 2	1	97	106	203	164	257	421
	2	77	109	186	163	244	407
	3	72	130	202	160	252	412
Speaker 3	1	62	120	182	118	202	320
	2	72	102	174	117	221	338
	3	83	122	205	125	218	343
Speaker 4	1	72	93	165	152	244	396
	2	62	129	191	140	245	385
	3	81	126	207	127	222	349
Speaker 5	1	46	114	160	127	253	380
	2	68	95	163	151	-	-
	3	41	106	147	158	216	374
Ratio of Onglide to Offglide		39%	61%	100%	37%	63%	100%

Table 3 Comparison of Onglide and Offglide durations of "oi" to that of underlying vowels

Consider another case of "ɑi". It is shown by line 1 Figure 1. The diphthong starts from F2 value, which is much higher than the F2 of "ɑ". F2 of "ɑ" is at 1150, while F2 of the onglide of "ɑi" is around 1500.

The prominence of the first vowel discussed in the Literature Review of this paper does not apply to the diphthongs in Urdu. Table 3 shows the comparison of the durations of

Deletion is a rule, which works towards reducing the number of syllables in a language. It is also responsible for the difference in the phonemic and phonetic transcriptions of words. The deletion rule is responsible in making the language simpler.

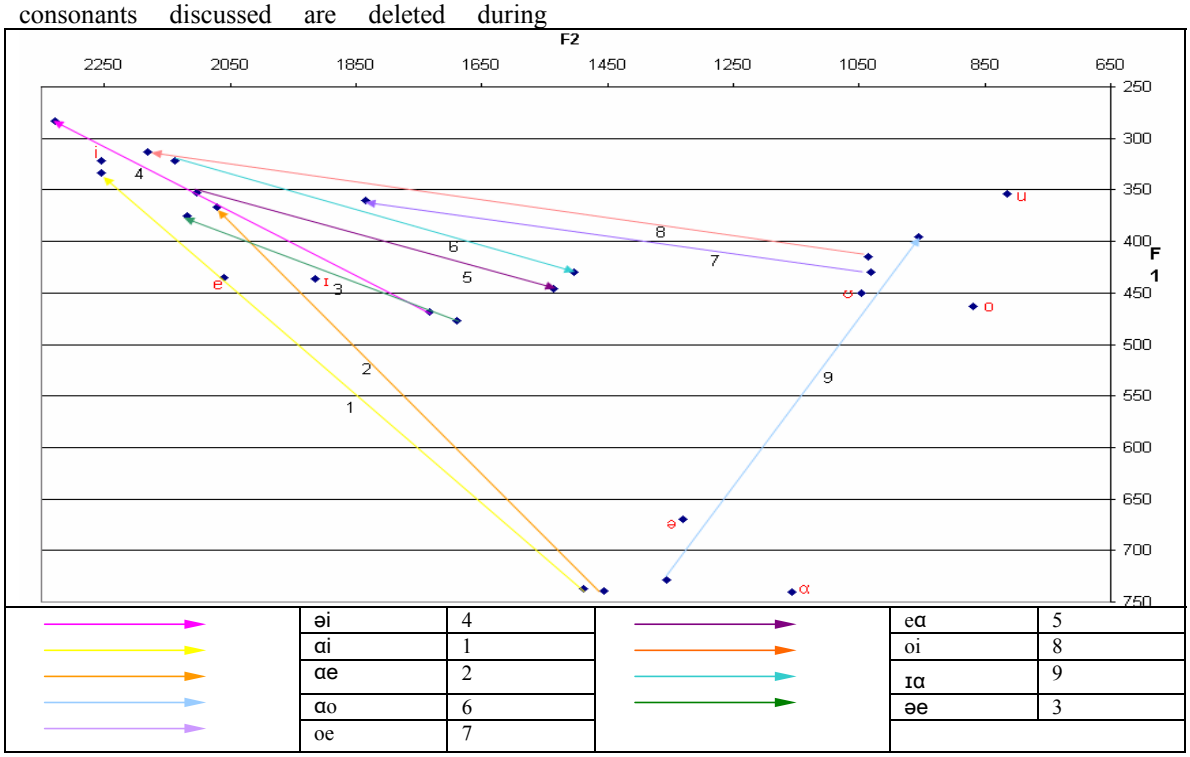
Consider the example of "nə.ʔe" which means "new". The segment formation of the word is CV.CVV. The consonant "ʔ" is deleted by most native Urdu speakers to form "nə.e", and the resulting segment sequence becomes CV.VV. According to a rule in Urdu where no

syllable can start with a vowel (except word initially), “e” cannot stand alone as one syllable. It has two choices. Either it should also be deleted so that the resulting sequence of segments is CV, or it should combine with the previous segment to form CVVV. The latter happens and re-syllabification occurs. “e” combines with the previous syllable to form the phonetic transcription “nəe”. Thus the monosyllabic word contains a diphthong: “əe”. The segment sequence in this word is CVVV, where the first is a short vowel and the second is a long vowel. Segment sequence in this word is CVVV, where the first is a short vowel and the second is a long vowel.

In Urdu, the consonant deleted is usually “ʔ” or “j”. Sometimes the consonant “v” is also deleted to form words containing diphthongs, however such diphthongs have not been found. It means that almost half of the subjects speak “v” and while the rest do not. It was found (taking into account the survey presented), that usually in Urdu only three consonants discussed are deleted during formation of diphthongs. They are: “ʔ”, “j” and “v”.

When the duration of the diphthongs was recorded in Table 3, it showed that the diphthongs are usually made up of one long and one short vowel. They were not found to be made up of two long vowels. The longest duration of any diphthong is recorded to be 221 milliseconds.

Phonemically, most of the time the timing slot may also be deleted to produce a diphthong. Consider the example of “koˑʔi” which carries the following vowel and consonant segments: CVV.CVV. The deletion rule results in the deletion of the consonant ʔ, and the resulting phonetic transcription is: “ko.i” which has the segments are CVV.VV. Since no syllable can begin with a vowel, therefore the vowel, “i” combines with the preceding syllable to form the structure CVVVV. Urdu does not allow such heavy syllables, therefore during the re-syllabification, a timing slot is deleted and the



	əi	4		eɑ	5
	ɑi	1		oi	8
	ɑe	2		ɪɑ	9
	ɑo	6		əe	3
	oe	7			

Figure 1 Representation of diphthongs using F1-F2 trajectories

Note: The line numbers appear below the lines

first vowel reduces to a short vowel. It does not however, lose its quality. The listeners perceive it as the long vowel: “o”. Figure 1 shows that this vowel gets mapped to the short vowel “ʊ”. In this way the deletion of timing slot results in CVVV, having the phonetic transcription “koi”.

In Urdu, phonemically, vowel segments can appear as either CV or CVV, or CVVV in case of diphthongs. Diphthongs are described as VVV since they consist of two vowels: the first of which is short and the

second is long Therefore during the re-syllabification mostly the first vowel reduces its timing slot as shown by the durations recorded in Table 3, and changes from a long vowel to a short one.

This study shows that Urdu has rising diphthongs (second vowel is of longer duration) which are very uncommon in the rest of the languages including English.

6. CONCLUSION

The 13 diphthongs discussed may not be the only diphthongs in the language Urdu. There may be other diphthongs, which we have not discussed in our paper, as the list is not an exhaustive list. Phonemically the existence of diphthongs (using minimal pairs) cannot be proved, since they are formed as a result of deletion of either the consonant, or the timing slot. The acoustic analysis shows that the quality may change due to deletion of timing slot, but we perceive it as the same underlying vowel.

7. SUMMARY

Phonemically Diphthongs do not exist in Urdu. The results of the survey show that phonetically, there are 13 diphthongs in Urdu. In all the cases they are formed from the deletion of the consonants: "ʔ", "j" and "v". In Urdu diphthongs, most of the underlying vowels are long. The first one loses its timing slot and it shows the formants of its corresponding short vowel. However, perceptually it does not lose its quality. Urdu has rising diphthongs where the duration of the offglide is greater than the onglide.

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APPENDIX A

Table 4 Table to show the survey results of 25 speakers
NS: Native Speaker of Urdu Language
1: Refer to Results section for occurrence of these diphthongs

Serial No.	Diphthong[1]	Result	Vote Count	NS1	NS2	NS3	NS4	NS5	NS6	NS7	NS8	NS9	NS10	NS11	NS12	NS13	NS14	NS15	NS16	NS17	NS18	NS19	NS20	NS21	NS22	NS23	NS24	NS25
1	ɪu˜	√	24	√	√	√	√	√	√	√	√	√	√	×	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2	əe	√	23	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	×	×	√	√
3	əɪ	√	23	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	×	√	×	√	√	√
4	ɑo	√	21	√	×	√	√	√	√	√	√	×	√	√	√	√	√	√	√	√	√	√	√	√	×	√	√	×
5	ɑi	√	21	√	×	√	√	√	√	√	×	√	√	√	√	√	√	√	√	√	√	√	×	√	×	√	√	√
6	ɑe	√	21	√	×	√	√	√	√	√	√	√	√	√	√	√	√	√	√	×	√	√	√	√	×	×	√	√
7	eɑ	√	19	√	√	√	√	√	×	×	√	×	×	√	√	√	√	√	×	√	√	√	√	√	×	√	√	√
8	oi	√	18	×	×	√	√	√	√	√	√	√	√	×	√	√	√	√	√	×	√	√	√	√	×	×	√	×
9	ɑẽ	√	17	√	√	√	√	√	√	√	×	√	√	√	√	×	√	√	√	×	×	√	√	√	×	×	×	×

10	oe	√	17	×	×	√	√	√	√	√	×	√	√	√	√	√	√	√	√	×	×	√	√	√	×	×	√	×
11	əi˜	√	16	×	×	√	√	√	√	√	×	√	√	√	√	√	√	√	√	×	×	√	√	√	×	×	×	√	×
12	ɪɑ	√	15	√	×	√	×	×	×	×	√	√	√	√	√	√	√	√	√	×	√	√	√	×	×	×	√	×
13	ɑu˜	√	13	√	×	√	√	√	√	√	×	×	×	×	×	√	√	√	×	×	√	√	×	√	×	×	√	×
14	ʊe	×	12	×	×	×	√	√	×	×	×	√	√	×	√	√	√	√	√	×	×	√	√	×	×	×	√	×
15	ʊɑ	×	12	×	×	×	√	√	×	×	×	√	√	√	√	√	√	√	√	×	×	×	√	×	√	×	×	√	×
16	ʊə	×	12	√	×	×	√	×	√	×	×	×	×	√	×	×	×	√	√	√	√	×	×	√	×	√	√	√
17	ɪe	×	8	×	×	×	√	×	×	×	√	×	×	√	√	√	×	×	×	×	√	×	√	×	×	×	√	×
18	ɪẽ	×	6	×	×	×	√	×	×	×	×	√	√	√	×	×	×	×	×	×	×	×	√	×	×	×	√	×
19	ɪɑ˜	×	5	√	√	×	×	×	×	×	×	×	√	×	√	×	×	√	×	×	×	×	×	×	×	×	×	×
20	oẽ	×	5	×	×	×	√	×	√	×	×	×	×	×	×	×	×	×	×	×	×	√	√	√	×	×	×	×
21	ɪo˜	×	4	×	×	×	×	×	×	√	×	×	×	√	×	×	√	×	×	×	×	×	√	×	×	×	×	×
22	uɑ˜	×	4	×	×	×	×	×	×	√	×	×	√	√	×	×	×	×	×	×	×	×	√	×	×	×	×	×

Table 5 Table to show the formants and duration of the 'ɪu˜' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	184.8	249	2163	3286	249	876	2329
	2	163.5	288	2081	3029	327	748	2237
	3	183.1	284	2251	3260	287	723	2435
Average (S # 1)		177.1	273.7	2165	3191.7	287.7	782.3	2333.7
Junaid	1	165	332	2080	2080	457	998	2329
	2	175	332	2121	2413	374	998	2731
	3	172	374	2080	2080	457	1164	2329
Average (S # 2)		170.7	346	2093.7	2191	429.3	1053.3	2463
Khurram	1	120	332	1996	2288	332	332	2329
	2	166	332	2080	2371	374	374	2413
	3	165	332	2080	2241	367	582	2352
Average (S # 3)		150.3	332	2052	2300	357.7	429.3	2364.7
Sajjad	1	135.3	332	2080	2454	332	1497	2329
	2	150.2	249	2163	2912	501	1085	2547
	3	170	249	2080	2496	291	1040	2329
Average (S # 4)		151.8	276.7	2107.7	2620.7	374.7	1207.3	2401.7
Khayyam	1	165.7	346	2150	2422	271	271	2175
	2	152.6	361	1881	2291	289	289	2205
	3	162.2	374	1988	2323	354	354	2244
Average (S # 5)		160.2	360.3	2006.3	2345.3	304.7	304.7	2208
Average (All)		*162*	*317.7*	*2084.9*	*2529.7*	*350.8*	*755.4*	*2354.2*

Table 6 Table to show the formants and duration of the 'əe' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	204.2	426	1644	2582	426	2131	2406
	2	204.1	332	1622	2579	356	2033	2247
	3	167.8	438	1706	2675	438	2145	2421
Average (S # 1)		192	398.7	1657.3	2612	406.7	2103	2358
Junaid	1	218	540	1662	2537	457	1996	2205
	2	193	582	1705	2579	416	2038	2246
	3	199	499	1705	2496	416	2038	2205
Average (S # 2)		203.3	540.3	1690.7	2537.3	429.7	2024	2218.7
Khurram	1	162	540	1788	2621	332	2080	2080
	2	176	499	1747	2662	374	2288	2288
	3	185	540	1747	2704	332	2038	2288
Average (S # 3)		174.3	526.3	1760.7	2662.3	346	2135.3	2218.7
Sajjad	1	181.7	441	1718	2406	343	1988	2334
	2	193.8	374	1580	2413	484	1962	2277
	3	213.3	499	1705	2413	214	2038	2246
Average (S # 4)		196.3	438	1667.7	2410.7	347	1996	2285.7
Khayyam	1	172.9	426	1723	2611	351	2329	2329
	2	172.3	542	1540	2567	351	2323	2323
	3	173.7	469	1766	2661	335	2348	2348
Average (S # 5)		173	479	1676.3	2613	345.7	2335.3	2335.3

Average (All)	*187.78*	*476.5*	*1690.5*	*2567.1*	*375*	*2118.7*	*2319.3*

Table 7 Table to show the formants and duration of the 'əɪ' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	199.4	416	1705	2579	249	2413	3661
	2	221.4	340	1728	2664	255	2465	3167
	3	167.8	411	1692	2653	343	2378	3453
Average (S # 1)		196.2	389	1708.3	2632	282.3	2418.7	3427
Junaid	1	195	582	1788	2579	332	2246	2246
	2	167	540	1705	2621	291	2329	2329
	3	208	540	1788	2537	332	2246	2454
Average (S # 2)		190	554	1760.3	2579	318.3	2273.7	2343
Khurram	1	Data discarded						
	2	157	540	1705	2621	291	2413	3785
	3	162	582	1705	2579	249	2413	3827
Average (S # 3)		159.5	561	1705	2600	270	2413	3806
Sajjad	1	172.6	426	1748	2409	255	2260	3009
	2	180.6	332	1705	2246	291	2205	2662
	3	195.5	499	1705	2537	332	2163	2621
Average (S # 4)		182.9	419	1719.3	2397.3	292.7	2209.3	2764
Khayyam	1	210.7	422	1887	2731	248	2399	2399
	2	176.4	417	1717	2646	255	2321	2321
	3	183.1	419	1724	2675	257	2417	2417
Average (S # 5)		190.1	419.3	1776	2684	253.3	2325.7	2325.7
Average (All)		*183.7*	*468.5*	*1733.8*	*2578.5*	*283.3*	*2328.1*	*2933.1*

Table 8 Table to show the formants and duration of the 'ɑo' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	229.6	761	1282	2500	434	869	2239
	2	222	819	1372	2497	405	855	2317
	3	217.5	783	1468	2545	430	881	2271
Average (S # 1)		223	787.7	1374	2514	423	868.3	2275.7
Junaid	1	203	748	1372	2662	499	1123	2329
	2	230	790	1372	2787	416	1123	2288
	3	256	790	1331	2579	416	1206	2246
Average (S # 2)		229.7	776	1358.3	2676	443.7	1150.7	2287.7
Khurram	1	172	702	1289	2205	374	915	2454
	2	196	707	1289	2621	374	873	2496
	3	181	707	1331	2329	416	956	2329
Average (S # 3)		183	705.3	1303	2385	388	914.7	2426.3
Sajjad	1	207	691	1339	2454	379	870	2385
	2	191	697	1462	2475	337	855	2160
	3	222.7	691	1383	2499	424	870	2277
Average (S # 4)		206.9	693	1394.7	2476	380	865	2274
Khayyam	1	214	693	1341	2255	335	939	2124
	2	187	636	1413	2581	353	1036	2205
	3	201	707	1289	2405	347	948	2250
Average (S # 5)		200.7	678.7	1347.7	2413.7	345	974.3	2193
Average (All)		*208.7*	*728.1*	*1355.5*	*2492.9*	*395.9*	*954.6*	*2291.3*

Table 9 Table to show the formants and duration of the 'ɑi' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	225.3	748	1539	2371	249	2329	3453
	2	182	768	1387	2328	346	2229	3245
	3	204.7	760	1457	2566	348	2312	3326
Average (S # 1)		204	758.7	1461	2421.7	314.3	2290	3341.3
Junaid	1	255	748	1456	2621	374	2288	2288
	2	190	790	1497	2496	332	2246	2371
	3	186	748	1622	2454	416	2205	2288
Average (S # 2)		210.3	762	1525	2523.7	374	2246.3	2315.7
Khurram	1	182	748	1289	2329	291	2288	3702
	2	198	790	1456	2454	332	2329	3785
	3	186	707	1456	2288	291	2246	3702
Average (S # 3)		188.7	748.3	1400.3	2357	304.7	2287.7	3729.7
Sajjad	1	181.4	687	1639	2326	264	2247	2723

	2	180	707	1580	2454	332	2246	2704
	3	206.6	707	1580	2288	445	2088	2310
Average (S # 4)		189.3	700.3	1599.7	2356	347	2193.7	2579
Khayyam	1	213.7	775	1284	2350	339	2246	2246
	2	198.6	684	1539	2756	304	2205	2205
	3	179.2	684	1552	2536	342	2328	2328
Average (S # 5)		197.2	714.3	1458.3	2547.3	328.3	2259.7	2259.7
Average (All)		*197.9*	*736.7*	*1488.9*	*2441.1*	*333.7*	*2255.5*	*2845.1*

Table 10 Table to show the formants and duration of the 'ɑe' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	214	873	1456	2413	355	1895	2241
	2	211	790	1372	2496	332	2080	2329
	3	212	852	1461	2497	426	1979	2314
Average (S # 1)		212	838	1430	2469	371	1985	2295
Junaid	1	255	832	1414	2579	416	2080	2338
	2	239	790	1497	2496	416	2080	2505
	3	273	790	1580	2579	416	1996	2547
Average (S # 2)		256	804	1497	2551	416	2052	2463
Khurram	1	197	707	1206	2329	332	2038	2246
	2	151	665	1456	2246	291	2246	2246
	3	197	707	1331	2288	416	1913	2246
Average (S # 3)		182	693	1331	2288	346	2066	2246
Sajjad	1	190.2	698	1560	2381	341	1970	2359
	2	197.8	707	1622	2454	332	2246	2422
	3	215.5	707	1664	2246	332	1913	2371
Average (S # 4)		201	704	1615.3	2360	335	2043	2384
Khayyam	1	204.1	681	1386	2399	352	1951	2797
	2	179.4	609	1549	2718	381	2337	2337
	3	185.5	687	1280	2386	355	2323	2323
Average (S # 5)		190	659	1405	2501	363	2204	2486
Average (All)		*208*	*740*	*1456*	*2434*	*366*	*2070*	*2375*

Table 11 Table to show the formants and duration of the 'eɑ' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	191.3	249	2080	3328	499	1539	2255
	2	218	352	2162	3455	446	1557	2186
	3	195	338	2055	3094	507	1547	2321
Average (S # 1)		201.4	313	2099	3292.3	484	1548	2254
Junaid	1	221	416	2038	2538	499	1580	2121
	2	183	416	1996	2454	582	1497	2205
	3	207	416	1955	2537	457	1996	2329
Average (S # 2)		203.7	416	1991.3	2509.7	512.7	1691	2218
Khurram	1	174	374	2205	2621	416	1622	2080
	2	165	332	2163	2870	416	1580	2038
	3	170	291	2163	2953	416	1539	2080
Average (S # 3)		169.7	332.3	2177	2814.7	416	1580.3	2066
Sajjad	1	206.7	332	2163	2912	332	1372	2288
	2	189.1	332	2121	2662	416	1456	2205
	3	214.2	332	2163	2704	416	1372	2329
Average (S # 4)		203.3	332	2149	2759.3	388	1400	2274
Khayyam	1	217	354	2080	2402	431	1466	2073
	2	206.8	408	2063	2471	429	1461	2063
	3	183.1	354	2147	2523	420	1461	2169
Average (S # 5)		202.3	372	2096.7	2465.3	426.7	1462.7	2068.3
Average (All)		*196.1*	*353.1*	*2102.5*	*2768.3*	*445.5*	*1536.4*	*2176.1*

Table 12 Table to show the formants and duration of the 'oi' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	220	416	873	2371	332	2329	2745
	2	185.7	416	873	2246	332	2329	3117
	3	203.8	332	873	2454	332	2413	2826

Average (S # 1)		203.2	388	873	2357	332	2353	2899.7
Junaid	1	203	416	1248	2205	332	2205	3619
	2	186	457	1123	2413	332	2246	3494
	3	202	416	1248	2246	332	2163	3785
Average (S # 2)		197	429.7	1206.3	2288	332	2204.7	3632.7
Khurram	1	165	416	998	2246	249	2163	2163
	2	191	416	915	2329	249	2413	2413
	3	207	374	956	2288	332	2246	2454
Average (S # 3)		187.7	402	956.3	2287.7	276.7	2274	2343.3
Sajjad	1	181.7	461	1031	2145	353	1925	2145
	2	174	416	1081	2246	249	1664	2246
	3	205.3	416	956	2288	249	1913	2496
Average (S # 4)		187	431	1022.7	2226.3	283.7	1834	2295.7
Khayyam	1	159.7	433	1124	2327	335	2329	2329
	2	163.2	419	1118	2307	349	2144	2144
	3	147	427	1125	2362	337	2250	2250
Average (S # 5)		156.6	426.3	1122.3	2332	340.3	2241	2241
Average (All)		*186.3*	*415.4*	*1036.1*	*2298.2*	*312.9*	*2181.3*	*2682.5*

Table 13 Table to show the formants and duration of the 'ɑẽ' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	233.4	540	1539	2579	473	2450	2812
	2	231.9	441	1543	2572	269	2499	3367
	3	209	522	1544	2494	332	2471	3326
Average (S # 1)		225	501	1542	2548	358	2473	3168
Junaid	1	243	540	1289	2704	416	2080	2080
	2	202	582	1372	2662	416	2080	2080
	3	201	582	1497	2704	416	1955	2205
Average (S # 2)		215	568	1386	2690	416	2038	2122
Khurram	1	203	457	1497	2621	332	2246	2246
	2	224	499	1497	2662	582	2246	2630
	3	226	582	1539	2662	540	2246	2246
Average (S # 3)		218	513	1511	2648	485	2246	2374
Sajjad	1	201	499	1456	2579	332	2163	2163
	2	222.7	499	1372	2496	260	2246	2246
	3	221	556	1385	2670	421	2289	2289
Average (S # 4)		215	518	1404	2582	338	2233	2233
Khayyam	1	208.9	517	1457	2444	352	2434	2434
	2	172	609	1463	2512	341	2408	2408
	3	198	518	1460	2591	376	1908	2426
Average (S # 5)		193	548	1460	2516	356	2250	2423
Average (All)		*213*	*530*	*1461*	*2597*	*391*	*2248*	*2028*

Table 14 Table to show the formants and duration of the 'oe' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	189.7	374	956	2413	344	1894	2153
	2	168.7	430	1033	2354	344	1808	2182
	3	178.3	439	947	2473	346	1895	2265
Average (S # 1)		179	414	979	2413	345	1866	2200
Junaid	1	185	540	1164	2454	457	2080	2296
	2	179	499	1123	2454	416	1788	2205
	3	179	499	1123	2413	416	1830	2121
Average (S # 2)		181	513	1137	2440	430	1899	2207
Khurram	1	146	416	956	2413	249	2246	2422
	2	199	457	998	2288	332	1913	2246
	3	199	416	956	2329	332	1955	2205
Average(S # 3)		181	430	970	2343	304	2038	2291
Sajjad	1	174.6	416	1123	2246	374	1622	2163
	2	181.2	374	956	2745	332	1747	2246
	3	165	332	956	2329	416	1622	2246
Average (S # 4)		174	374	1012	2440	374	1664	2218
Khayyam	1	192.3	372	1118	2583	346	1730	2077
	2	151.2	446	1116	2264	345	1725	2233
	3	187	437	956	2221	350	1662	2318
Average (S # 5)		177	418	1063	2356	347	1706	2209
Average (All)		*178*	*430*	*1032*	*2399*	*360*	*1835*	*2225*

Table 15 Table to show the formants and duration of the 'əĩ̃' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	222.1	430	1882	2205	268	2420	3441
	2	218.8	423	1816	2314	248	2414	3342
	3	210	435	1813	2441	338	2490	3529
Average (S # 1)		217	429.3	1837	2320	284.7	2441.3	3437.3
Junaid	1	233	457	1955	2288	457	2038	2288
	2	219	416	1955	2288	332	2246	2246
	3	204	416	2038	2288	374	2163	2163
Average (S # 2)		218.7	429.7	1982.7	2288	387.7	2149	2232.3
Khurram	1	189	416	1830	2371	332	2496	2496
	2	234	374	2080	2413	291	2496	2496
	3	233	416	1996	2496	332	2329	2787
Average (S # 3)		218.7	402	1968.7	2426.7	318.3	2440.3	2593
Sajjad	1	211	437	1903	2253	262	2318	2318
	2	199.9	434	2022	2261	266	2326	2326
	3	204.8	424	1923	2169	268	2370	2370
Average (S # 4)		205.2	431.7	1949.3	2227.7	265.3	2338	2338
Khayyam	1	196.9	439	2163	2163	247	2419	2419
	2	169.2	438	1960	2214	299	2329	2329
	3	191	375	1811	2364	353	2319	2319
Average (S # 5)		185.7	417.3	1978	2247	299.7	2355.7	2355.7
Average (All)		*209.1*	*422*	*1843.1*	*2301.9*	*311.1*	*2344.8*	*2591.3*

Table 16 Table to show the formants and duration of the 'ɪɑ' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	238.3	332	2038	2912	416	1539	2163
	2	218	354	2154	3016	430	1546	2230
	3	210	348	2228	3110	510	1555	2413
Average (S # 1)		222.1	344.7	2140	3012.7	452	1546.7	2268.7
Junaid	1	184	374	2163	2163	416	1580	2288
	2	202	332	2163	2163	416	1664	2205
	3	228	332	2163	2704	457	1622	2080
Average (S # 2)		204.7	346	2163	2343.3	429.7	1622	2191
Khurram	1	208	249	2288	2870	540	1497	2288
	2	216	291	2246	2662	416	1497	2329
	3	179	291	2163	2621	416	1456	2163
Average (S # 3)		201	277	2232.3	2717.7	457.3	1483.3	2260
Sajjad	1	212.5	332	1955	2246	416	1456	2163
	2	222.7	332	1996	2371	332	1372	2080
	3	217.7	332	1913	2288	416	1372	2205
Average (S # 4)		217.6	332	1954.7	2301.7	388	1400	2149.3
Khayyam	1	198	264	2244	2508	418	1474	2093
	2	190.5	329	2131	2401	425	1470	2107
	3	166	341	2209	2505	432	1457	2248
Average (S # 5)		184.8	311.3	2194.7	2471.3	425	1467	2149.3
Average (All)		*206*	*322.2*	*2136.9*	*2569.3*	*430.4*	*1503.8*	*2203.5*

Table 17 Table to show the formants and duration of the 'ɑũ̯' diphthong
S: Native Speaker of Urdu Language

Speaker	#	Duration	ST_F1	ST_F2	ST_F3	END_F1	END_F2	END_F3
Hassan	1	228	359	1897	2748	334	890	2032
	2	244.5	335	1884	2917	258	773	2401
	3	247.6	355	1941	2852	335	710	2642
Average (S # 1)		240	349.7	1907.3	2839	309	791	2358.3
Junaid	1	222	457	1747	2621	416	416	2329
	2	201	499	1622	2246	416	956	2413
	3	223	374	1747	2787	332	1040	2329
Average (S # 2)		215.3	443.3	1705.3	2551.3	388	804	2357
Khurram	1	207	416	1747	2496	332	832	2496
	2	257	416	1788	2454	332	374	2496
	3	224	540	1539	2121	332	832	2621
Average (S # 3)		229.3	457.3	1691.3	2357	332	679.3	2537.7
Sajjad	1	223	423	1893	2583	356	356	2360
	2	222.9	425	1894	2575	340	340	2405

	3	226	424	1900	2638	357	357	2594
Average (S # 4)		224	424	1895.7	2598.7	351	351	2453
Khayyam	1	211	475	1625	2400	336	673	2233
	2	181	433	1617	2485	335	873	2248
	3	195.4	505	1636	2527	334	630	2321
Average (S # 5)		195.8	471	1626	2470.7	335	725.3	2267.3
Average (All)		*220.9*	*429.1*	*1765.1*	*2563.3*	*343*	*670.1*	*2394.7*

Table 18 Table to show the formants of the cardinal vowels

Vowel	Speaker	F1	F2
i	Hassan	336	2184
	Junaid	345	2212
	Khurram	258.7	2404.7
	Khayyam	319.7	2275.7
	Sajjad	346.7	2194.3
	Average	321.2	2254.1
ɪ	Hassan	433	1902
	Junaid	437	1901
	Khurram	369.3	2021.7
	Khayyam	479	1929.7
	Sajjad	461.3	1821.7
	Average	435.9	1915.2
e	Hassan	428.7	2040.7
	Junaid	466.7	1977
	Khurram	426.7	2079.7
	Khayyam	427.5	2171.5
	Sajjad	424	2030
	Average	434.7	2059.6
ə	Hassan	666.3	1383
	Junaid	687.3	1296
	Khurram	598.3	1341
	Khayyam	740.3	1370.3
	Sajjad	659	1255.3
	Average	670.2	1329.1
ɑ	Hassan	802.3	1115.7
	Junaid	719.7	1153.3
	Khurram	711.3	1115.3
	Khayyam	777.3	1202.3
	Sajjad	689.3	1200.3
	Average	740	1157.4
u	Hassan	338	783.3
	Junaid	348.7	861.7
	Khurram	335.3	689
	Khayyam	406	982.3
	Sajjad	341.7	759.7
	Average	353.9	815.2
o	Hassan	426.3	860
	Junaid	503.3	861.3
	Khurram	439.3	778
	Khayyam	517.7	979
	Sajjad	426.7	861.7
	Average	462.7	868
ʊ	Hassan	486.7	1062.7
	Junaid	432.3	1065.7
	Khurram	395.7	937.7
	Khayyam	496	1157.3
	Sajjad	440.3	1004.3
	Average	450.2	1045.5