7

ACOUSTIC SPACE OF HINDI VOWELS

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INTRODUCTION

Since Peterson and Barney's article on formant patterns in 1952, acoustic studies of vowels has been studied for many languages. In most such studies formant frequencies were extracted in some phonetic and prosodic context but we are interested in the quadrilateral shape of vowel space, and relative positioning of the vowels of the language in that space. We also examine how this shape gets redefined under the influence of gender. According to Ohala (1999), vowels are classified in terms of an abstract 'vowel space' which is represented by a four-sided figure known as 'Vowel Quadrilateral'. This space bears a relation to the position of the tongue in vowel production.

Acoustic analysis of sounds has various implications. Mirza (1986, 357-369) uses acoustic analysis for preparing a phonetic guide and shows how a learner can make use of square (grid) formed by first two formant frequencies to adjust his tongue position so that he could pronounce the vowel accurately. Acoustic analysis of vowels also has its application in Second Language learning. Kewley-Port et.al. (1996) used acoustic analysis to demonstrate that vowel intelligibility varies depending on the vowels present in the native language. His was a data based study of American English vowels produced by Japanese speakers.

Ansarin (2004) gave a phonetic chart of Persian vowels prepared on acoustic grounds. This chart is believed to be the first authentic chart which has been developed on acoustic grounds using the formant values of all Persian vowels.

Vorperian & Kent (2007) considers age specific data on formant frequencies to create an anatomic-acoustic description of maturation of the vowel acoustic space for English. According to them, one advantage of formant specification is the systematic relationship between formant pattern and vowel articulation. They call the quadrilateral formed by average (f1 against f2) plot Vowel Acoustic Space.

The applications of acoustics of vowels especially in terms of acoustic space includes speech technology, TTS studies, Speaker characterization studies and speech pathology as well.

The present study aims to give acoustic space of vowels of Hindi as spoken in south Delhi. Relative positioning of vowels on vowel quadrilateral will help us determine the acoustic space of vowels in Hindi. For this, we will plot f1 against f2-f1 as obtained from the spectrograms of these vowel articulations. There are various articulatory descriptions of Hindi available in the literature but acoustic descriptions are limited in number. Some eminent scholars who have worked on Hindi are, R.N. Srivastava(1998), Fairbanks and Mishra (1966) and Kellog (1972), Kostic et al (1975), Koul (1994) etc. Most of these scholars worked on the phonetics and phonology of Hindi but Kostic et al (1975), gave the formant values for each Hindi vowel.

The present study takes into account all the 10 Hindi vowels which are, /i/, /ɪ/, /e/, /ɛ/, /ə/ /a/, /ɔ/, /o/, /u/, /U/. The study includes the calculation of formant frequencies with the help of PRAAT software and their respective plotting on the graphs.

In vowels, F1 can vary widely from 300 HZ to 1000HZ. The lower it is; the closer the tongue is to the roof of the mouth. Generally speaking higher F1 therefore means a more open vowel. F2 can vary from 850 Hz to 2500 Hz; the F2 value co-relates to the frontness and backness of the highest part of the tongue during articulation. F3 co-relates to lip rounding. There exists a direct relation between the vowel height and F1, as inversely proportional. Thus, a high vowel has a low F1 as in the high vowel [i] and [u] whereas low vowels have higher F1 as in the low vowel [a]. Again, F2 is higher for the front vowels such as [i] and low for the back vowels such as [u]. Similarly the amount of lip rounding will reduce all the formant frequencies. Hence the F1, F2 and F3 of all the rounded vowels will be lower compared to their unrounded counterparts. (Ladefoged, 1962: 104, Vaishna Narang, 1995: 52)

METHODOLOGICAL DETAILS AND PROCEDURAL STEPS INVOLVED

DATA ELICITATION PROCEDURES

SUBJECTS

Subjects for the present study are native and monolingual speakers of Hindi so that there is minimal influence of other languages. Subjects are from the semi-urban areas of Delhi. The age of the subjects range between 15-20 years. The educational qualification, social and economic status of all the subjects is quite uniform. All the subjects were born and brought up in Delhi. Five male and female speakers participated in the study.

DATA / SAMPLE

Words were chosen such that the vowel phonemes occur in all the positions, i.e. initial, medial and final. The speakers were made to speak each word thrice. Thus there are 30(10 vowels* 3words) stimuli and 900(3words* 10 speakers* 10 vowels* 3repetitions) samples. Thus a random sample of 900 words recorded. Out of this sample of 900 words, we selected words having vowel at medial position and this gave us a select sample of 300 words.

DATA RECORDING METHODS

The data was recorded in the sound proof recording room of the language Laboratory of Jawaharlal Nehru University. Recording and analysis was done using Praat Software. The voice files were converted into WAV file in order to save them for further use.

DATA ANALYSIS

PRAAT software was used for recording and analyzing data. Analysis using PRAAT includes calculation of formant frequencies. First the –f1 and – (f2-f1) values of all the three repetitions of every vowel were plotted for each informant. Then the average of –f1 and – (f2-f1) values of the three repetitions of each vowel were calculated and plotted for each speaker. After that that average of -f1 and – (f2-f1) for each vowel of all male and female speakers were calculated and plotted on Microsoft EXL sheet separately. Since the formant frequencies are inversely related to the traditional articulatory parameters; negative values had to taken for plotting. In addition, the frequencies have been arranged in accordance with the Bark scale, in which perceptually equal intervals of pitch are represented as equal distances along the scale.

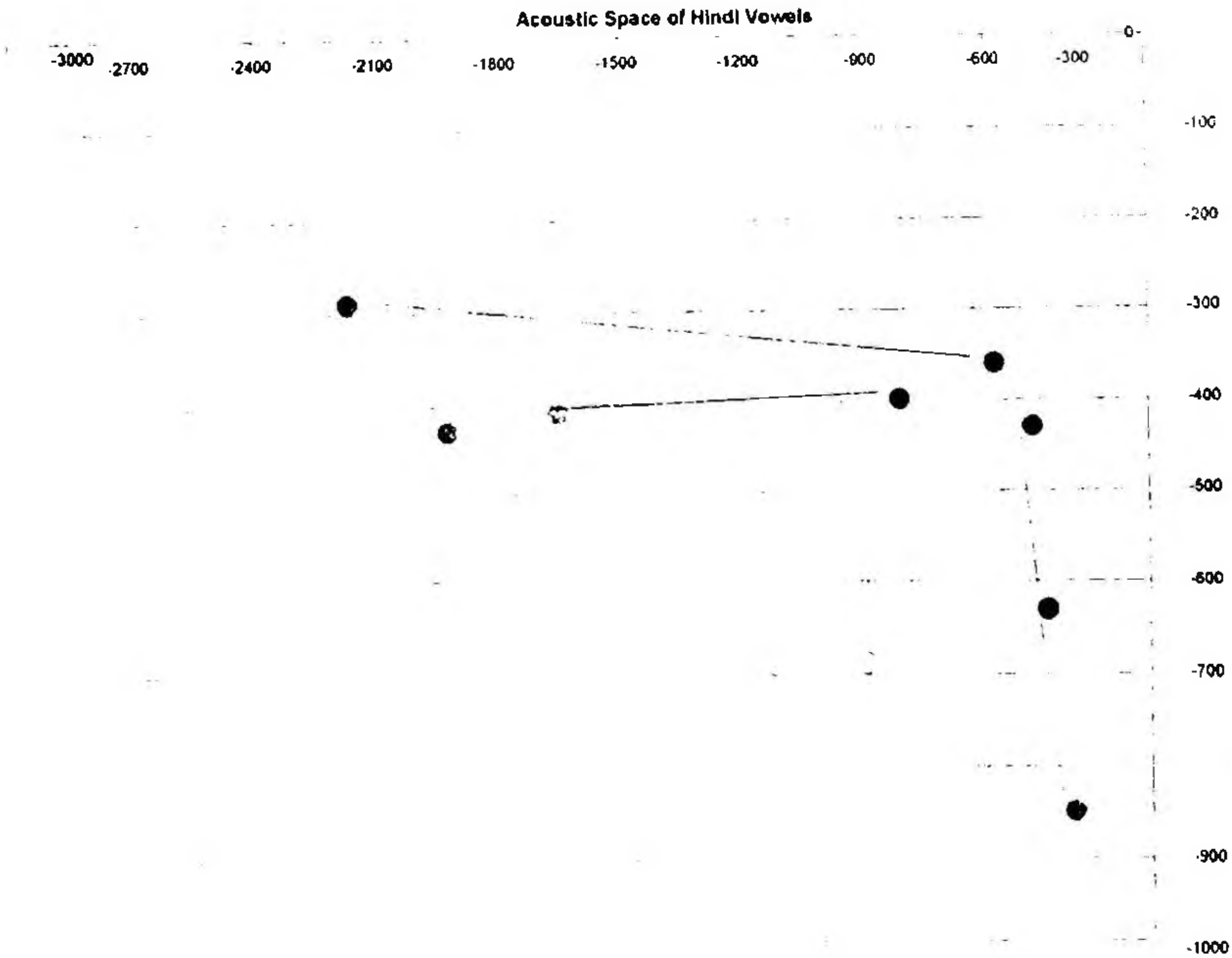
RESULTS AND DISCUSSION

ACOUSTIC SPACE

Table showing the average formant values for all vowels of all ten speakers of Hindi

Vowels	-f1	-f2	-(f2-f1)
/i/	-291.245	-2459.07	-2167.82
/ɪ/	-412.365	-2064.97	-1652.6
/e/	-432.415	-2355.05	-1922.63
/ɛ/	-677.14	-1920.37	-1243.23
/ə/	-687.64	-1581.88	-894.235
/a/	-848.77	-1243.84	-395.065
/ɔ/	-630.495	-1086.35	-455.855
/o/	-430.01	-920.495	-490.485
/u/	-360.605	-942.515	-581.91

Graph Showing the Acoustic Space of vowels of Hindi



The Vowel space of Hindi which we obtained after consolidating the data from ten speakers shows that vowels /o/ and /u/ are very close to each other in terms of vowel height. Vowel /ɛ/ and /a/ also show very less difference in terms of height. Moreover, vowel /ɛ/ is slightly centralized; its position being very closer to vowel /ə/ in terms of both height and front-back criterion.

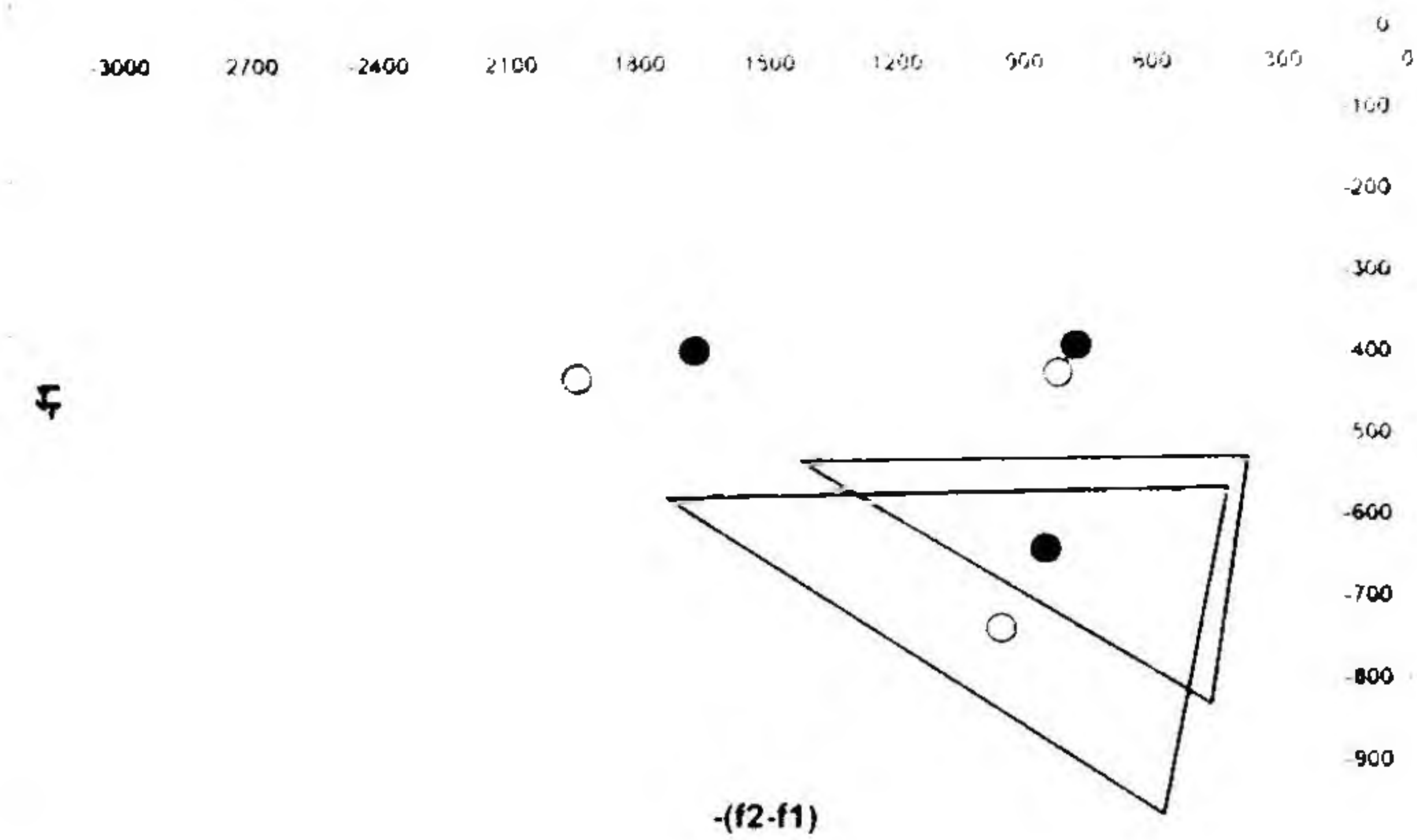
Anderson et.al (1996, 283) shows how the formant values of 5 Hebrew vowels differs with the difference in gender. Next section shows the average formant frequencies and their respective plots for the male and female speakers separately to show the gender differences.

Table showing average formant values of vowels for female and female Hindi speakers.

Female	-f1	-f2	-(f2-f1)	Male	-f1	-f2	-(f2-f1)
/i/	-293.92	-2683.62	-2379.79	/i/	-288.57	-2234.51	-1945.94
/ɪ/	-429.72	-2366.60	-1936.88	/ɪ/	-395.01	-1763.33	-1662.62
/e/	-454.85	-2493.52	-2038.67	/e/	-409.98	-2216.57	-1806.58
/ɛ/	-767.82	-2056.48	-1288.66	/ɛ/	-586.46	-1784.26	-1197.80
/ə/	-736.77	-1682.86	-946.09	/ə/	-638.51	-1480.89	-842.38
/a/	-881.20	-1309.02	-427.82	/a/	-816.34	-1178.65	-362.32
/ɔ/	-687.55	-1052.83	-360.85	/ɔ/	-573.44	-1119.87	-546.43
/o/	-427.64	-913.31	-485.67	/o/	-432.38	-927.68	-495.29
/u/	-387.66	-1023.29	-635.64	/u/	-333.55	-861.74	-528.19
/U/	-409.71	-1259.49	-849.78	/U/	-388.94	-1163.18	-774.23

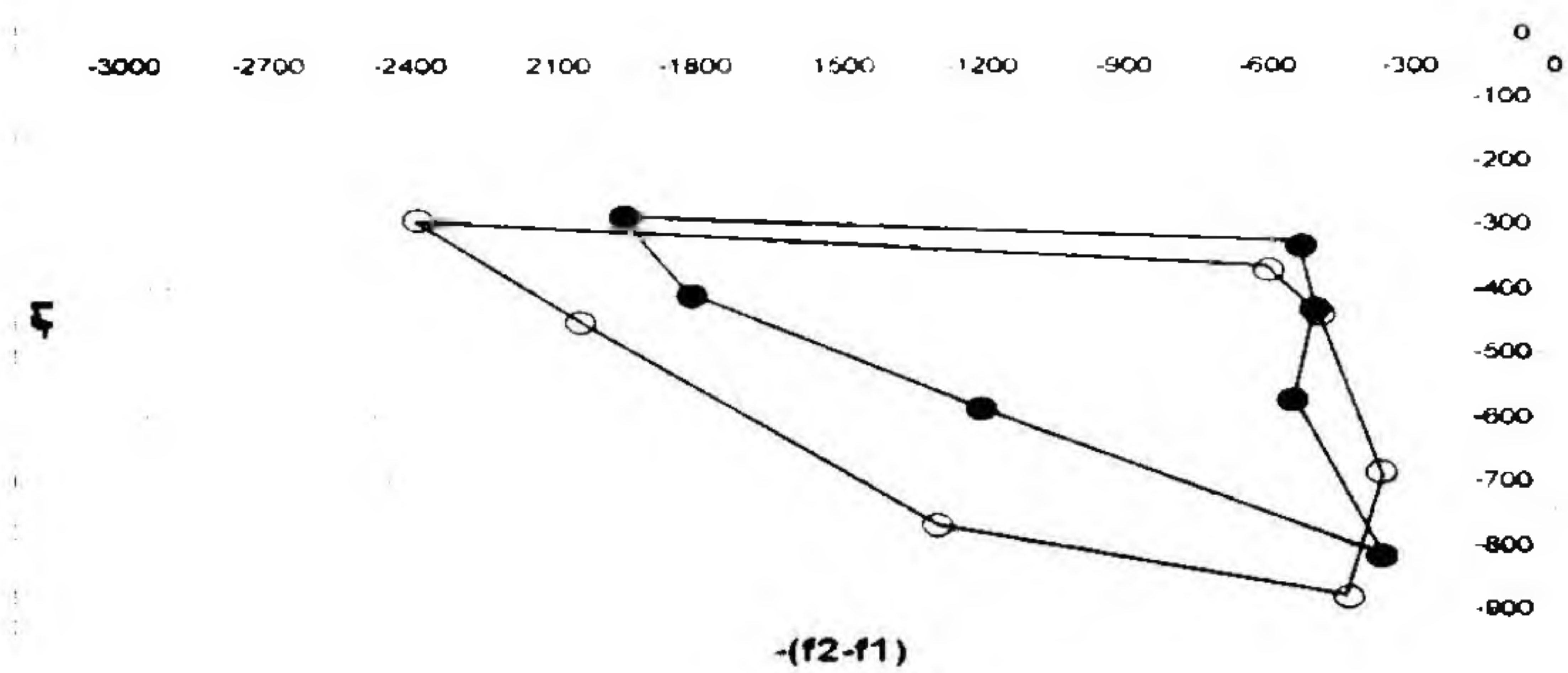
The graph showing the inner vowel space of male and female (points in lemon color represents female informants while the points in blue represent male informants)

inner vowel space



The graph showing the outer vowel space of male and female Hindi speakers (the points in white denote the female speakers while the points in black denote the male Hindi speakers)

OUTER VOWEL SPACE



We can sum-up the differences between the acoustic space of male and female by saying that the acoustic space of females is wide and moved towards left and the downwards while the acoustic space for males is smaller and moved towards upward direction. This again indicates higher f1 and f2 values for female informants.

DISCUSSION

The Vowel space of Hindi shows that vowels /o/ and /u/ are very closer to each other in terms of vowel height and backness because of very slight difference between the F1 and F2 of the two. Vowel /ɛ/ and /a/ also show very less difference in terms of height because of the slight difference in the f1 values of the two vowels. A very less difference in the F1 and F2 values of vowels /ɛ/ and /ə/ is responsible for the centralization of vowel /ɛ/ , its position being very closer to vowel /ə/ in terms of both height and front-back.

The acoustic space of the vowels gets redefined with the change in gender. The Acoustic space of the male and female informants consolidated in the form of the two triangles for the inner and outer space of male and female informants shows that the Acoustic space of female informants is wider and shifted to the left and lower side of the graph while the acoustic space of male informants is smaller in size and shifted to the right and upper side of the graph. This is also explained by the table for the formant values of male and female informants. It shows that the f2 of female informants is always higher than the male informants shifting the acoustic space of females to the left and f1 values of female informants are also higher than male informants shifting their acoustic space to the lower side of the graph.

The present study can be perused further by taking a much larger database and more parameters and variables other than formant frequency and gender respectively.

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