A FORMANT ANALYSIS OF THE CLEAR, NASALIZED AND MURMURED VOWELS IN GUJARATI

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Gujarati, a language of Gujarat State of Western India, has a series of clear (normal), nasalized and murmured (breathy or aspirated) vowels, the study of which is interesting both from a phonemic and from a phonetic point of view. I undertook a comparative formant analysis of these vowels based on spectrograms in June, 1966. Two lists were spoken by three informants: SK, RD and RT. List I contained clear and nasalized vowels spoken in words and in isolation. List II contained clear and murmured vowels spoken in words, phrases and sentences. List II contained commutable pairs. Nasalized murmured vowels were taken only as specimens.

Care was taken to prepare the lists according to the principles laid down by various phoneticians about the influence of the consonants on the vowel formants. Combinations of dental (alveolar) consonants with front vowels and of labial consonants with back vowels have generally been preferred in list I. Wherever this was not possible, an [h] or a velar or [l] was selected. It did not become possible to follow this criterion in the case of list II.

Both lists were read twice by each informant. RT read list II five times. Spectrograms were taken of one reading. Thus, in list I one example of each word has been measured for each person. There were 41 samples of the clear vowels and 44 of the nasalized vowels. List II contained 4-5 examples of each word, altogether 126 samples in pairs. RT had a few more. Three kinds of spectrograms were taken of each sample: wide band, narrow band, and narrow band section. In all, approximately 227o spectrograms have been taken and measured.

F_o (the fundamental) was measured on the section by dividing the distance between the first and the eleventh harmonic by ten. Generally the section was taken in the middle of the vowel. The frequencies of the formants were determined by a comparison between the three kinds of spectrograms. As the wide band spectrograms gave somewhat higher values, and seemed to be less reliable than the narrow band and section, the measurements were mainly based on the two latter

types. The peak of the envelope on the section was considered to be the centre frequency of the formant.

Generally there was no difficulty in measuring F_o. It was difficult to locate the centre frequency for weak and split formants and for two very close formants. Nasal consonants or [h] preceding a vowel also gave some difficulties.

The Kay Electric Sonagraph purchased in 1953 was used for analysis, the new Sonagraph purchased in 1967 was used for some control spectrograms.

The charts give a graphical display of F1 versus F2. There is overlapping between the areas of [a] and [ã] for all informants. Moreover, the areas of [a] and [ə̃] are very close to each other. The same is true of [u] and [ũ]. In RT a slight overlapping between [u] and [ũ] is seen. In SK [a], [ã], [ə̃] (and also [ə]) are very close to each other, while in RT [ɔ̃] is closer to [a]. In SK and RD [a] and [ə̃] are both found in the same area as [a].

There is almost a complete overlapping of the F1-F2 areas of the clear and murmured vowels (see charts).

Tables of averages of the clear and nasalized vowels, and the clear and murmured vowels have been given on pages 121-124.

Some of the charts have been given on pages 128 ff.

<u>Clear and nasalized vowels. The major characteristic features of nasalized vowels.</u>

The following features of the nasalized vowels have been observed:

(i) There is no constant difference in F_o. In many cases F_o is higher for the nasalized vowels, but not always. The average of F_o for [ĩ], [ũ] and [ã] of all informants is higher than in the corresponding oral vowels. Although the differences are small and not found in all vowels, it should be noted that they are constant in the case of the close or narrow vowels. More investigations are necessary.

(ii) The open nasalized vowels ([ɛ̃ ã ə̃ ɔ̃]) have a higher F1 than the corresponding clear vowels, whereas [ũ] has a lower F1 than [u]. In SK and RT the nasalized [ĩ] has a somewhat lower F1 than [i].

(iii) F1 for the open nasalized vowels is weakened. This has been said to be the major cue for nasality by various scholars, (1-5) and it is quite evident on the spectrograms.

Table 1. SK. averages of clear and nasalized vowels. (List I. A-B)

No.	Samples	No. of samples	F_o	Fs	F1	F2	F3	F4
1.	[i]	(9)	13o		263	2358	2989	4ooo
2.	[ĩ]	(5)	143		255	2758	325o	4o33
3.	[e]	(6)	131	(225)(1)	42o	22oo	2783	382o
4.	[ɛ̃]	(6)	132	237	671	2221	2825	3683
5.	[a]	(8)	118	(2o4)( )	747	14o9	2212	(2983?)
6.	[ã]	(6)	126	238	779	1375	2137	(365o?)(1)
7.	[ə]	(5)	128		6o3	133o	2455	(38oo?)(1)
8.	[ə̃]	(4)	13o	239	7o6	125o		3683
9.	[o]	(5)	127	(222)	493	77o		
1o.	[õ]	(6)	126	242	63o	9o5	(28oo?)(1)	
11.	[u]	(5)	128		313	721		
12.	[ũ]	(6)	142		253	625	(23oo?)(1)	2862

Table 2. RD. averages of clear and nasalized vowels. (List I. A-B)

No.	Samples	No. of samples	F_o	Fs	F1	F2	F3	F4
1.	[i]	(6)	135		274	2358	29oo	38o4
2.	[ĩ]	(5)	139		278	262o	32o3	394o
3.	[e]	(5)	132	(2o5)	427	2166	266o	389o
4.	[ɛ̃]	(6)	133	283	627	219o	2775	3927
5.	[a]	(9)	124	(2o4)	849	1315	2525	3211
6.	[ã]	(6)	13o	29o	932	1314	2379	3442
7.	[ə]	(5)	131	(21o)	595	145o	2475	3794
8.	[ə̃]	(4)	13o	236	785	136o	2462	(36oo?)(1)
9.	[o]	(5)	131	(2oo)	474	912	(245o?)(2)	345o
1o.	[õ]	(6)	134	256	617	949	2528	3542
11.	[u]	(5)	131		33o	816	(25oo?)(1)	
12.	[ũ]	(6)	133		268	678	2612	

Table 3. RT. averages of clear and nasalized vowels. (List I. A-B)

No.	Samples	No. of samples	F_o	Fs	F1	F2	F3	F4
1.	[i]	(6)	169		277	21o4	2558	3312
2.	[ĩ]	(5)	177		255	243o	3o6o	335o?
3.	[e]	(6)	147		357	1896	253o	3454
4.	[ɛ̃]	(6)	169	222	748	1971	2667	345o
5.	[a]	(8)	142		781	1196	2537	32oo
6.	[ã]	(6)	165	(2o5??)	795	1183	(2723?)	3212
7.	[ə]	(5)	16o		595	1225	25oo	3256
8.	[ə̃]	(4)	157	224	7o1	1175	2644	3382
9.	[o]	(5)	164		396	88o	26o6	3235
1o.	[õ]	(6)	161	256	677	925	2487??	337o
11.	[u]	(5)	149		276	816	249o	(325o?)(2)
12.	[ũ]	(6)	186		253	7oo	2228	(??)

Table 4. SK. averages of clear and murmured vowels. (List II-C.)

No.	Samples	No. of samples	F1	F2	F3	F4
1.	[bi, ǰi:r]	11	27o	24o9	3o27	3954
2.	[bi, ǰi:r]	11	272	2394	2959	38o2
3.	[pelo, se:ǰ]	8	452	2o59	2639	3583
4.	[pelo, se:ǰ]	8	478	1962	2631	36o7
5.	[mɛ:k]	5	542	2215	3o5o	3535
6.	[mɛ:k]	5	555	22o5	2925	3585
7.	[ba:r, maro, wali]	12	729	1344	2298	3647
8.	[ba:r. maro. wali]	9	712	1333	2278	3525
9.	[kəɣi]	5	562	1397	22o8	3422
1o.	[kəɣi]	5	545	1378	2238	3675(2)
11.	[mo:r, ko:ɣ, po:r, do:ɣ. ko]	2o	493	83o	2413	3656
12.	[mo:r, ko:ɣ, po:r, do:ɣ. ko]	18	494	867	2437	3623
13.	[du:dh]	4	28o	942	2575	3825
14.	[du:d]	4	282	9o8	255o	3687

Table 5. RD. averages of clear and murmured vowels. (List II-C.)

No.	Samples.	No. of samples	F1	F2	F3	F4
1.	[bi, či:r]	8	253	2438	315o	38o3
2.	[b̥i, č̥i:r]	8	249	2487	3o28	3831
3.	[pelo, se:ǰ, me:k]	12	463	21o1	2689	3686
4.	[p̥elo, s̥e:ǰ, m̥e:k]	12	466	21o1	276o	3931
5.	[ba:r, maro, wali]	11	852	1229	2595	3288
6.	[b̥a:r, m̥aro, w̥ali]	11	852	1229	2595	3288
7.	[kəɾi]	4	564	1363	2298	3725
8.	[k̥əɾi]	4	577	1375	2419	3800
9.	[mo:r, ko:ɾ, po:r, do:ɾ, ko]	19	482	872	25o5	3348
1o.	[m̥o:r, k̥o:ɾ, p̥o:r, d̥o:ɾ, k̥o]	19	5o4	911	26o7	3273
11.	[du:dh]	4	3o4	931	2442	365o?(1)
12.	[d̥u:d]	4	35o	944	241o	346o

Table 6. RT. averages of clear and murmured vowels. (List II-C and D.)

No.	Samples.	No. of samples	F1	F2	F3	F4
1.	[bi, ǰi:r]	8	259	2169	2824	3467
2.	[b̤i, ǰ̤i:r]	7	259	2121	2764	3468
3.	[pelo, se:ǰ, me:l]	12	392	1817	26o4	3446
4.	[p̤elo, s̤e:ǰ, m̤e:l]	6	378	1751	2662	35o8
5.	[mɛ:k]	4	485	1887	27oo	3419
6.	[m̤ɛ:k]	2	55o	1862	2725	355o
7.	[ba:r, maro, wali, pa:ʔ, taro, ma:l, lawo]	22	759	1172	2688	3698
8.	[b̤a:r, m̤aro, w̤ali, p̤a:ʔ, t̤aro, m̤a:l, l̤awo]	1o	759	1161	27o4	3761
9.	[kəʔi]	4	514	1415	2279	3438
1o.	[k̤əʔi]	4	5o7	13oo	24o2	3444
11.	[mo:r, ko:ʔ, po:r, do:ʔ, ko, boɭ̃]	22	388	867	26o8	3583
12.	[m̤o:r, k̤o:ʔ, p̤o:r, d̤o:ʔ, k̤o, b̤oɭ̃]	13	39o	882	265o	3633
13.	[du:dh]	4	29o	962	2525	3o62
14.	[d̤u:d]	3	282	932	2525	2983

I have noted weakening of F2 for the nasalized [ũ] in SK. Fant has referred to such a possibility. (1)

(iv) Higher formants are weakened. F3 is more affected than F4, and is sometimes eliminated. Both F3 and F4 tend to be raised.

The exact location of F3 and F4 sometimes makes difficulties because the formants may be split, and there may be extra resonances.

This observation is also generally in accordance with the observations made by other phoneticians.

(v) A sub-formant (a nasal formant) in the open nasalized vowels appears between 2oo-3oo cps. This F_s is said to be a secondary cue for nasality. However, it seems to be a very important cue. F_s of nasalized vowels is higher in frequency than a sub-formant occurring in clear vowels. It is also stronger in intensity.

(vi) There seems to be a zero in the open nasalized vowels between 4oo-5oo cps. This is also mentioned as a characteristic feature of nasalization of vowels. The valley in this frequency area seems to be due to an anti-resonance and not simply due to the raising of the formants in the process of nasalization.

Weakening of the third harmonic and reinforcement of the second is worth noting.

(vii) Small weak peaks are found at irregular frequencies. Extra formants are found, but they differ according to vowels and informants. However, the frequency region pointed out by Hattori, Fujimura and Kajiyama still seems to be the main region of such formants (between 1ooo and 25oo cps).

(viii) I have noticed an increase in the bandwidths of formants, especially of F1, in some spectrograms. However, I have not observed this in F1 of [ĩ] and [ũ]. Probably F2 of [ũ] sometimes has more bandwidth than F2 of [u]. I have not undertaken any measurements of formant bandwidth.

(ix) Gujarati vowels seem to be uniformly nasalized throughout. In this respect they differ from the French nasalized vowels (cp. Hattori (2). Also see Kongsdal in ARIPUC(1966) (3)). The

nasalized vowels in French Canadian, as investigated by Jean Gondron, seem to possess similar features. Kongsdal has, however, found a constant degree of nasalization in isolated French vowels.(3)

Clear and murmured vowels.

(i) Lowering of pitch is said to be an important characteristic feature of murmured vowels.(6) My measurements do not support this assumption. It must, however, be remembered that the measurements of F_o for different vowels were made approximately in the middle of the vowel, and not at exactly the same place.

(iia) There are no constant and regular differences between the formant frequencies of clear and murmured vowels. But many times the formants of the murmured vowels are higher than those of the clear vowels. The difference is, however, so small that one cannot take this into account. The overlapping is obvious.

The second harmonic of the murmured vowels often seems to be weaker in energy than the corresponding harmonic of the clear vowels. In nasalized vowels this harmonic is stronger than that of the clear vowels.

(iib) The formants of clear vowels are more clearly visible than those of nasalized vowels. A comparison between the nasalized and murmured vowels gives the same result. This does not mean that the formants of murmured vowels are quite normal and regular. Many irregularities are seen in the spectrograms, varying for different persons and word samples, a few being common to all informants. F1 of open murmured vowels is not always affected by the process of murmurization or aspiration. If it is affected, it is weakened. The following characteristics have been noticed: (1) Weakening of F1, (2) Weak and split higher formants. (3) A hole in the spectrogram in the higher frequency region, or sometimes lower. This may be found in the spectrograms of clear vowels, too. (4) F4 seems to be weaker than F3 in contradistinction to the nasalized vowels. (5) Only a few times noise has been noticed at very high frequencies. I did not attempt to measure formants higher than F4.

(iii) Whereas F_s of nasalized vowels is raised a little, that of the murmured vowels seems to be slightly lower.

(iv) Extra formants seem to occur in the same frequency regions as have been mentioned in the discussion of the nasalized vowels.

(v) Sometimes an extra stress is heard. It is not clear whether the murmured vowels are normally perceived as more strongly stressed than the clear vowels.

(vi) No constant change in the length of the murmured vowels has been observed, but exact measurements have not been undertaken.

In bisyllabic words the consonant following the murmured vowel is relatively shorter than the consonant following the clear vowel. In some cases the second vowel is also of shorter duration.

References:

(1) G. Fant, Acoustic Theory of Speech Production, pp. 148-149, and 159.

(2) S. Hattori, K. Yamamoto, and O. Fujimura, "Nasalization of vowels in relation to nasals", JASA 3o (1958), pp. 267-274.

(3) Ole Kongsdal Jensen, Træk af de franske nasalvokalers akustiske og fysiologiske struktur, pp. 12-23. Also "Features of the acoustical and physiological structure of the French nasal vowels", ARIPUC 1 (1966), pp. 59-66.

(4) Svend Smith, "Vocalization and added nasal resonance", Folia Phoniatrica (1951), p. 167.

(5) House and Stevens, "Analog studies of nasalization", Journal of Speech and Hearing Disorders 21 (1956), pp. 218-232.

(6) P. B. Pandit, "Nasalization, aspiration, and murmur in Gujarati", Indian Linguistics (1957).

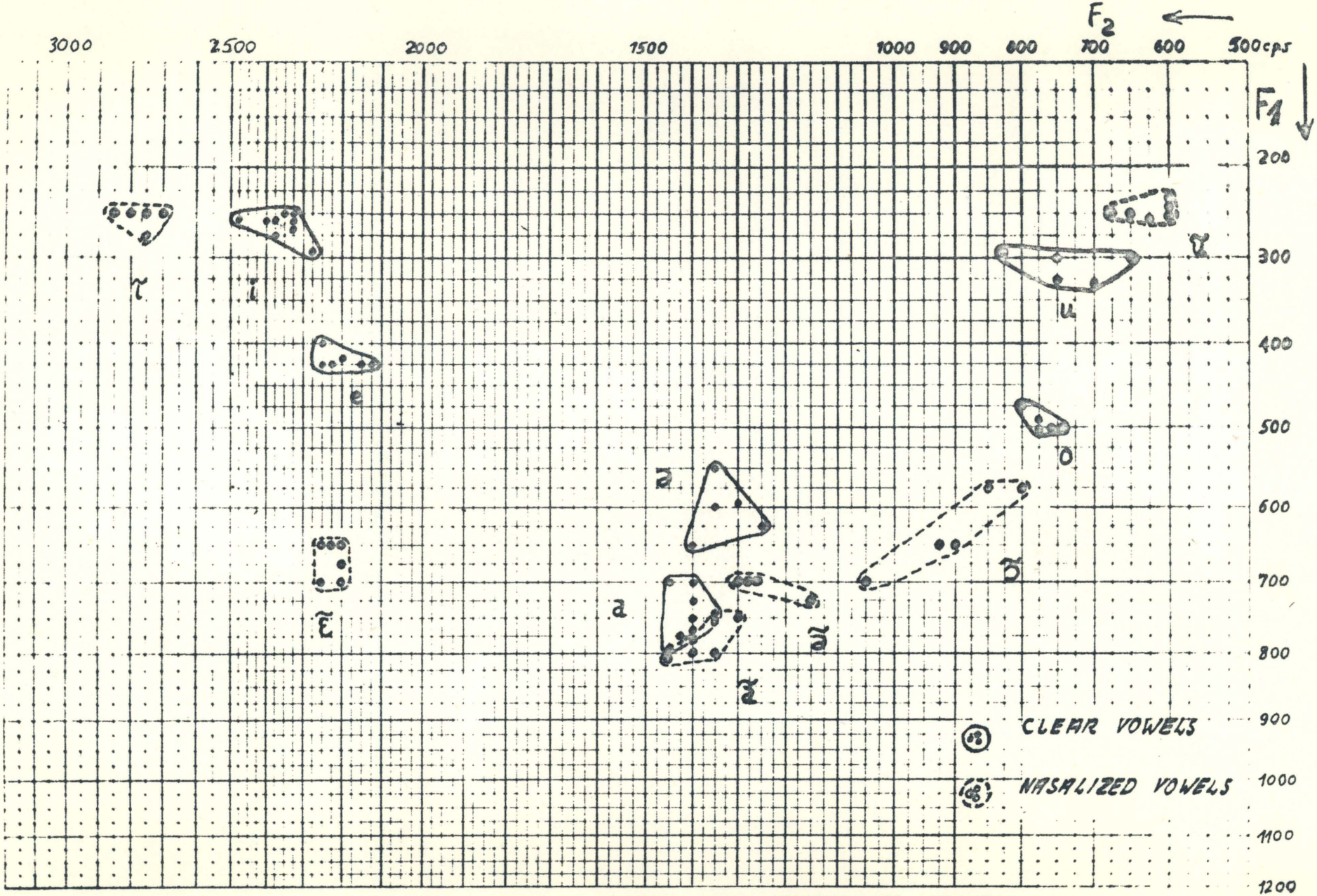

Chart 7 SK CLEAR AND NASALIZED VOWELS

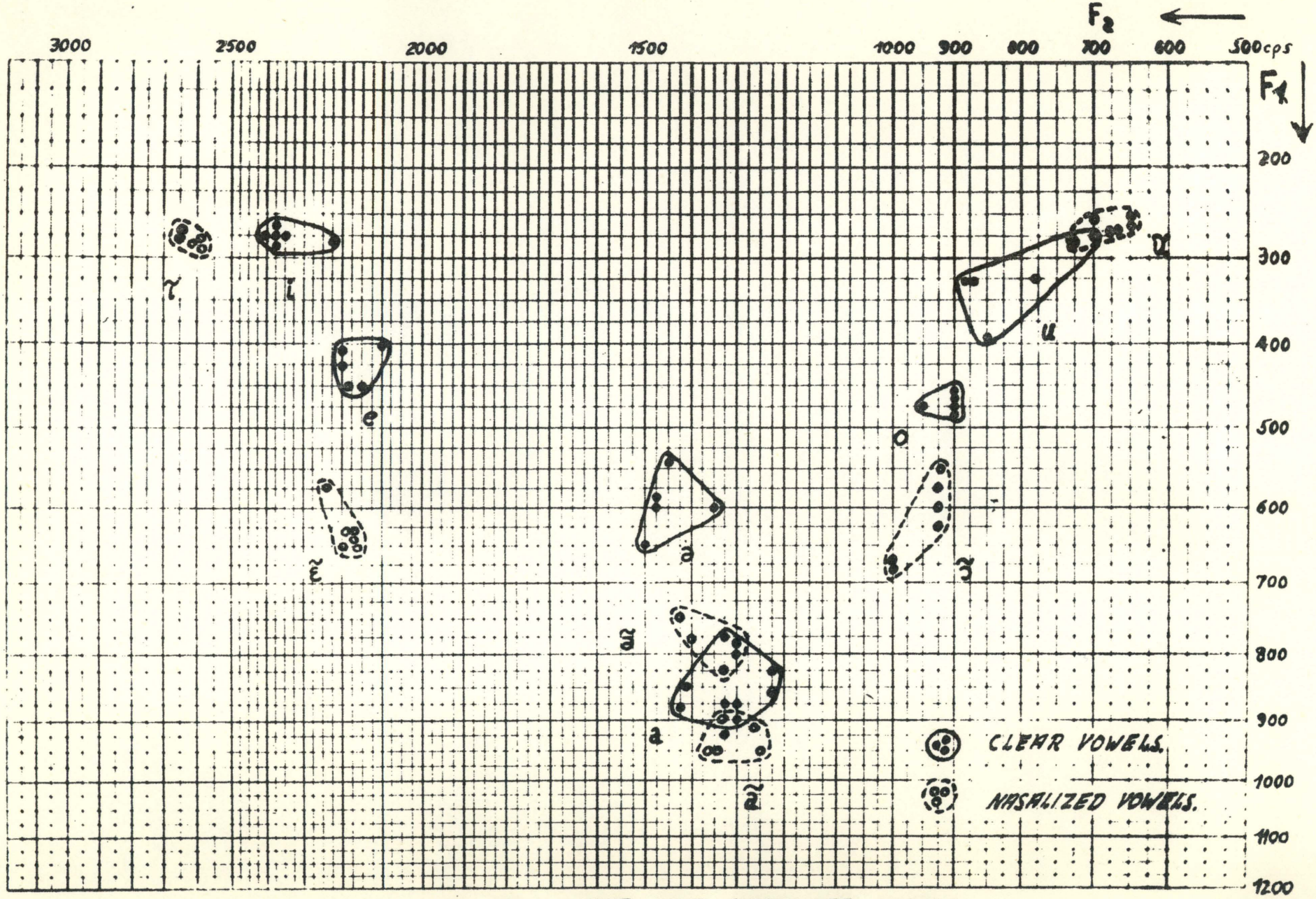

Chart 8 RD CLEAR AND NASALIZED VOWELS

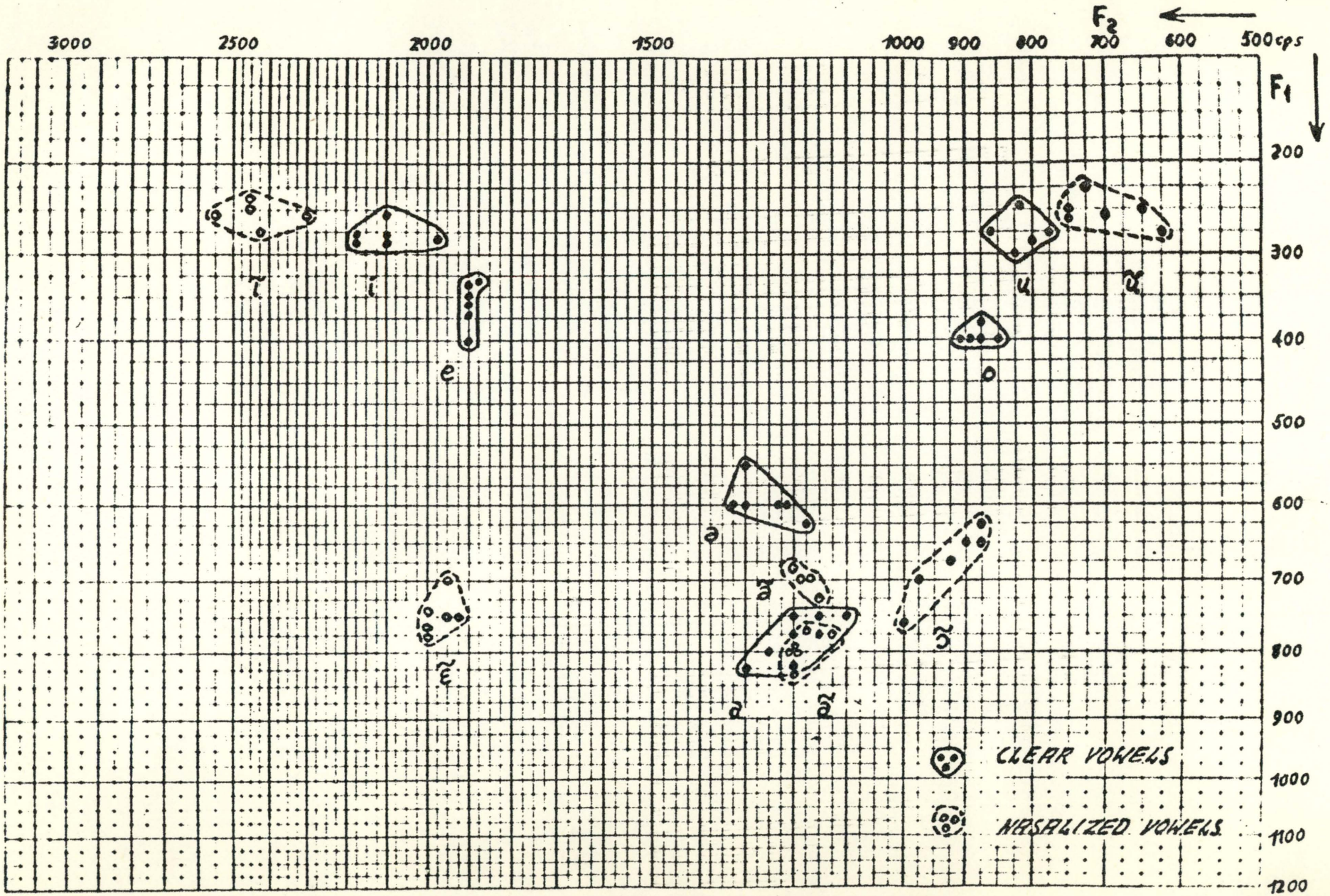

Chart 9 RT CLEAR AND NASALIZED VOWELS

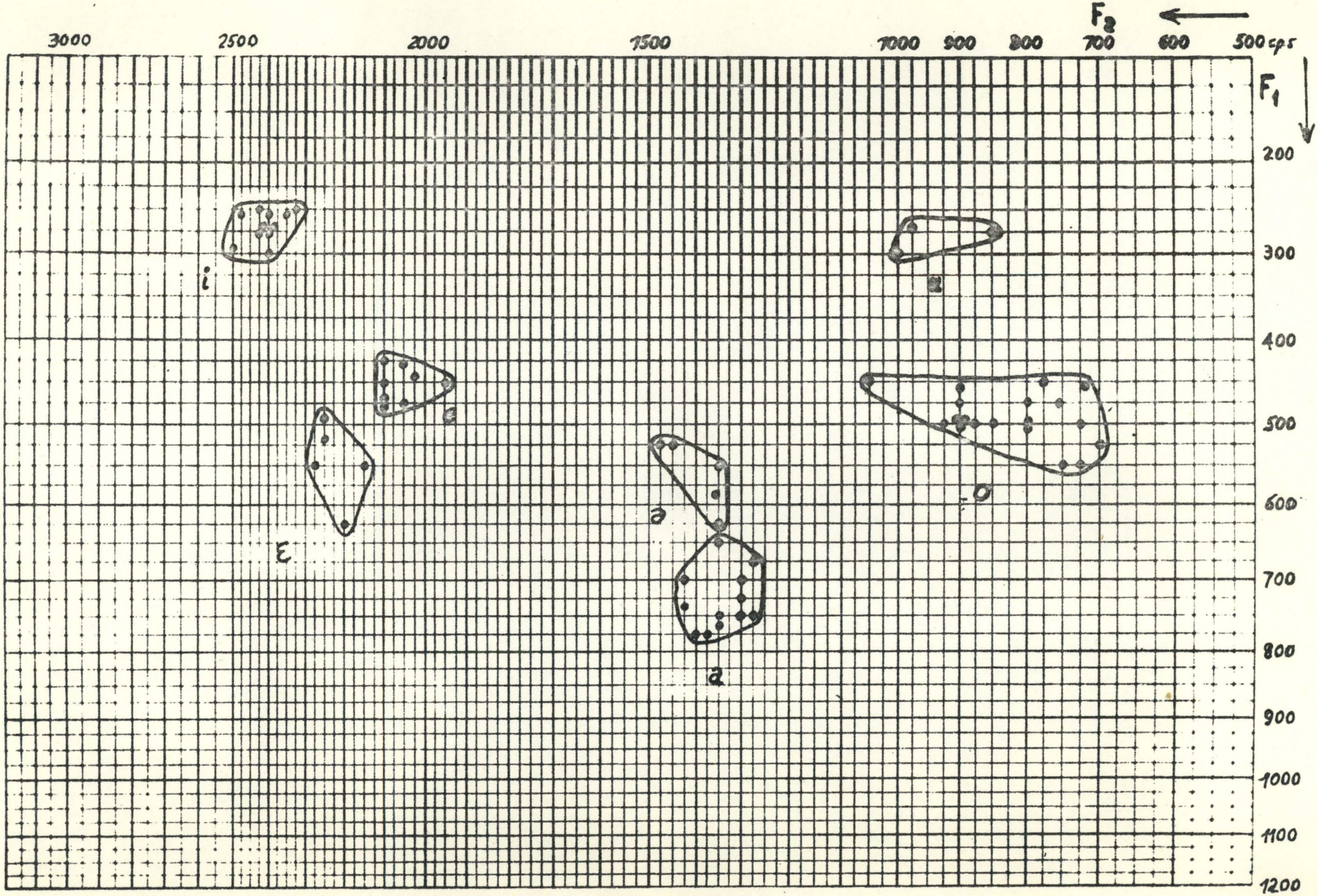

Chart 10 SK CLEAR VOWELS

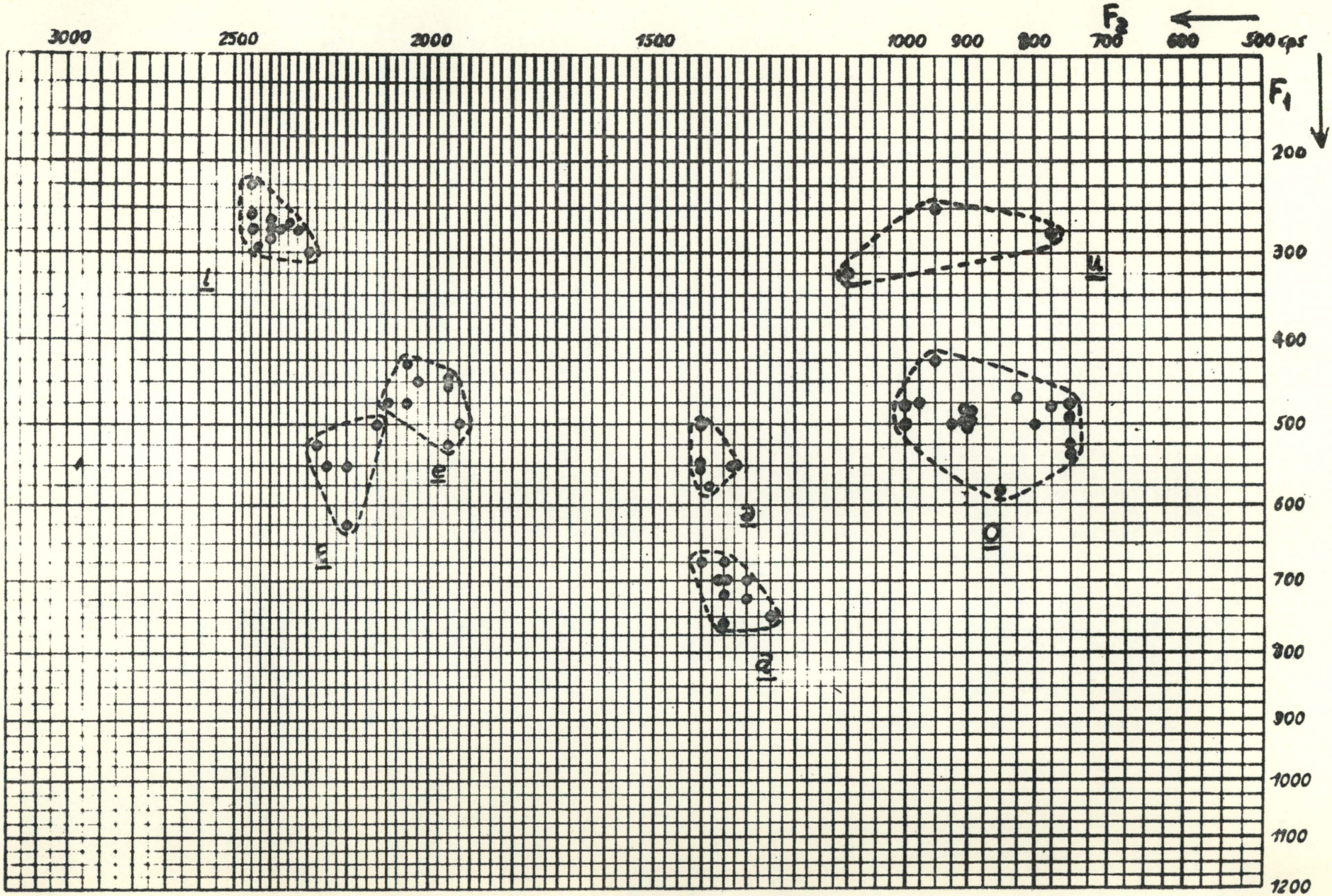

Chart 11 SK MURMURED VOWELS.