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AN ACOUSTIC OVERVIEW OF PORTUGUESE VOWELS

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The vowels of Portuguese have been the subject of many varying studies. The vast majority of these studies has been largely intuitive in nature and They have also largely followed the same pattern. The tremendously complex phonological system has been reduced to generalizations, which though commendable in their effort and intent, do not present the reality of detail and thorough investigation that Portuguese merits. The very fact that Portuguese possesses nasal vowels leads to that important distinction. The history of the Romance languages would, in turn, suggest that tonic versus atonic vowels should also be studied because of their different evolution.

Linguists familiar with Portuguese would generally agree that in tonic position the vowel system of Brazilian Portuguese is made up of a set of seven oral vowels. In graphic form it appears this way:

i	u
e	o
ε	ο
a	

These vowels were first studied acoustically by Lacerda & Canellada in a comparative study of Spanish and Portuguese vowels. They made recordings of their own voices and analyzed the acoustic signals using a chromograph, an early type of oscilloscope. They studied not only the tonic vowels, but the atonic vowels as well. However, no conclusions could be drawn from their research because of the primitive nature of their equipment. Their findings were first published serially in the Revista de Filología Española beginning in 1942, and in book form in 1945. In 1950, Lacerda published a book analyzing the sounds of Portuguese utilizing the same research techniques.

During the same period, great strides in the area of experimental phonetics were being made in the United States. In 1941, a spectrographic development project was begun by Bell Telephone Laboratories. By 1943, an experimental model had been completed and was being used to explore "visual hearing" possibilities. The most

significant feature for our purposes was its ability to separate the compound sound wave into its unique components allowing phoneticians to readily distinguish vowel quality.

Only a few researchers have applied spectrographic techniques to the study of Portuguese vowels. Among the more significant studies dealing with tonic vowels are Head (1965), Martins (1973), Fails (1977), Godínez (1981) and Clegg & Fails (1983). A review of most of these articles is found in Godínez (1981).

Head's study was phonemic in nature but based on acoustic results. He did a distinctive feature analysis of Carioca and Lisbon speech. Martins' study is a careful, controlled analysis of Peninsular tonic vowels. She chose 8 university educated males and had them repeat a sentence inserting 69 different test words to provide both syntactic and phonetic control. Godínez patterned his study somewhat after that of Martins. He analyzed 9 male speakers from different regions of Brazil. He had them repeat a set of 7 words within a model sentence and then, like Martins, averaged the results. The results from the study by Martins appear in Table 1.

Vowel	F1	F2
i	294	2344
e	403	2084
ɛ	501	1893
ɐ	511	1602
a	626	1326
ɔ	531	994
o	426	864
u	315	678

Table 1. The formant frequencies of Portuguese tonic oral vowels according to Martins (1973).

In our previous studies (Fails 1977; and Clegg and Fails (1983) we obtained formant frequencies for the tonic oral vowels which compare favorably with the results of Martins and Godínez. The averaged results of our 1983 study are given in Table 2.

Vowel	F1	F2	F3
i	280	2187	2915
e	402	1824	2608
ɛ	522	1770	2546
a	709	1342	2339
ɔ	514	983	2295
o	435	857	2229
u	318	832	2357

Table 2. The formant frequencies of Portuguese tonic oral vowels according to Clegg & Fails (1983).

In addition to oral vowel studies, there have also been traditional studies on the nasal vowel system in tonic position. They posit a system of five nasalized vowels for Portuguese where the distinctions between open and closed /e/ as well as between open and closed /o/ are neutralized. They can be represented graphically this way:

ĩ		ū̃
ẽ̃	õ̃	õ̃

The most significant acoustic studies dealing with nasal vowels are those of Head (1965), Head & Lacerda (1966) and Almeida (1971) and (1976). We read the results of our own research on nasalized vowels at the AATSP convention in August. A summary of our results include the following:

1) The high nasalized vowels [ĩ, ū̃] showed approximately the same formant frequencies as their oral counterparts.

2) The mid nasalized vowels [ẽ̃, õ̃] lie acoustically in between the oral vowels [e, ɛ] and [o, ɔ] respectively. This is acoustic evidence for the neutralization of the mid vowels in a nasal environment.

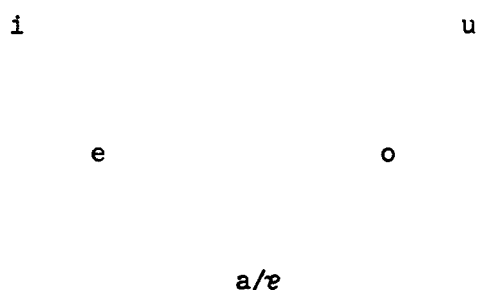
3) The low vowel when nasalized is markedly raised causing an adjustment in the traditional vocalic triangle. The averaged results are given in Table 3.

Vowel	F1	F2	F3
ĩ	285	2203	3013
ẽ	466	1902	2685
ẽ̃	556	1434	2381
õ	486	987	2362
ũ	318	900	2371

Table 3. The formant frequencies of Portuguese nasalized vowels according to Clegg & Fails (1983).

The results of these previous studies aid in understanding certain aspects of the vowel system. However, there are several other areas that need to be considered. One of these is vowel timbre in atonic position. Both Martins and Godínez, as well as most others, studied only tonic vowels.

Most traditional studies indicate that in atonic non-final position there is a set of five oral vowels. There is some controversy as to whether this is really a five vowel set or if there are seven vowel phonemes as in tonic position. There is also some question as to the timbre of the phoneme /a/. A graphic representation of the five vowel set looks like this:



In final atonic position, consensus provides a set of three oral vowels as well. However, no acoustic data is available for these vowels either. A graphic representation looks like this:



The purpose of this study was to add spectrographic evidence to substantiate the existing data and to provide new information on atonic vowels.

We designed a wordlist including examples of each vowel in tonic, initial atonic, pretonic, post-tonic and final atonic positions. We also provided examples of each of these categories in both open and closed syllables. In order to test for open /e/ and /o/ in atonic position we included the sentences "Um café pequeno é um cafezinho" and "Uma bola pequena é uma bolinha." Finally, a series of words with consonant clusters was added that could trigger the "i intercalada."

We followed general procedure in the selection of our informants. We were cautious to ensure their normal speech capability, uniform age and sex and socio-economic background. In the literature it was pointed out, as might be expected, that there was a sharp difference between male and female speakers. We therefore chose 10 male informants. They ranged in age from twenty to twenty-nine and came from five different regions of Brazil (São Paulo, Rio de Janeiro, Brasília, Paraná and Paraíba).

Recordings were made using the condenser microphone of a Sony 5600 cassette recorder. The cassettes were then played through a Harman/Kardon CD301 tape deck into a Digital Sona-Graph™ model 7800. We first made 3D Sonagrams displaying from 0-4000 Hz. through a 250 Hz. analysis filter. We also ran power spectra on one speaker to corroborate the 3D spectrograms and to provide additional information on the intensity. The nuclei of the vowel formants were measured with a calibrated hand ruler and were recorded. F1 and F2 were subsequently plotted on Koenig graph charts for visual facility.

FINDINGS

1) **Tonic.** The formant frequencies we obtained for the tonic oral vowels compared favorably with results of other scholars and with our own previous research. The only area of difference is in the second formant of phoneme /u/. Our results in this study indicate a higher second formant. No appreciable difference was found in formant frequencies between tonic vowels in open syllables and those in closed syllables. The averaged results are given in Table 4 and are graphed in Fig. 1.

Vowel	F1	F2
i	293	2149
e	383	1936
ɛ	539	1659
a	713	1264
ɔ	545	939
o	399	780
u	318	896

Table 4. The formant frequencies of Portuguese tonic oral vowels.

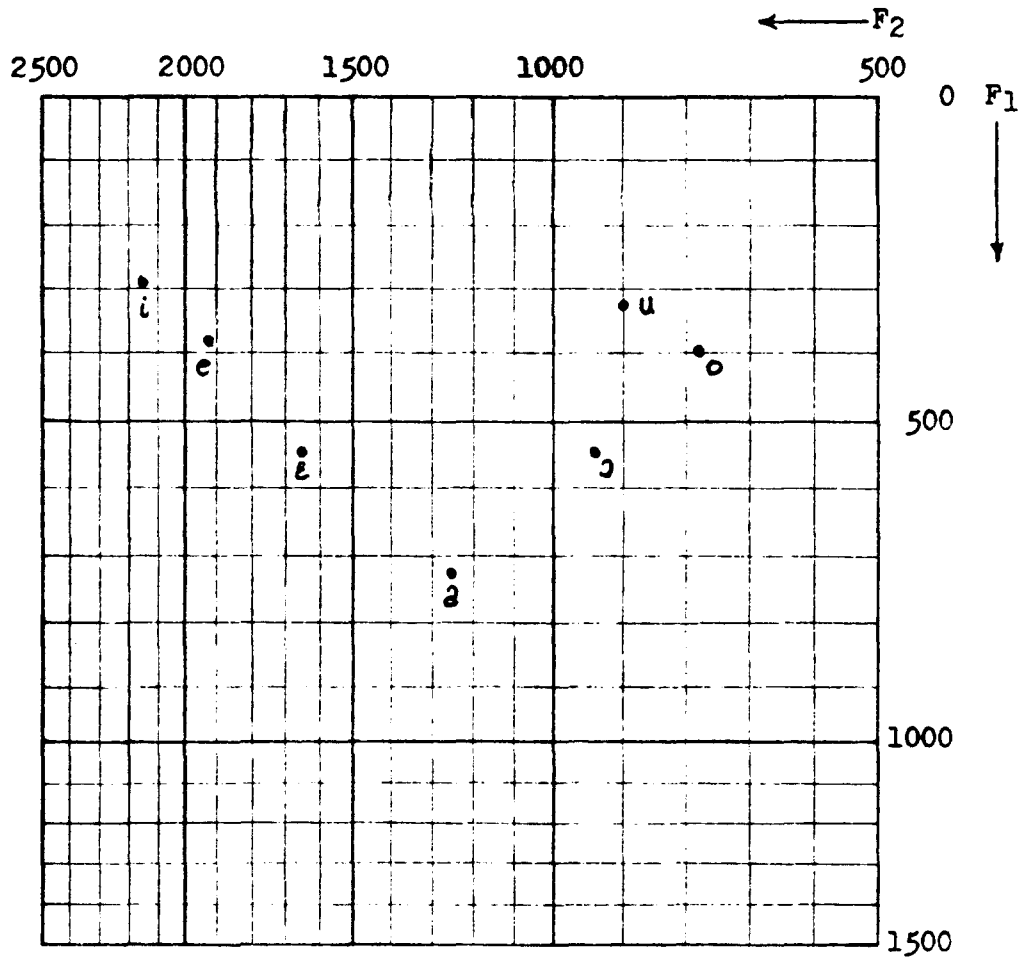


Fig. 1. The tonic vowels of Portuguese.

2) Pretonic. We found no appreciable differences between the formant frequencies of initial atonic versus pretonic vowels nor between open and closed syllables for these two positions. Our results show a five-vowel system. The averaged formant frequencies for pretonic vowels are given in Table 5 and graphed in Fig. 2.

Vowel	F1	F2
i	286	2120
e	364	1940
a	635	1319
o	388	779
u	292	821

Table 5. The formant frequencies of Portuguese pretonic oral vowels.

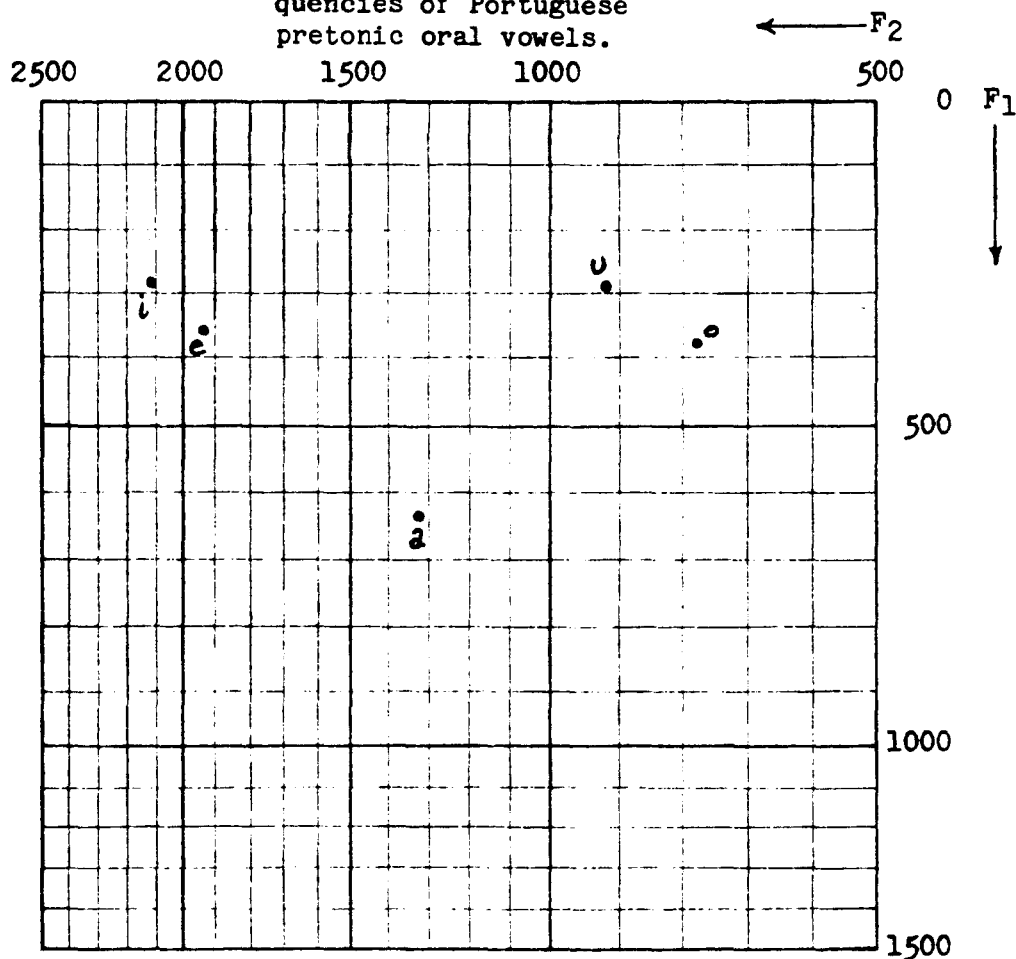


Fig. 2. The pretonic vowels of Portuguese.

The test words ("opção", "optar", "repugnante" and "advogado") designed to elicit the "i intercalada" produced varying results. There were several cases where there were no "intercaladas". Those cases where a high vowel was produced resulted in a first formant frequency of 315 and a second formant frequency of 2042 which compares to a tonic /i/.

We also included in our study the two sentences that examined the open /e/, /o/ in pretonic position. Azevedo (1981, p. 12) notes that while the opposition between open and closed /e/, /o/ is systematically neutralized in atonic position, the open vowels may occur in pretonic position in morphological derivations. In our pairs of words "café/cafezinho" and "bola/bolinha" we found that the second formants of both vowels compare favorably with the second formants of their tonic counterparts. However, the first formants are situated midway between the first formants of the tonic open and closed phonemes /e/ and /o/. This is shown graphically in Fig. 3.

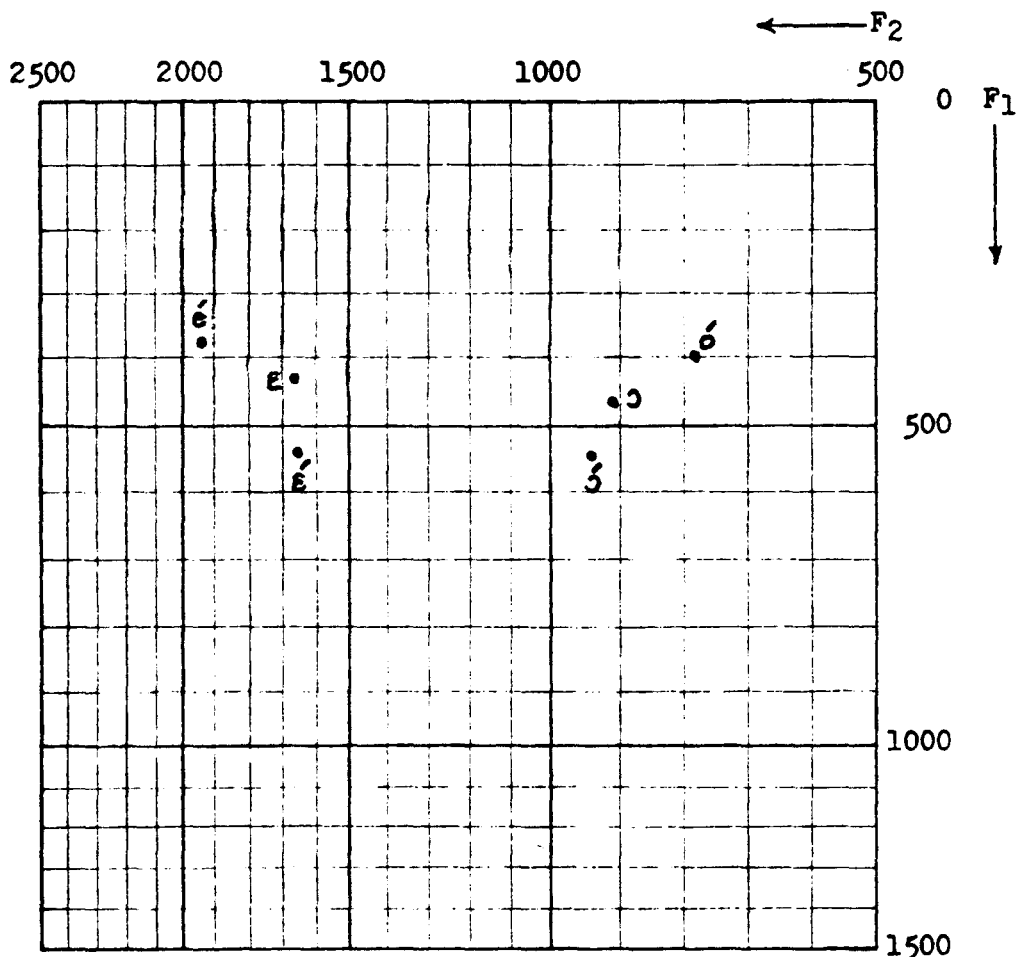


Fig. 3. The pretonic vowels of "cafezinho" and "bolinha" compared with open and closed tonic /e/ and /o/.

3) **Post-tonic.** The formant frequencies of post-tonic vowels are shown in Table 6 and graphed in Fig. 4.

Vowel	F1	F2
i	303	1942
e	348	1900
a	408	1340
o	328	918
u	300	822

Table 6. The formant frequencies of Portuguese post-tonic oral vowels.

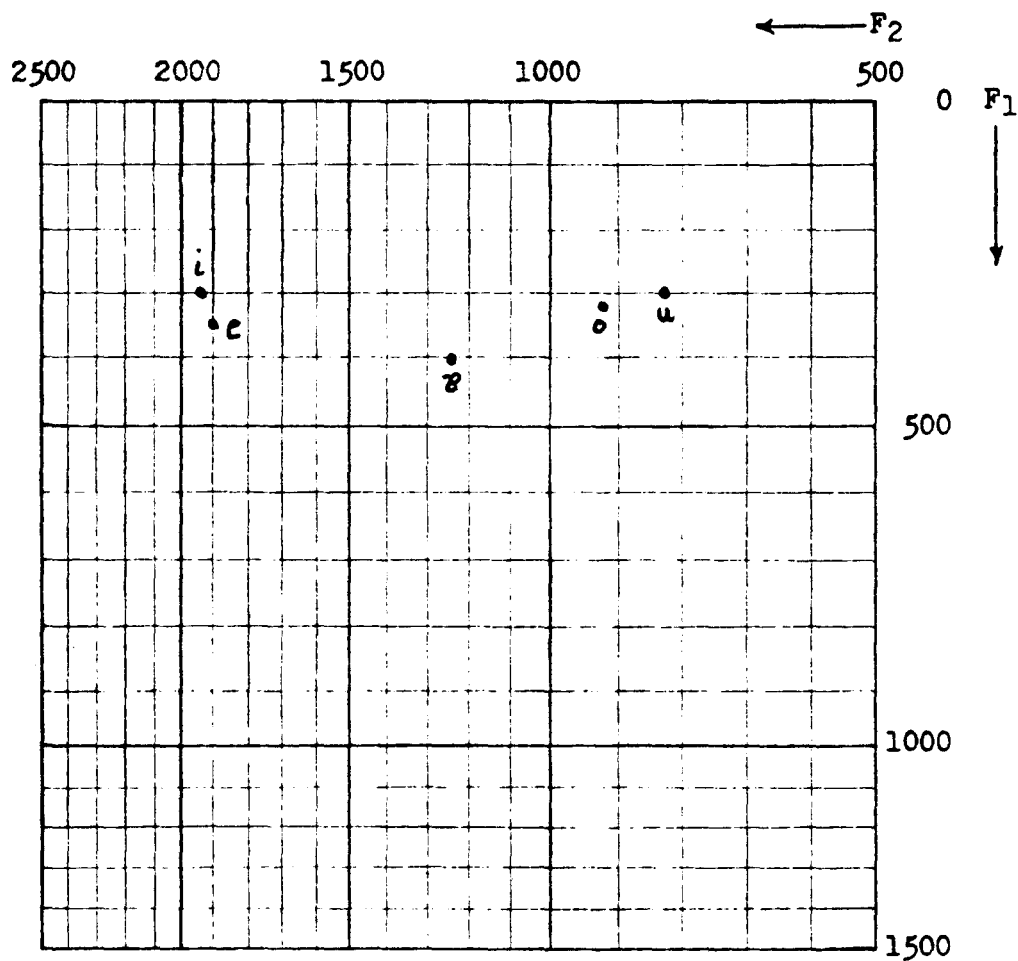


Fig. 4. The post-tonic vowels of Portuguese.

3) **Final atonic.** We found no appreciable difference in vowel formant frequencies between open and closed syllables in final atonic position. The formant frequencies of final atonic vowels are shown in Table 7 and graphed in Fig. 5.

Vowel	F1	F2
i	290	2039
e	445	1416
u	329	809

Table 7. The formant frequencies of Portuguese final atonic oral vowels.

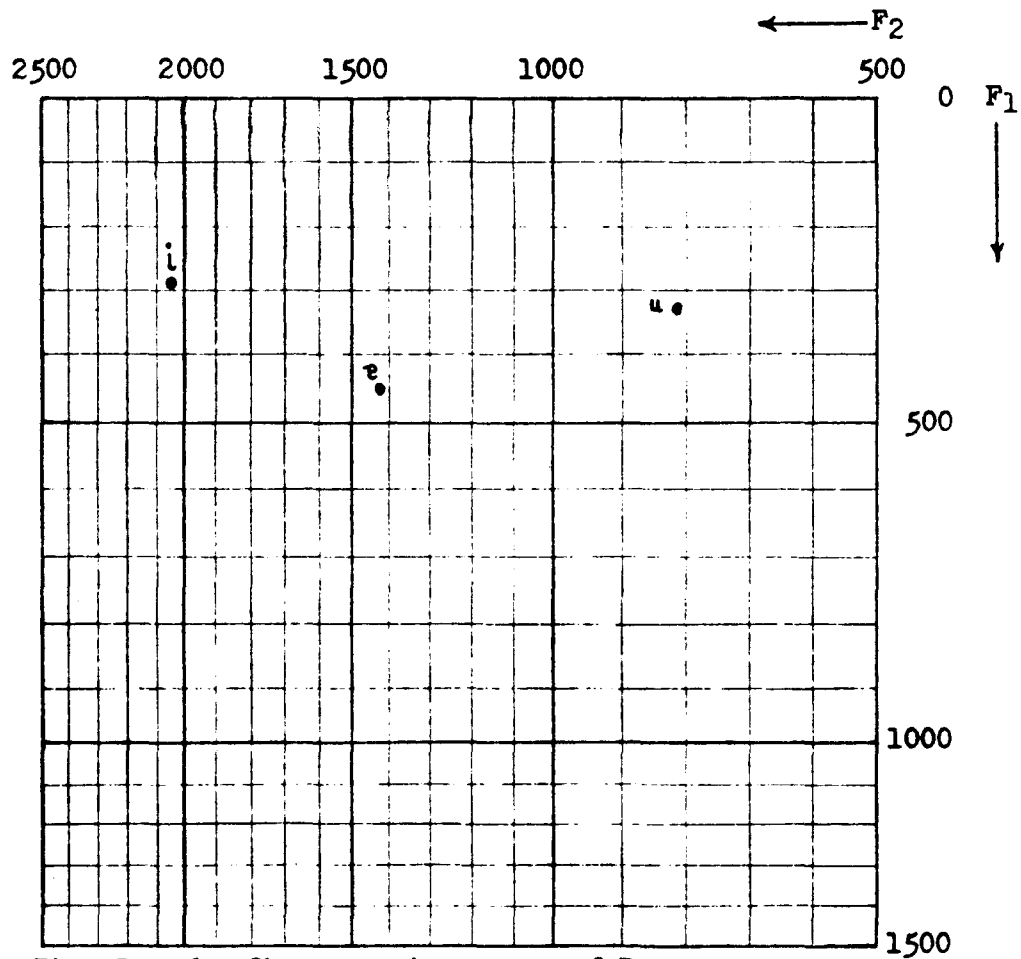


Fig. 5. The final atonic vowels of Portuguese.

CONCLUSIONS

The results of our study show:

- 1) There is no appreciable difference in vowel formant frequencies between open and closed syllables in any position.
- 2) There is no appreciable difference in vowel formant frequencies between initial atonic and pretonic vowels.
- 3) There is a seven-vowel system in tonic position in Brazilian Portuguese as shown in Fig. 6. They are included to provide a point of comparison for the atonic vowels.
- 4) There is a five-vowel system in pretonic position shown in Fig. 6. In this system, the high vowels /i/ and /u/ are comparable to their tonic counterparts. The mid vowels /e/ and /o/ are comparable to tonic closed /o/ and /e/. They do not converge to a point midway between the open and closed mid vowels. The low vowel /a/ is slightly raised as compared with its tonic counterpart.
- 5) The post-tonic vowels are shown in Fig. 6. There is a merging of the high and mid vowels in post-tonic position. These vowels appear to moving towards a neutralization. The low vowel /a/ is highly raised to a position above that of the final atonic /a/.
- 6) There is a three-vowel system in final atonic position. This is shown in Fig. 6.

This research should serve to broaden as well as confirm what we know about the vowel system in Brazilian Portuguese.

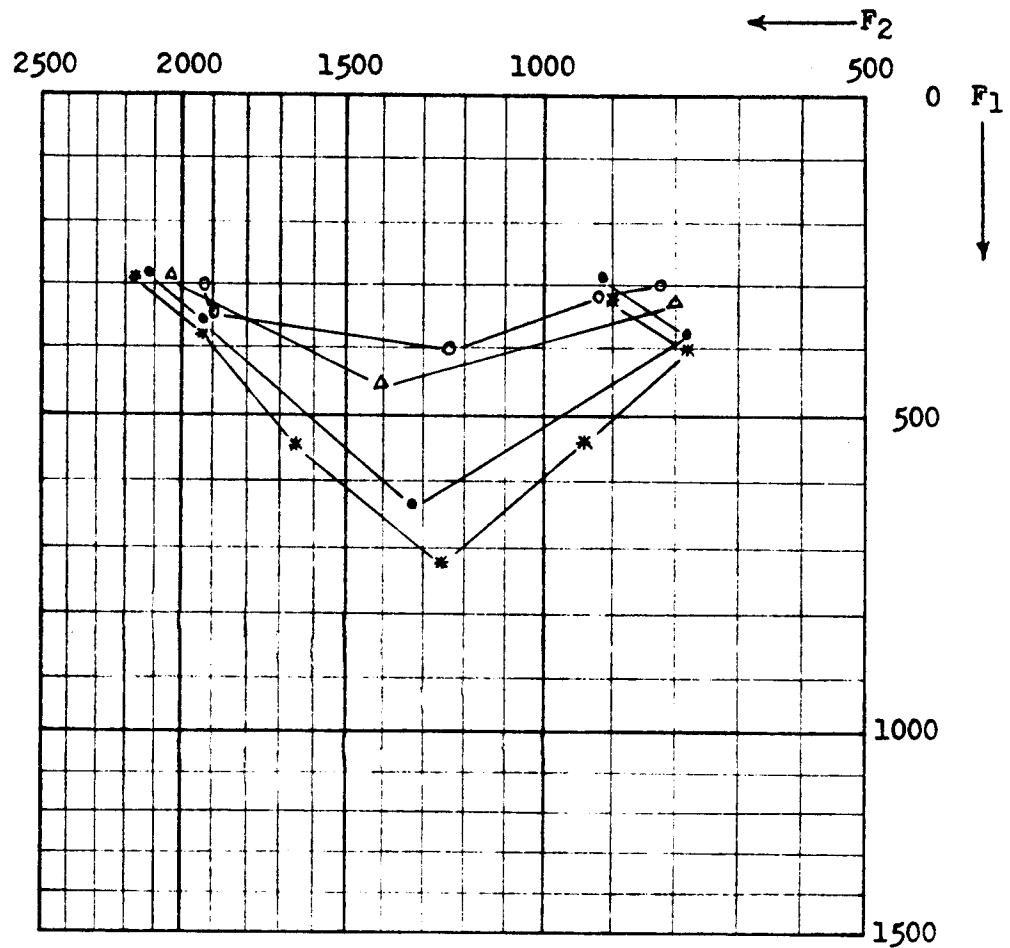


Fig. 6. A comparison of the tonic and atonic vowels of Portuguese. Tonic vowels are designated with $*$, pretonic vowels with \bullet , post-tonic vowels with \circ , and final atonic vowels with \triangle .

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