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CONTENTS

ORAL VOWEL REDUCTION IN BRAZILIAN PORTUGUESE

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Abstract: In Brazilian Portuguese, there are at least two types of unstressed syllables: pretonic and final. Phonologically, this is shown by the fact that the system of 7 phonemic oral vowels in stressed syllables is decreased to 5 in pretonic syllables and to 3 in unstressed final syllables. This paper examines the changes in vowel quality and quantity which occur as the number of contrasts decreases. Spectrographic analysis of formant frequencies and durations for 4 male speakers show that centralization is greater and durations shorter finally than in pretonic position.

Reduction of vowels in unstressed syllables occurs in most, if not all, languages to some degree, although the amount and type varies from language to language. Factors which have been found to differentiate stressed from reduced vowels have included vowel quality and duration (Lehiste 1970, Gay 1978 a, b).

Portuguese is normally analyzed as having three different phonemic oral vowel sets depending on location of stress: /i e ɛ a ɔ o u/ in stressed position, /i e ə o u/ before stressed syllables, and /i ə u/ in unstressed word-final position (Mattoso Camara 1972). For convenience, vowels in syllables preceding stressed syllables will be called by the traditional term pretonic.

Few acoustic studies of Portuguese have been published and most of these deal with Continental Portuguese (see Godinez 1978b for a bibliography of phonetic studies of Portuguese). Of those on Brazilian Portuguese, only two are relevant to our study. Godinez (1978a) measured formant frequencies of stressed vowels in Brazilian Portuguese and compared them with those reported by Delgado Martins (1973) for Continental Portuguese. Major (1979, 1981) measured syllable length as a by-product of his study of interstress intervals in Brazilian Portuguese.

Our study was designed to determine the nature of formant frequency change as the contrastive sets went from seven phonemes in stressed position, to five in pretonic position, and three in word-final position. We also were interested in what durational differences might accompany the qualitative differences.

PROCEDURES

Words for this study (Table 1) were selected so that vowels in the three stress conditions appeared in similar phonetic environments. The principal

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Table 1. Words Used for Analysis

Set A. Words elicited in the Frame 'Diga _____ mais uma vez, tá?'

Disyllabic			Trisyllabic		
1. chique	[ˈʃi̲ki̲]	'chic'	10. chiqueza	[ʃi̲ˈkezə]	'elegance'
2. seca	[ˈse̲ke̲]	'drought'	11. secura	[se̲ˈkurə]	'dryness'
3. cheque	[ˈʃɛki̲]	'check'	12. checado	[ʃe̲ˈkadu]	'checked'
4. saca	[ˈsa̲ke̲]	'sack'	13. sacola	[sə̲ˈkɔlə]	'handbag'
5. choque	[ˈʃɔki̲]	'shock'	14. chocado	[ʃo̲ˈkadu]	'shocked'
6. soco	[ˈso̲ku̲]	'blow with the fist'	15. soquete	[so̲ˈketʸi]	'ramrod'
7. suco	[ˈsu̲ku̲]	'juice'	16. sucoso	[su̲ˈkozu]	'juicy'
8. Chica	[ˈʃi̲kə]	a nickname	17. sicario	[si̲ˈkaryu]	'hired assassin'
9. saco	[ˈsa̲ku̲]	'bag'	18. sequestro	[se̲ˈkwɛ̃stru]	'kidnapping'
			19. sacrario	[sə̲ˈkraryu]	'sanctuary'
			20. socorros	[so̲ˈkɔxus]	'aids'
			21. sucata	[su̲ˈkatə]	'scrap iron'

Set B. Phrases with Final Vowels Between Voiced Consonants

1. tese grada	[ˈtɛzi̲ ˈgradə]	'scholarly thesis'
2. gole grande	[ˈgɔli̲ ˈgrãdʸi]	'big gulp'
3. Lisa Gomes	[ˈli̲zə̲ ˈgomis]	a female name
4. gola grande	[ˈgɔlə̲ ˈgrãdʸi]	'big collar'
5. jogo duro	[ˈjogu̲ ˈduru]	'hard game'
6. siso duro	[ˈsizu̲ ˈduru]	'hard wisdom tooth'

Underlined vowels were used for formant frequency comparisons.

corpus (hereafter referred to as Set A) consisted of 21 words: 9 disyllabic words with stress on the first syllable and 12 trisyllabic words with stress on the second syllable. The disyllabic words were selected to provide at least one example of the 7 phonemic stressed vowels and 3 examples each of the 3 phonemic unstressed word-final vowels. In the disyllabic words, all stressed vowels occurred in the environment /s _ k/ or /ʃ _ k/; all unstressed vowels in the environment /k _ # m/.

The 12 trisyllabic words of Set A were stressed on the second syllable. Pretonic vowels were in the same /s _ k/ and /ʃ _ k/ environments as the stressed vowels in disyllabic words. Seven trisyllabic words derived from disyllabic words containing the seven stressed vowels provided examples of how each of these underlying vowels is realized as one of the 5 phonemic pretonic vowels. To these were added five unrelated words containing each of the 5 phonemic pretonic vowels in the environment /s _ k/ or /ʃ _ k/. Because there were no consistent differences between pretonic vowels derived from stressed vowels and other pretonic vowels, all pretonic vowels have been grouped together in the analysis.

Words from Set A were placed in the carrier sentence "Diga _____ mais uma vez, 'ta?" 'Say _____ one more time, OK?' The tag question was added to induce speakers to place sentence emphasis on <u>mais</u> or <u>vez</u>. The speakers were asked to read the sentences naturally and were allowed to record the sentences as many times as they wanted or needed.

Because unstressed final vowels after /k/ often turned out to be partially or totally devoiced, accurate measurement of formant frequencies was difficult. To provide additional data on final vowels, a supplementary set of 6 phrases (Set B) with unstressed word-final vowels in voiced environments was added.

The sentences and phrases were read by four adult male speakers of three different dialects of Brazilian Portuguese: Carioca (Speakers A and P), Gaucho (Speaker R) and Mineiro (Speaker G). Recordings were made at the University of Kansas Language Laboratory and broad-band expanded scale spectrograms (80-3200 Hz.) were made on a Kay Sonagraph Model 6061-B. Formant frequencies were normally measured at a point after transitions where both F1 and F2 seemed to have leveled off and become stable.

Measurements were made of the F1 and F2 frequencies of:

1) stressed vowels in the 9 two-syllable words of Set A

2) pretonic vowels in the 12 three-syllable words of Set A

3) final unstressed vowels in the original 9 two-syllable words of Set A and in the six additional words of Set B.

Since each word was read by 4 speakers, a total of 144 vowels were compared.

Durations of Set A utterances, test words, and syllables, vowels, and consonants within the test words were also measured. No intensity measurements were made but visual inspection of the spectrograms shows, as expected, that unstressed vowels appear to be lower in intensity than stressed vowels, especially in final position.

RESULTS

FORMANT FREQUENCY

First and second formant frequencies of each of the 120 vowels from Set A are given in Appendix A. Formant frequency means for vowels in Set A are given in Table 2.

Comparison of Stressed and Pretonic Vowels

Mean formant frequencies of each stressed and pretonic vowel are plotted in Figure 1. One continuous line connects stressed vowels and another continuous line connects the pretonic vowels. Broken lines show the acoustic displacement of the unstressed vowels with respect to the stressed ones.

Mean F1 frequencies of pretonic vowels are at a point halfway between those of adjacent vowels, which corresponds to a lowering of the higher vowels [i, e, o, u] and a raising of the lower vowels [ɛ, a, ɔ].

Mean F2 frequencies of the pretonic vowels [e, ə, o, u] all indicate centralizing tendencies, with the back vowels exhibiting more centralization than [e]. However, the F2 of [i] has nearly the same F2 frequency as its stressed counterpart. Since F2-F1 correlates well with backing (Lindau 1978), there appears to be little if any backing for [i].

Only Speaker G deviated from the overall pattern. His stressed vowels [ɛ] and [ɔ] in two-syllable words have lower first formant frequencies (456 and 434 Hz., respectively) than pretonic [e] and [o] (475 and 486 Hz. respectively). Whether this raising of [ɛ] and [ɔ] is due to dialect differences (G is the only speaker of the Mineiro dialect), to some idiosyncratic personal characteristic, or to chance cannot be determined from the limited data of the present study. However, it should be noted that his stressed vowels [ɛ] and [ɔ] in trisyllabic words all have higher first formants than the same vowels in the two-syllable words.

The articulatory pattern of vowel reduction from stressed to pretonic vowels in Portuguese can be summarized as follows:

1) There is less displacement of the high vowels on the vertical axis than of the low vowels, indicating a movement toward a pole located in the upper mid area.

Table 2. Formant Frequency Means for Vowels in Set A

Source Words*	Vowel	Vowel Positon	F1 Speakers A	P	G	R	All Ss	F2 Speakers A	P	G	R	All Ss
10,17		Pretonic	335	334	361	391	355	1971	1996	1997	2053	2004
1,8	/i/	Stressed	306	321	319	343	321	1886	1992	2053	2036	1992
1,3,5		Final	432	404	352	406	411	1953	2022	1937	2073	2001
11,12,18	/e/	Pretonic	423	457	475	449	451	1691	1791	1734	1972	1797
2		Stressed	417	418	427	434	424	1814	2000	1818	2031	1916
3	/ɛ/	Stressed	565	517	456	527	516	1684	1818	1773	1840	1779
13,19		Pretonic	523	589	597	631	585	1431	1527	1349	1479	1446
4,9	/a/	Stressed	626	664	730	717	684	1418	1494	1392	1376	1420
2,4,8		Final	566	568	527	530	548	1499	1548	1480	1436	1491
5	/ɔ/	Stressed	556	589	434	573	538	1103	1091	1096	973	1066
14,14,20	/o/	Pretonic	466	503	486	465	480	1179	1346	1142	1153	1205
6		Stressed	452	408	390	444	424	1082	1180	968	890	1030
16,21		Pretonic	361	354	395	371	370	1081	1243	1117	1124	1141
7	/u/	Stressed	326	326	354	357	341	1080	1162	943	884	1017
6,7,9		Final	436	434	410	409	422	1051	**	963	**	1007

* Numbers refer to words in Appendix A.
** Unmeasurable

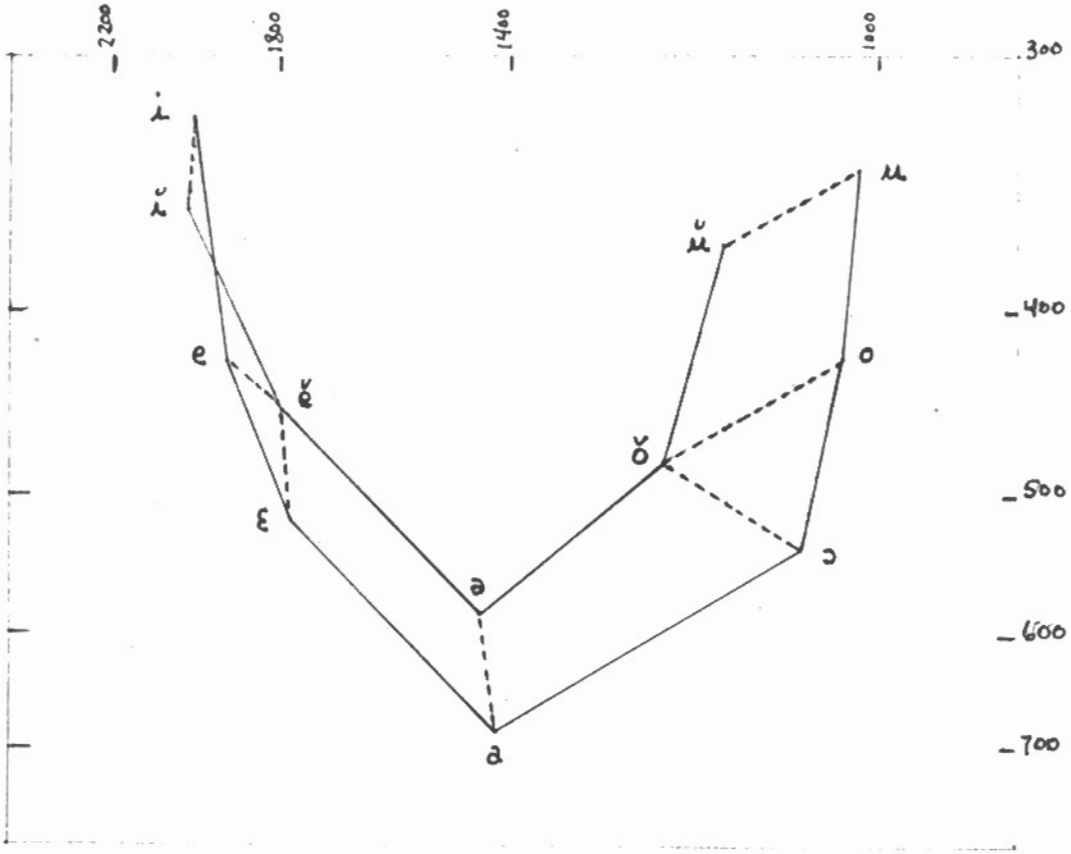

Figure 1. Acoustic Chart of Vowel Reduction in Portuguese: Stressed and Pretonic Vowels

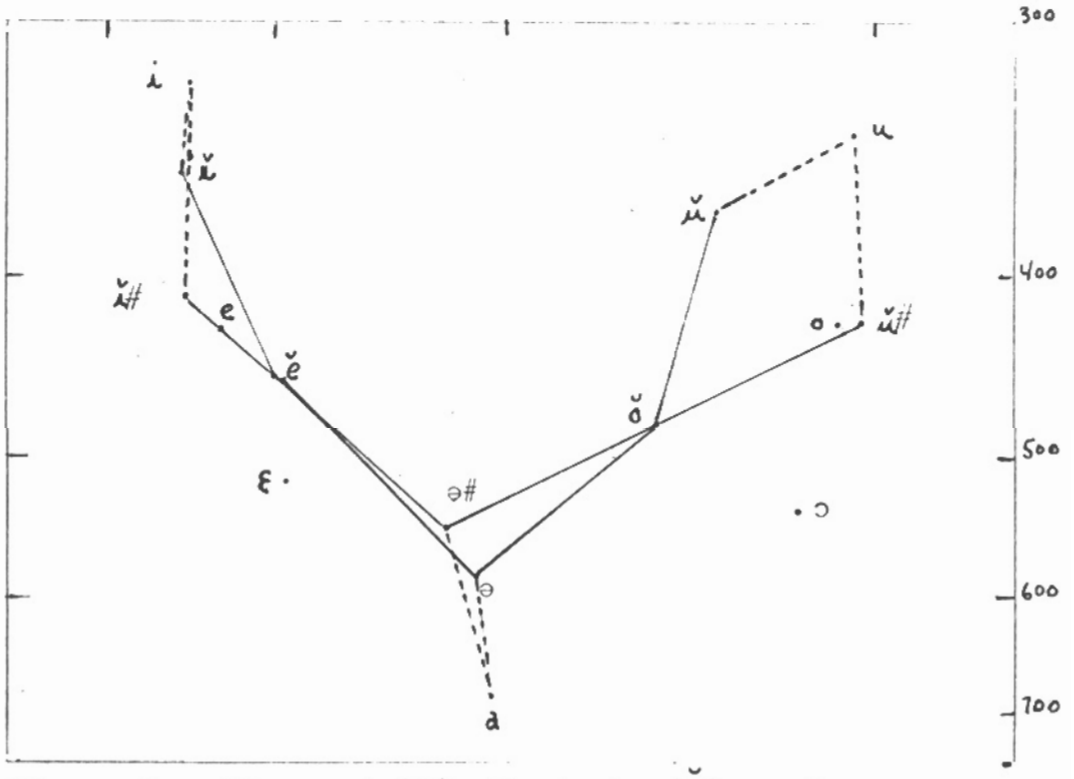

Figure 2. Stressed (V), Pretonic (V̆), and Unstressed Final (V#) Vowels - Set A

2) The centering seems to be toward a pole which is farther forward than the exact acoustic center.

3) The high front vowel is not significantly centered.

Unstressed Word-Final Vowels

There were a number of difficulties in obtaining measurements of word-final vowels after /k/. These vowels were generally very short, with a voiceless portion following /k/, weak second formants and, especially for [i] and [u], no clear steady state. In these cases, measurements were taken at the onset of voicing for both formants. Because this was often immediately prior to the /m/ closure, the formant frequencies may have been influenced by the transition to /m/. In a few cases, no measurements could be made because no formants were visible.

Mean formant values of stressed, pretonic and final vowels in Set A are plotted in Figure 2. Two continuous lines connect the final and pretonic vowels respectively. Broken lines show the acoustic displacement of the pretonic vowels [i, ə, u] and final vowels from stressed [i, a, u].

Mean F1 frequencies of final high vowels are at a point halfway between those of adjacent pretonic vowels. Final high vowels are therefore lower than pretonic high vowels, and in fact closer to stressed [e] and [o] than to any other vowels. The final low vowel is slightly higher than its pretonic counterpart.

On the vertical axis, then, final vowels seem to continue the trend of the pretonic, in that high vowels lower and low vowels raise. This time, however, F1 displacement of the low vowel is slightly less than F1 displacement of the high vowels (a difference of about 18 Hz).

Mean F2 frequencies of final vowels show differing behaviors for each of the three vowels. The F2 mean of final [i] is about the same as that of stressed and pretonic /i/. Stress, therefore, has little influence on the second formant of /i/. The F2 mean of final /ə/ shows a slight displacement (about 50 Hz) toward a higher frequency in relation to pretonic [ə]. The F2 mean of final [u] shows a lower value than that of its pretonic counterpart. On the horizontal axis, then, the two high vowels show no centering, while the low vowel shows some fronting.

In view of the difficulties encountered in measuring second formant frequencies of the final high vowels after /k/, word-final vowels in voiced environments (Set B) were also analyzed. Individual measurements and means of these vowels are given in Appendix B. Except for the second formant of [u] in one token, both formants were clearly observable in all vowels. The mean formant frequencies of these vowels are plotted in Figure 3 and compared with the final vowels in Set A.

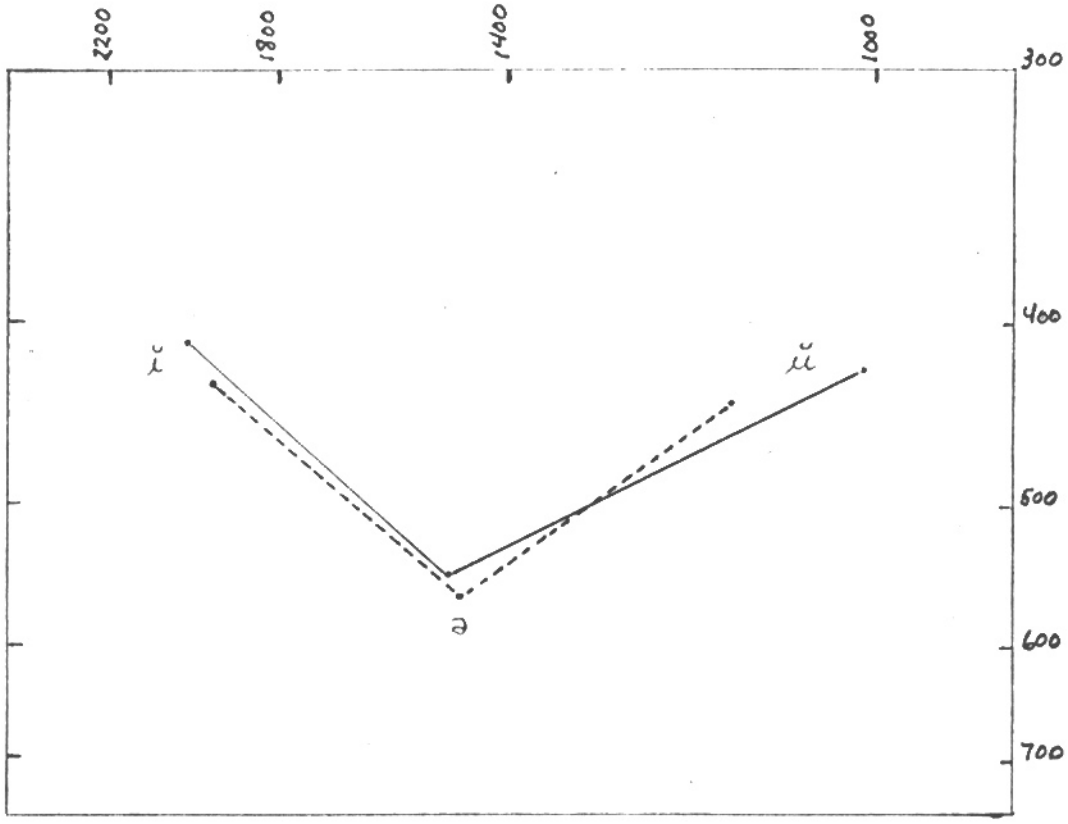

Figure 3. Unstressed Final Vowels: Continuous Line: Set A; Dashed Line: Set B

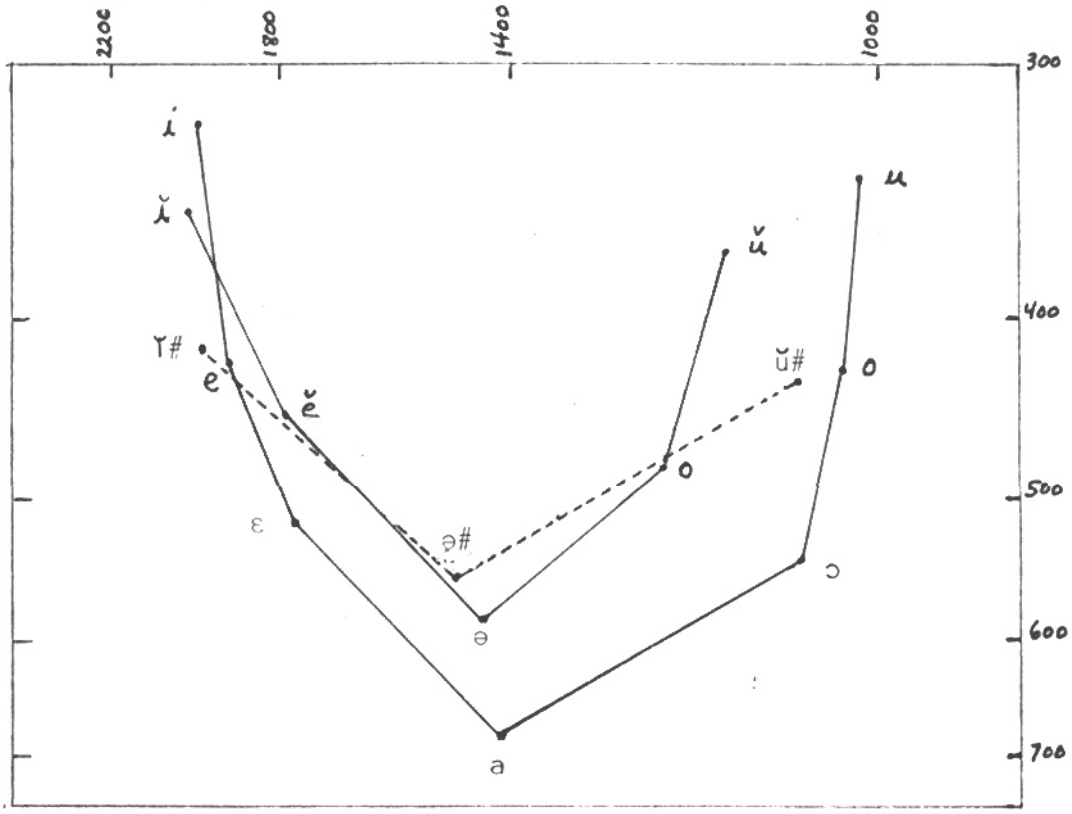

Figure 4. Acoustic Chart of Vowel Reduction in Portuguese: Stressed (V), Pretonic (V), and Unstressed Final (V#) Vowels

The differences of mean formant frequencies observed between the two was found to be minimal:

	i		u
F1	15 Hz.	16 Hz.	19 Hz.
F2	-56 Hz.	-13 Hz.	128 Hz.

Since differences of less than 20 Hz. in the first formant frequency region and 50 Hz. in the second formant frequency region are probably not perceptible (Flanagan 1957), the only significant difference is in the second formant of [u]. Although the difference in F2 of unstressed [u] may mean that the phonetic environment did make a difference or that there were measurement errors in Set A, Set B basically confirms the measurements of Set A. Therefore, the mean frequencies of both sets of final vowels were averaged and are plotted in Figure 4 for comparison with stressed and pretonic vowels.

DURATION

Mean durations of words in Set A and the sentences in which they occured are shown in Table 3. Mean durations for two-syllable test words vary from 324 msec. to 378 msec., and sentences containing them vary from 1451 msec. to 1550 msec. The mean word duration varies from 22% to 25% of sentence duration. Speakers used different speaking rates, but individual speakers' overall mean word durations ranged between 22% and 26% of their overall mean sentence duration. R had the highest overall mean test word duration (409 msec.) but his overall sentence durations were only 90% as long as those of the person with the slowest speaking rate (P).

Mean durations of three-syllable words vary from 464 msec. to 591 msec. and those of sentences from 1552 msec. to 1704 msec. Such increased variation might be due to the fact that not all words in this set have the same number of phonemes. The word durations vary from 29% to 36% of sentence durations. Again, speakers show different rates of speech and once again P had the slowest overall rate of speaking while R had the greatest mean duration of test words.

Individual measurements of syllabic durations are given in Appendix C. Words 18 and 19 are omitted because they had consonant clusters between the first and second syllables. Table 4 shows mean syllable durations.

Table 3. Word and Sentence Durations (in msec.)

	A		P		G		R		Means		Percent
	Word	Sent.	Word	Sent	Word	Sent.	Word	Sent.	Word	Sent.	
1.[ˈʃiki]	285	1250	382	1740	290	1435	340	----	324	1475	22.0
2.[ˈsekə]	285	1230	410	1800	350	1510	388	1550	358	1523	23.5
3.[ˈʃɛki]	325	1305	420	1770	330	1535	425	1550	375	1540	24.4
4.[ˈsakə]	335	1295	384	1670	328	1595	455	1640	376	1550	24.3
5.[ˈʃɔki]	370	1320	405	1685	310	1480	425	1585	378	1518	24.9
6.[ˈsoku]	276	1295	385	1655	348	1370	412	1545	355	1466	24.2
7.[ˈsuku]	310	1290	370	1635	355	1480	440	1570	369	1494	24.7
8.[ˈʃikə]	300	1265	403	1730	300	1310	395	1500	350	1451	24.1
9.[ˈsaku]	295	1268	445	1830	345	1530	405	1520	373	1537	24.3
Speaker Means	309	1280	400	1724	328	1472	409	1558	362	1506	24
Percent	24		23		22.3		26.3		24		
10. [ʃiˈkezə]	410	1360	578	1823	442	1470	540	1615	493	1567	31.5
11. [seˈkurə]	402	1405	465	1753	460	1458	530	1590	464	1552	29.9
12. [ʃeˈkadu]	458	1480	515	1836	452	1660	536	1585	490	1640	29.9
13. [səˈkolə]	428	1420	485	1812	428	1620	550	1690	473	1626	28.9
14. [ʃoˈkadu]	413	1428	488	1750	452	1635	570	1640	481	1613	29.8
15. [soˈketʸi]	471	1470	540	1805	490	1595	510	1570	503	1610	31.2
16. [suˈkozu]	465	1445	550	1905	520	1508	510	1570	511	1607	31.8
17. [siˈkaryu]	461	1460	530	1762	555	1740	515	1550	515	1628	31.6
18. [seˈkwɛstru]	517	1520	550	1750	661	1855	630	1690	590	1704	34.6
19. [səˈkraryu]	438	1470	510	1710	575	1800	697	1720	555	1675	33.1
20. [soˈkɔxus]	535	1525	609	1675	605	1695	615	1650	591	1636	36.1
21. [suˈkatə]	430	1255	545	1665	580	1645	528	1550	521	1554	33.5
Speaker Means	452	1445	530	1771	518	1640	561	1618	516	1619	31.8
Percent	31.3		29.9		31.6		34.7		31.8		

Table 4. Mean Duration of Stressed and Unstressed Syllables in Set A

Syllable	Two-Syllable Words	Three-Syllable Words
Stressed	243.2 msec.	246.5 msec.*
Pretonic		154 msec.
Unstressed Final	118.5 msec.	(99.6 msec.)
Percent**	49%	62%

* Only CV syllables
** Duration of unstressed final and pretonic syllables as a percent of the duration of stressed syllables

Unstressed final syllables are only 49% as long as stressed syllables in two-syllable words whereas pretonic syllables are 62% as long as stressed syllables in three syllable words. Although stressed syllables are of approximately equal length in two- and three-syllable words, this result should be interpreted with caution because the syllables began with different consonants: /s/ or /ʃ/ for two syllable words and /k/ for three syllable words, were not balanced for vowel quality, and preceeded different consonants. All of these factors have been shown to influence duration (Lehiste 1970).

Individual measurements of vowel duration are given in Appendix D. Table 5 displays mean durations of each vowel in stressed, pretonic and unstressed final position. Of the stressed vowels in two syllable words, [a] and [ɔ] are the longest, and [i] and [e] the shortest. As to the unstressed vowels, [ə] is the longest in both positions; [u] is the shortest pretonic and [i] the shortest final vowel. Such intrinsic duration differences between high and low vowels have been found in other languages as well (Lehiste 1970).

Table 6 shows the overall means for vowels in each position.

Table 6. Mean Duration of Stressed and Unstressed Vowels in Set A

Vowel	Two-Syllable Words	Three-Syllable Words
Stressed	104.4 msec.	139.6 msec.*
Pretonic		64 msec.
Unstressed Final	39.3 msec.	
Percent**	38%	46%

* Only vowels in CV syllables
** Duration of unstressed final and pretonic vowels as a percent of the duration of stressed vowels

Table 5. Vowel Durations

Vowels		Words	Individual Speaker Means				Mean of all Speakers
			A	P	G	R	
Stressed	i	2S*	74.5	107.5	60	85.5	81.9
		3S	-	-	-	-	-
	e	2S	70	118	69	80	84.3
		3S	100	171	104	137.5	128.1
	ɛ	2S	105	164	92	115	119
		3S	-	-	-	-	-
	a	2S	104.5	161	98	132	123.9
		3S	114.25	168.75	121	173.25	144.3
	ɔ	2S	120	153	90	130	123.3
		3S	115	188.5	111.5	177	148
	o	2S	85	138	96	120	109.8
		3S	125	150	138	195	152
	u	2S	82	104	80	100	91.5
		3S	80	110	103	165	114.5
Pretonic	i	3S	57.5	64.5	50.5	47	54.9
	e	3S	61.7	76.3	52	66	64
	ə	3S	64	85	62.5	90	75.4
	o	3S	64.7	75.7	63.3	81	71.2
	u	3S	48.5	55.5	46	53	50.8
Unstressed Final	i	2S	21.3	44	18.7	33.3	29.3
	ə	2S	44.3	70	43.7	58	54
	u	2S	26.3	51.7	23	37	34.5

* 2S: two-syllable words; 3S: three-syllable words.

Unstressed vowels are shorter than stressed vowels and final unstressed vowels are shorter than pretonic vowels. The fact that, contrary to expectations, stressed vowels in three-syllable words are longer than stressed vowels in two-syllable words may be accounted for by the fact that the post-vocalic consonant was always /k/ in two-syllable words but post-vocalic consonants in three-syllable words included voiced fricatives and liquids. In a variety of other languages, vowels have been shown to be shorter before voiceless stops than in other environments (Lehiste 1970).

The duration of unstressed final vowels in two-syllable words is 38% of stressed vowel duration while duration of pretonic vowels in three-syllable words is 46% of stressed vowels. Comparing the duration of syllables with the duration of vowels, we see that vowels reduced more than syllables did. Pretonic syllables were 62% as long as stressed syllables but pretonic vowels were only 46% as long as stressed vowels. Similarly, final syllables were 49% as long as stressed syllables but final vowels were only 38% as long as stressed vowels. It is clear that vowels reduce more than consonants.

Table 7 shows the mean duration of syllable-initial consonants preceding stressed and unstressed final vowels in two-syllable words, and preceding pretonic and stressed vowels in three-syllable words (see Appendix E for individual measurements).

Table 7. Durations of Syllable Initial Consonants in Stressed and Unstressed Syllables

Consonant	Stressed Syllable	Unstressed Syllable	Percent*
ʃ	140.6 msec.	90.8 msec.	65%
s	137.4 msec.	92.4 msec.	67%
k	104.9 msec.	79.3 msec.	76%

*Duration of consonant in unstressed syllable as a percent of the duration of the same consonant in an unstressed syllable.

The relative durations of consonants in unstressed syllables to those in stressed syllables are shown in percentages. Although the inherent differences between stops and fricatives do not permit comparison within words, comparisons of identical consonants in different words show that consonants are clearly longer at the beginning of stressed syllables than at the beginning of unstressed syllables. It should also be noted that stressed /s/ and /ʃ/ in word initial position are 45-50 msec. longer than when unstressed whereas medial /k/ is only 25 msec. longer.

COMPARISON WITH OTHER STUDIES

Our data on formant frequencies of stressed vowels differ only slightly from frequency means given by Godinez (1978a). The two sets of means are shown graphically in Figure 5. Among the possible explanations which may account for the differences are dialect differences, phonetic environments, the small number of speakers and the limited number of tokens in both studies.

Comparative studies of vowel reduction in English, German, French and Spanish were carried out by Pierre Delattre (1969). On the basis of formant frequency measurements and x-rays, he found that of the four languages studied, Engish showed the greatest degree of vowel reduction and Spanish the least, with German and French having intermediate values. Portuguese resembles French more than any of the other languages he studied. Formant frequencies of stressed and unstressed vowels in Engish and French given by Delattre are displayed in Figures 6 and 7. The degree of centralization in Portuguese is about the same as in French but less than in English. However, in French, the pattern of midvowel reduction is one of raising of the lower-mid vowels /ɛ / and /ɔ/ toward the upper-mid vowels /e/ and /o/, the latter preserving their height. In Portuguese, not only are the lower-mid vowels raised but the upper-mid vowels are lowered, resulting in a complete merger of vowels in the mid region. Thus, the pole of acoustic centering in Portuguese is probably lower than that in French.

In Portuguese, back vowels undergo more centralization than front vowels, while in French back and front vowels show about the same amount of centralization. Thus, while in both French and Portuguese, the acoustic pole is more to the front than in English, it is less front in French than in Portugese.

Major (1981) studied syllable duration as evidence in favor of stress-isochrony in Portuguese. Using one-, two- and three-syllable nonsense words in which all syllables were la to control for inherent durational differences among phonemes, he found syllable duration to be inversely proportional to the number of syllables in a word. For instance, the stressed syllable in a two-syllable word was slightly longer than that in a three-syllable word (15 msec. for one speaker). We found only a 3 msec. difference but neither 3 msec. nor 15 msec. is a perceptible difference (Lehiste 1970.13). The data reported by Major for one speaker show that the unstressed syllable of ˈlala is 53% of the duration of the stressed syllable in that word and that the pretonic syllable of la ˈlala is 68% of the stressed syllable in that word. These data support our conclusion that pretonic syllables are reduced less than final syllables and are in fact rather close to our 49% and 62% in words of the same syllable and stress pattern. It would appear, then, that the fact that phonetic environments were not identical in our study does not invalidate our generalizations concerning reduction of vowel duration.

In an article about the voiceless allophones of unstressed final vowels in the Carioca dialect, Miriam Lemle (1966) attributes vowel devoicing to

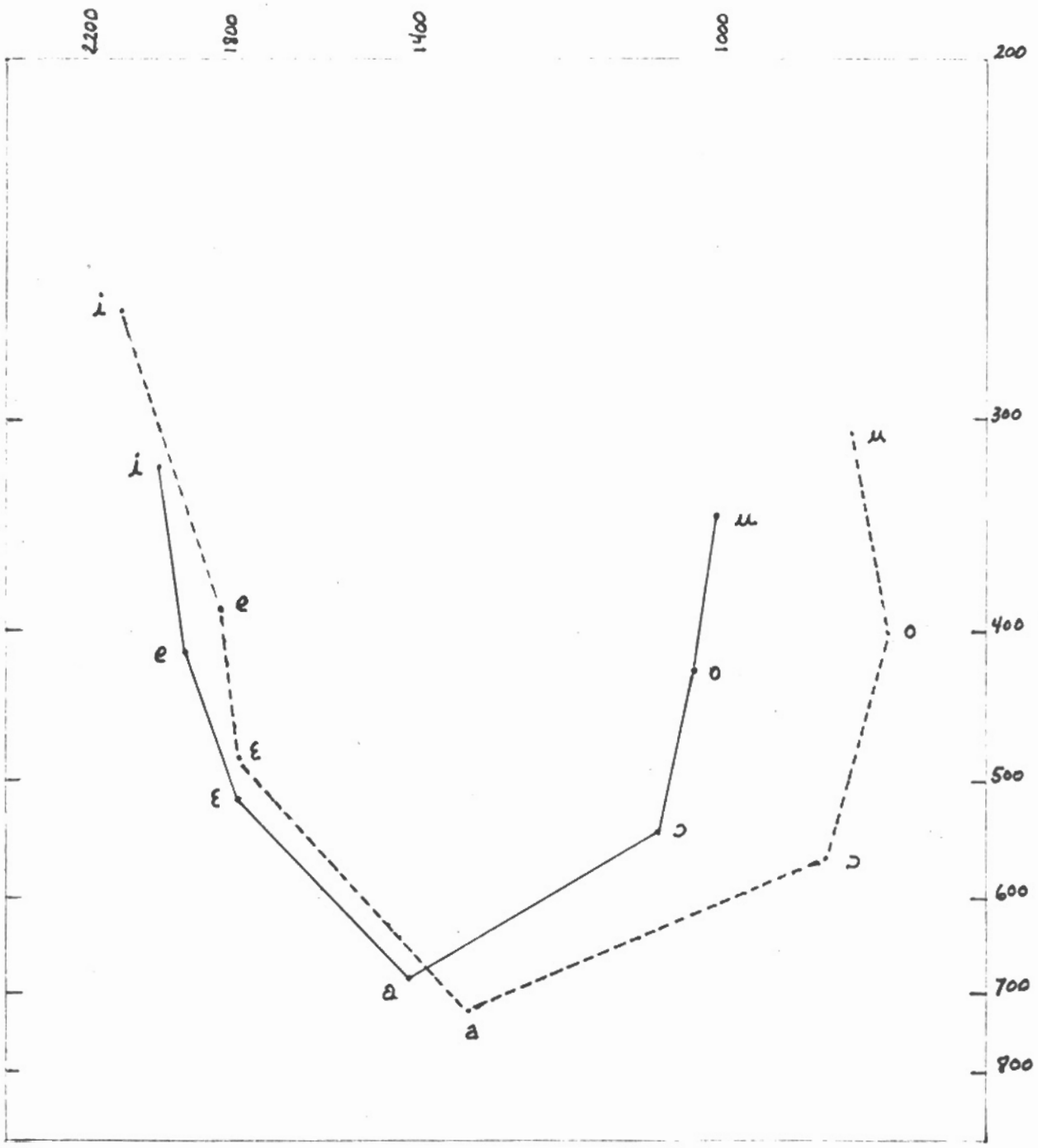

Figure 5. Portuguese Stressed Vowels: Continuous Line: Set A; Dashed Line: Godinez's Data

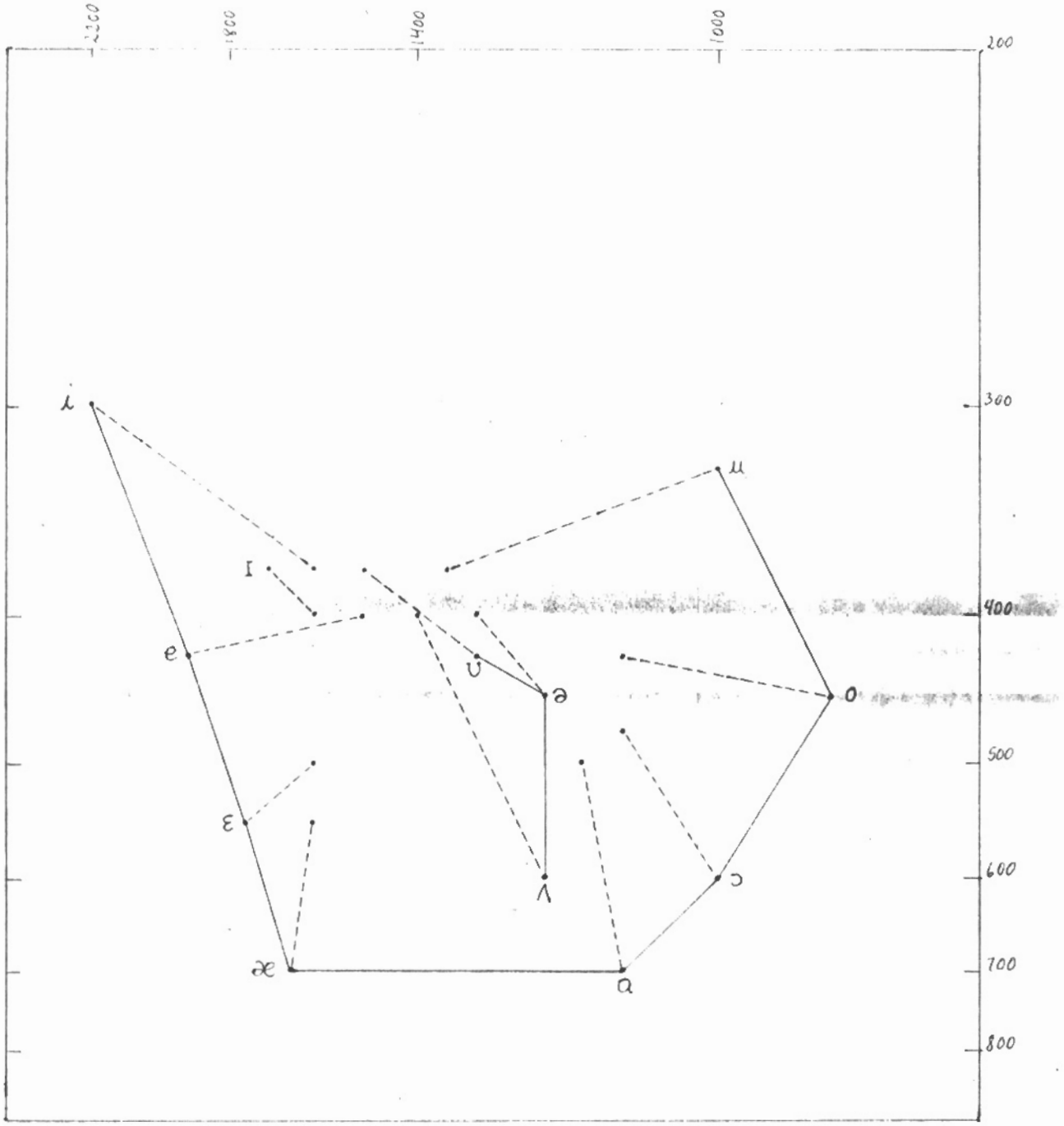

Figure 6. Acoustic Chart of Vowel Reduction in English (Delattre, 1969)

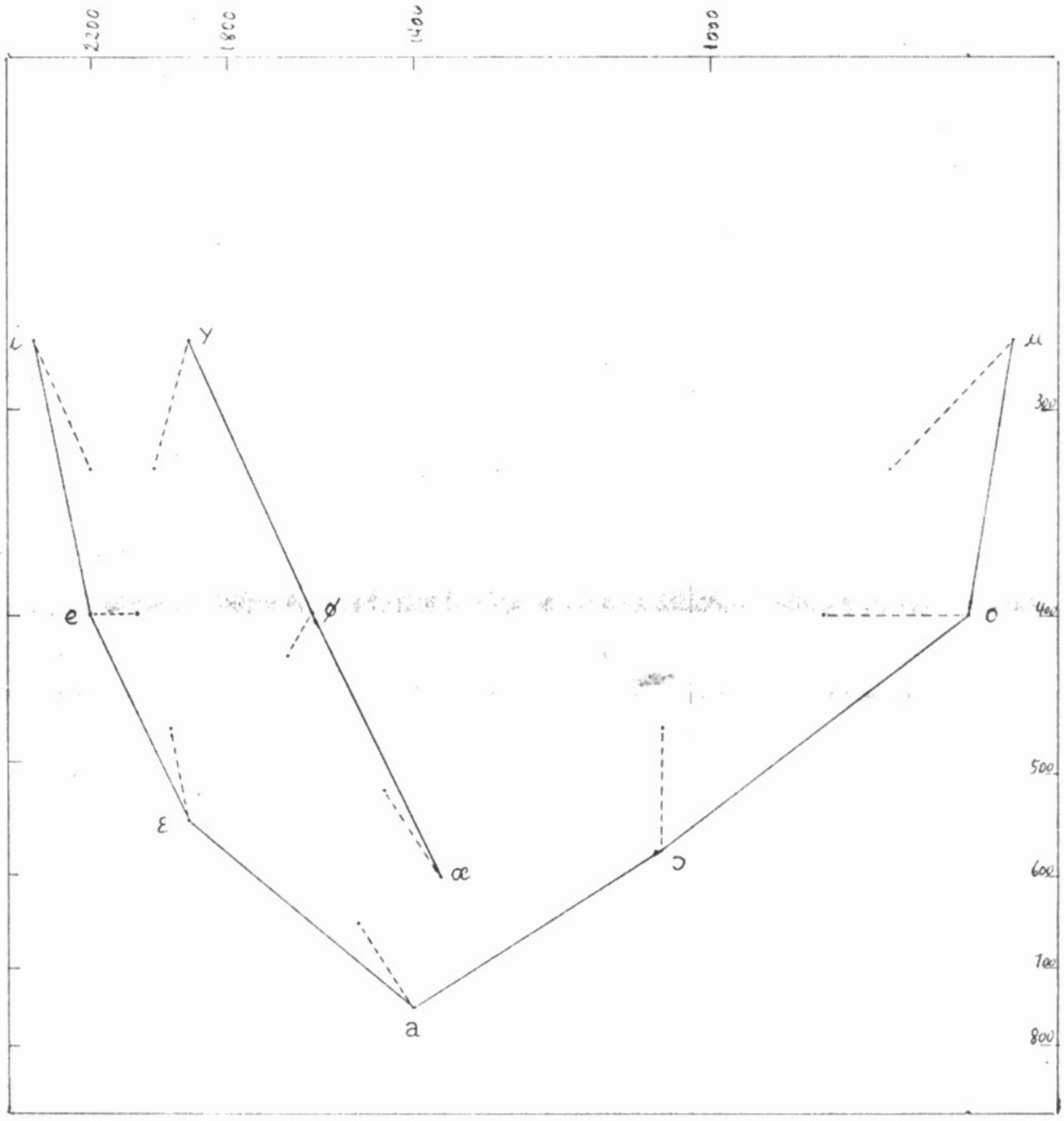

Figure 7. Acoustic Chart of Vowel Reduction in French (Delattre, 1969)

falling intonation patterns occurring in phrase-final and sentence-final position. The article does not specify whether a spectrographic analysis was performed on her data. Our study did not look at sentence-final vowels but it does suggest that devoicing of sentence-medial word-final vowels is, at least in part, dependent on stress pattern, vowel quality and phonetic environment. Unstressed final high vowels were sometimes completely devoiced in the /k_ # m/ environment, but no devoicing was observable when these vowels were in a voiced consonant environment (Set B). By contrast, the low vowel was never completely devoiced in either environment. Stressed vowels and pretonic vowels never devoiced even though they were between voiceless consonants.

CONCLUSIONS

To summarize, spectrographic evidence clearly shows the progressive qualitative and quantitative reduction of the Portuguese vowels as the system decreases from seven stressed to five unstressed pretonic to three unstressed word-final vowels. In terms of vowel quality change, the formants shift toward an acoustic center located in the mid region between the front and central positions. Reduction from seven stressed vowels to five pretonic vowels occurs in both the vertical and horizontal dimensions but reduction from the five vowel system to the three vowel system tends to be mainly accomplished in the vertical dimension, with little or no displacement in the horizontal dimension.

An unexpected finding was that the two unstressed final high vowels [i, u] have formant frequencies closer to stressed [e, o] respectively than to stressed [i, u]. This has phonological implications because phonemic /e/ and /o/ are assumed to underlie unstressed final [i] and [u]. We have no answer to the question of why these unstressed final vowels, which are both acoustically and phonologically close to the stressed upper mid vowels, are perceived as [i] and [u]. We can only speculate that the listener, realizing from the short duration that the vowels are reduced, compensates by interpreting the formants as shortfalls for higher targets.

Quantitatively, there is also a progression so that pretonic vowels are approximately half as long as stressed vowels and final vowels are about two-thirds the length of pretonic vowels. In other words, durations of pretonic vowels are reduced by half and durations of unstressed final vowels are reduced by two-thirds when compared to stressed vowels.

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Appendix A. Vowel Formant Frequencies (Set A)

Words	Vowels		Speakers				Means
			A	P	G	R	
1. 'ʃiki	i	F1	285	328	295	330	309.5
		F2	1926	2030	2045	2013	2003.5
	ĭ	F1	429	400	-	394	407.7
		F2	1864	2042	-	2074	1993.3
2. 'sekə	e	F1	417	418	427	434	424
		F2	1814	2000	1818	2031	1915.75
	ə	F1	559	557	514	524	538.5
		F2	1530	1642	1500	1441	1528.25
3. 'ʃɛki	ɛ	F1	565	517	456	527	516.25
		F2	1684	1818	1773	1840	1778.75
	ĭ	F1	433	420	395	401	412.25
		F2	2072	2036	1951	2075	2033.5
4. 'sakə	a	F1	631	666	790	727	703.5
		F2	1423	1488	1387	1384	1420.5
	ə	F1	570	605	539	515	557.25
		F2	1500	1531	1462	1413	1476.5
5. 'ʃɔki	ɔ	F1	556	589	434	573	538
		F2	1103	1091	1096	973	1065.75
	ĭ	F1	435	392	397	423	411.75
		F2	1924	1987	1922	2071	1976
6. 'soku	o	F1	452	408	390	444	423.5
		F2	1082	1180	968	890	1030
	ŭ	F1	457	441	413	376	421.75
		F2	1050	-	895	-	972.5

Appendix A. (continued)

Words	Vowels		Subjects				Means
			A	P	G	P	
7. 'suku	u	F1	326	326	354	357	340.75
		F2	1080	1162	943	884	1017.25
	ŭ	F1	409	427	427	414	419.25
		F2	1000	-	960	-	980
8. 'ʃikə	i	F1	326	313	343	355	334.25
		F2	1845	1954	2060	2059	1979.5
	ə	F1	570	543	529	551	548.25
		F2	1468	1471	1479	1453	1467.75
9. 'saku	a	F1	621	662	670	707	665
		F2	1412	1500	1396	1368	1419
	ŭ	F1	443	434	391	437	426.25
		F2	1104	-	1033	-	1069
10. ʃi'kezə	ĭ	F1	345	329	354	395	355.75
		F2	1975	2000	2058	2027	2015
	e	F1	435	462	465	430	448
		F2	1895	1951	1957	1962	1941.25
	ə	F1	575	528	500	500	525.75
		F2	1418	1531	1370	1397	1429
11. se'kurə	ĕ	F1	427	471	470	429	449.25
		F2	1678	1790	1747	2000	1803.75
	u	F1	424	415	409	377	406.25
		F2	908	886	918	778	872.5
	ə	F1	500	528	568	528	531
		F2	1447	1609	1442	1426	1481

Appendix A. (continued)

Words	Vowels		Subjects				Means
			A	P	G	R	
12.	e	F1	400	429	476	449	438.5
ʃe'kadu		F2	1708	1800	1767	1917	1798
	a	F1	557	653	847	725	695.5
		F2	1415	1561	1383	1399	1439.5
	u	F1	449	413	424	437	430.75
		F2	1294	1527	900	-	1240.3
13.	ə	F1	545	582	612	660	599.75
sə'kɔlə		F2	1405	1476	1350	1457	1422
	ɔ	F1	590	573	534	589	571.5
		F2	1008	1181	1046	1023	1064.5
	ə	F1	570	582	556	557	566.25
		F2	1216	1250	1330	1310	1276.5
14.	o	F1	480	486	500	472	484.5
ʃo'kadu		F2	1178	1360	1191	1110	1209.75
	a	F1	586	643	604	614	611.75
		F2	1426	1531	1330	1456	1435.75
	u	F1	419	410	436	425	422.5
		F2	1271	1344	1249	1397	1315.25
15.	o	F1	447	465	500	471	470.75
so'ketʸi		F2	1218	1394	1205	1202	1254.75
	e	F1	424	453	428	414	429.75
		F2	2012	2078	2078	2120	2072
	i	F1	-	430	-	-	430
		F2	-	1828	-	-	1828

Appendix A. (continued)

Words	Vowels		Subjects				Means
			A	P	G	R	
16.	u	F1	354	338	396	384	368
su'kozu		F2	1065	1253	1104	1132	1138.5
	o	F1	424	438	471	455	447
		F2	913	1173	903	966	998.75
	u	F1	409	412	414	430	416.25
		F2	1053	-	1044	1172	1089.67
17.	i	F1	325	339	368	387	354.75
si'karyu		F2	1966	1991	1936	2080	1993.25
18.	e	F1	442	471	480	470	465.75
se'kwɛstru		F2	1687	1784	1688	2000	1789.75
19.	ə	F1	500	596	582	602	570
sə'kraryu		F2	1456	1578	1347	1500	1470.25
20.	o	F1	471	558	459	453	485.25
so'kɔxus		F2	1140	1284	1030	1147	1150.25
	ɔ	F1	561	564	500	570	548.75
		F2	983	1068	890	1026	991.75
21.	u	F1	368	369	394	357	372
su'katə		F2	1097	1232	1130	1116	1143.75
	a	F1	586	671	772	665	673.5
		F2	1455	1138	1390	1439	1355.5
	ə	F1	554	583	550	500	546.75
		F2	1446	1638	1334	1322	1435

Appendix B. Unstressed Final Vowel Formant Frequencies in Voiced Environment (Set B)

Words	Vowels		Speakers				Overall Means	Combined Means of Both Sets
			A	P	G	R		
'tɛzi		F1	419	414	403	418		
		F2	1765	2052	1917	2010	F1 426	418.3
	i						F2 1945	1973
'gɔli		F1	431	458	431	430		
		F2	1916	2000	1856	2042		
'lizə		F1	594	623	561	525		
		F2	1462	1642	1647	1449	F1 564	556
	ə						F2 1478.25	1484.5
'gɔlə		F1	536	563	536	575		
		F2	1436	1478	1374	1338		
'žogu		F1	416	435	426	448		
		F2	982	979	934	1029	F1 441	431.7
	u						F2 1135	1071
'sizu		F1	427	484	424	468		
		F2	-	1510	1187	1166		

Appendix C. Durations (in msc.) of Stressed and Unstressed Syllables

Words	Stressed Syllables					Final Syllables					Percent
	A	P	G	R	Means	A	P	G	R	Means	
1. 'ʃiki	192	264	189	217	215.5	93	118	101	123	108.75	
2. 'sekə	179	269	213	238	224.75	106	141	137	150	133.5	
3. 'ʃɛki	230	304	222	309	266.25	95	116	108	118	109.25	
4. 'sakə	227	263	226	281	249.25	108	121	102	174	126.25	
5. 'ʃɔki	260	294	217	291	265.5	110	111	93	134	112	
6. 'soku	200	273	244	266	245.75	78	112	104	146	110	
7. 'suku	212	252	255	265	246	98	118	100	175	122.75	
8. 'ʃikə	203	266	193	225	221.75	93	137	107	170	126.75	
9. 'saku	205	309	236	269	254.75	90	136	109	136	117.75	
Means	212	277.1	221.7	262.3	243.3	96.8	123.3	106.8	147.3	118.6	49%

Appendix C. (continued)

Words	Pretonic Syllables					Stressed Syllables					Percent
	A	P	G	R	Means	A	P	G	R	Means	
10. ʃi'kezə	139	161	151	131	145.5	191	289	199	265	236	
11. se'kurə	147	162	158	155	155.5	188	215	224	295	230.5	
12. ʃe'kadu	158	171	158	164	162.75	220	264	209	282	243.75	
13. sə'kɔlə	139	157	150	170	154	217	242	198	282	234.75	
14. ʃo'kadu	137	166	146	178	156.75	207	247	228	277	239.75	
15. so'ketʸi	150	166	166	162	161	209	253	220	225	226.75	
16. su'kozu	152	165	149	140	151.5	223	275	275	298	267.75	
17. si'karyu	176	159	173	142	162.5	210	293	260	293	264	
20. so'kɔxuz	144	148	150	156	149.5	235	348	231	319	283.25	
21. su'katə	128	148	150	137	140.75	197	264	241	251	238.25	
Means	147	160.3	155.1	153.5	154	209.7	269	228.5	278.7	246.5	62%

Appendix D. Vowel Durations (in msc.) - Set A

Words	Vowels	Speakers				Means
		A	P	G	R	
1. 'ʃiki	i	66	103	55	86	77.5
	i	28	46	17	42	33
2. 'sekə	e	70	118	69	80	84.25
	ə	48	69	50	41	52
3. 'ʃɛki	ɛ	105	164	92	115	119
	i	16	40	18	25	24.75
4. 'sakɔ	a	107	145	90	118	115
	ə	48	61	34	69	53
5. 'ʃɔki	ɔ	120	153	90	130	123.25
	i	20	46	21	34	30.25
6. 'soku	o	85	138	96	120	109.75
	u	16	50	24	41	32.75
7. 'suku	u	82	104	80	100	91.5
	u	28	54	25	40	36.75
8. 'ʃikə	i	83	112	65	85	86.25
	ə	37	80	47	64	57
9. 'saku	a	102	177	106	146	132.75
	u	35	51	20	30	34
Means	Stressed	91	134.9	82.6	108.9	104.4
	Final	30.7	55.2	28.4	42.8	39.3

Appendix D. (continued)

Words	Vowels	Speakers				Means
		A	P	G	R	
10. ʃi'kezə	i	66	103	55	86	77.5
	e	100	193	108	155	139
11. se'kurə	e	60	80	56	55	62.75
	u	80	110	103	165	114.5
12. ʃe'kadu	e	60	80	55	72	66
	a	129	166	115	180	147.5
13. sə'kɔlə	ɔ	60	86	65	90	75.25
	ə	105	137	98	158	124.5
14. ʃo'kadu	o	57	80	65	87	72.25
	a	110	155	113	183	140.25
15. so'ketʸi	o	72	77	67	80	74
	e	100	149	100	120	117.25
16. su'kozu	u	47	58	49	54	52
	o	125	150	138	195	152
17. si'karyu	i	62	66	50	44	55.75
	a	120	187	148	184	159.75
20. so'kɔxuz	o	65	70	58	76	67.25
	ɔ	125	240	125	196	171.5
21. su'katə	u	50	53	43	52	49.5
	a	98	167	108	146	129.75
Means	Pretonic	59.9	72.1	55.3	68.6	64
	Stressed	109.2	165.4	115.6	168.2	139.6
18. se'kwestru	e	65	69	48	71	63.25
19. sə'kraryu	ə	68	84	60	90	75.5

Appendix E. Duration of Syllable Initial Consonants

	Two-Syllable Words						Three-Syllable Words						Percent
	Vowel	A	P	G	R	Means	Vowel	A	P	G	R	Means	
ʃ	i	126	161	134	131	138	i	87	98	100	81	91.5	
	ɛ	125	140	130	192	146.75	e	98	91	106	92	96.75	
	ɔ	140	141	127	161	142.25	o	81	85	81	91	84.5	
	i	120	154	128	140	135.5							
Means		127.8	149	129.8	156	140.6		88.3	91.3	95.7	88	90.9	65%
s	e	109.	151	144	158	140.5	e	87	82	102	100	92.75	
	a	120	118	136	163	134.25	ə	79	71	85	80	78.75	
	o	115	135	148	146	136	o	78	89	89	82	84.5	
	u	130	148	175	165	154.5	u	105	107	100	86	99.5	
	a	103	132	130	123	122	i	113	93	123	98	106.75	
							e	107	76	100	85	92	
							ə	68	80	100	168	104	
							o	79	78	92	80	82.25	
							u	78	95	107	85	91.25	
Means		115.4	136.8	146.6	151	137.5		88.2	85.7	99.8	96	92.4	67%

Appendix E. (continued)

	m Two-Syllable Words						Three-Syllable Words*						Percent
	Vowel	A	P	G	R	Means	Vowel	A	P	G	R	Means	
k	i	65	72	84	82	75.75	e	91	96	91	110	97	
	ə	58	72	87	109	81.5	u	108	105	121	130	116	
	i	79	76	90	93	84.5	a	91	98	94	101	96	
	ə	60	60	68	105	73.25	ɔ	112	105	100	124	110.25	
	i	90	65	72	100	81.75	a	97	92	115	94	99.5	
	u	60	62	80	105	76.75	e	109	104	120	105	109.5	
	u	70	64	75	135	86.	o	98	125	133	103	114.75	
	ə	60	57	60	106	70.75	a	90	106	112	109	104.25	
	u	55	85	89	106	83.75	ɔ	110	108	106	123	111.75	
							a	99	97	133	105	108.5	
Means		66.3	68.1	78.3	104.6	79.3		100.5	103.6	112.5	110.4	106.75	74%

* Only CV syllables.