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BRAZILIAN PORTUGUESE STRESSED VOWELS:  
A Durational Study

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With the intention of determining some of the durational characteristics of the seven vowels which occur in stressed position in Brazilian Portuguese, [i e ε a ɔ o u], the following procedures were undertaken:

1. For each vowel, a minimal or near-minimal pair of words was selected, with the important difference being the voicing of the consonant following the stressed vowel. In all cases, the consonants are stops or affricates. All words are of three syllables of the shape CVCVCV, with the stress on the penultimate syllable. Because of the difficulty in finding even a near-minimal pair of the shape required, two pairs were included for testing [o]: a minimal prepositional phrase do loto [dulotu], do lodo [dulodu], and a second, single morpheme pair, decoro [dɛkoru], maroto [marotu]. However, since the differences in durational measurements were minimal between the two pairs, the study includes only data from the do loto-do lodo pair. (See Appendix 3 for the data from both pairs.)

2. Sentence frames were devised to check variability of duration in relation to sentence position. For initial and final positions, the frames X não é o mesmo que Y and Y não é o mesmo que X '\_\_\_ is not the same as \_\_\_' were used, where X and Y are the members of the word/phrase pairs for each vowel. For medial position, each of the words was placed in the frame Diga (word) mais uma vez, 'tá? 'Say (word) once again, OK?' (See Appendix 1 for a copy of the script and glosses.)

3. Three male native speakers of Brazilian Portuguese were asked to read the prepared script into a microphone in a sound-proofed recording chamber. Only male speakers were used to facilitate subsequent spectrographic analysis. The three had ample time to familiarize themselves with the script beforehand, and were instructed to read each sentence as though it were isolated, pausing only between sentences and reading at a natural rate of speech. The three were recorded on a reel-to-reel recorder at 7½ i.p.s.

4. A spectrogram of each sentence was made from the tape recording on a Kay Sona-Graph Spectrum Analyzer Model 6061B.

5. On each spectrogram, the following measurements were taken:  
a. duration (in milliseconds) of the whole utterance.  
b. duration of the test words.  
c. duration of the test vowels.

There was little difficulty in determining the boundaries for

measurement due to the acoustic characteristics of the sound segments involved, so the accuracy of measurements is thought to be in the  $\pm 10$  msc. range.

6. Computations were made to determine answers to the following questions:
- a. What is the mean over-all or inherent duration of each of the seven test vowels?
  - b. What is the mean duration of each of the vowels when occurring before voiced consonants?
  - c. What is the mean duration of each of the test vowels when occurring before voiceless consonants?
  - d. What is the mean duration of each of the test vowels in each of the three sentence positions--initial, medial and final?
  - e. What percentage of the word duration is comprised by the test vowel?
  - f. What percentage of the entire utterance is comprised by the test vowel?

#### Observations.

Individual Speaker Characteristics. Of the 14 'X...Y' sentences, 11 of speaker A's were of longer duration than both B's and C's; of the 14 'Diga...' frames, 12 of A's were the longest. B had the greatest number of shortest utterances in the 'X...Y' frame (11 of 14), and C the greatest number of shortest utterances in the 'Diga...' frame (12 of 14).

Speaker C's test vowels were generally the shortest in all positions, both pre-voiced and pre-voiceless consonant. Of a possible 42 vowels (7 vowels x 3 sentences x 2 environments), 26 of C's were measured as the shortest of the three speakers--12 pre-voiced, 14 pre-voiceless. Speaker A had 5 shortest pre-voiced vowels and 5 shortest pre-voiceless vowels. Speaker B had 4 shortest pre-voiced vowels, and only one shortest pre-voiceless vowel.

Speaker B had 13 longest pre-voiced vowels and 12 longest pre-voiceless vowels, for a total of 26 out of 42 possible. Speaker A had 6 longest pre-voiced vowels and 9 longest pre-voiceless vowels (total 15 of 42). Speaker C had only one longest vowel, [i] in pre-voiced position.

Speaker B's vowels were much the longest of the three speakers in sentence-final words. The durations of these vowels were frequently as much as 30-40 msc. longer for B than for A or C, thus causing the mean duration of the final position test stressed vowel to be, perhaps, misleadingly long.

It is interesting to note that the durations of the utterances do not always correspond to the durations of the target vowels, so that even though B's 'X...Y' frame durations were generally shorter than A's

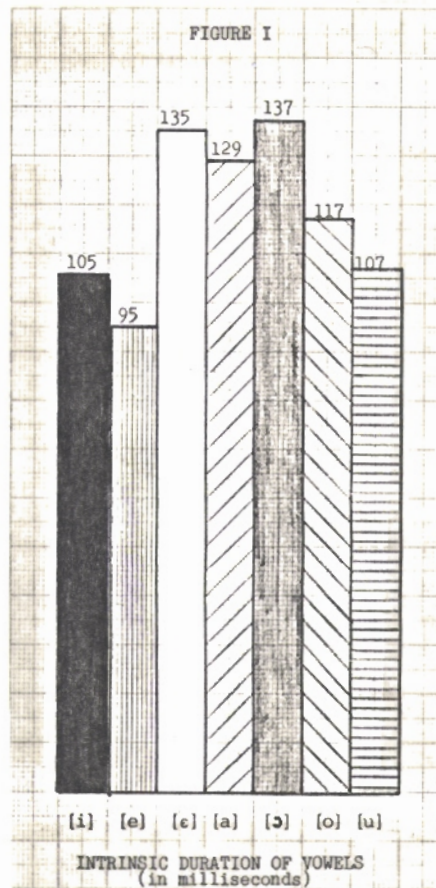


or C's (11 of 14), the vowels in the 'X' word were longest in 7 of 14 cases, and in the 'Y' word, or sentence-final position, in 13 out of 14 cases. The '...não é o mesmo que...' portions of B's sentences were, of course, correspondingly much shorter than A's or C's, thus giving the shorter total utterance durations.

Intrinsic Duration. The durations of every occurrence of each stressed vowel in all positions were added together and an average taken across speakers. The resulting figures are shown in Table I, and are graphed in Figure I. As can be seen, the open mid vowels [ɔ] and [ɛ] are the longest (137 msc and 135 msc respectively), followed by [a] (129 msc.), [o] (117), [u] (107), [i] (105), and [e] (95). This ranking is in part consistent with the findings cited in Lehiste (1970), where she summarizes: 'As far as the vowels are concerned, their duration appears to be correlated with tongue height: other factors being equal, a high vowel is shorter than a low vowel' (p. 18). However, the lowest of the seven is not the longest in Brazilian Portuguese, and the mid close [e] is considerably shorter than high [i] and [u].

TABLE I  
MEAN DURATION OF STRESSED VOWEL  
BY VOICING OF FOLLOWING CONSONANT  
AND OVERALL MEAN DURATION (INHERENT LENGTH)

Vowels	Pre- Voiced	% of Word	Pre- Voiceless	% of Word	Overall Mean Duration
[i]	112	26.5	98	23.4	105
[e]	97	20.0	92	19.0	95
[ɛ]	146	32.2	124	25.5	135
[a]	132	29.6	125	27.5	129
[ɔ]	155	34.9	118	25.4	137
[o]	123	29.0	111	25.9	117
[u]	108	25.1	105	24.5	107
All Vowels	126	28.2	110	24.5	118

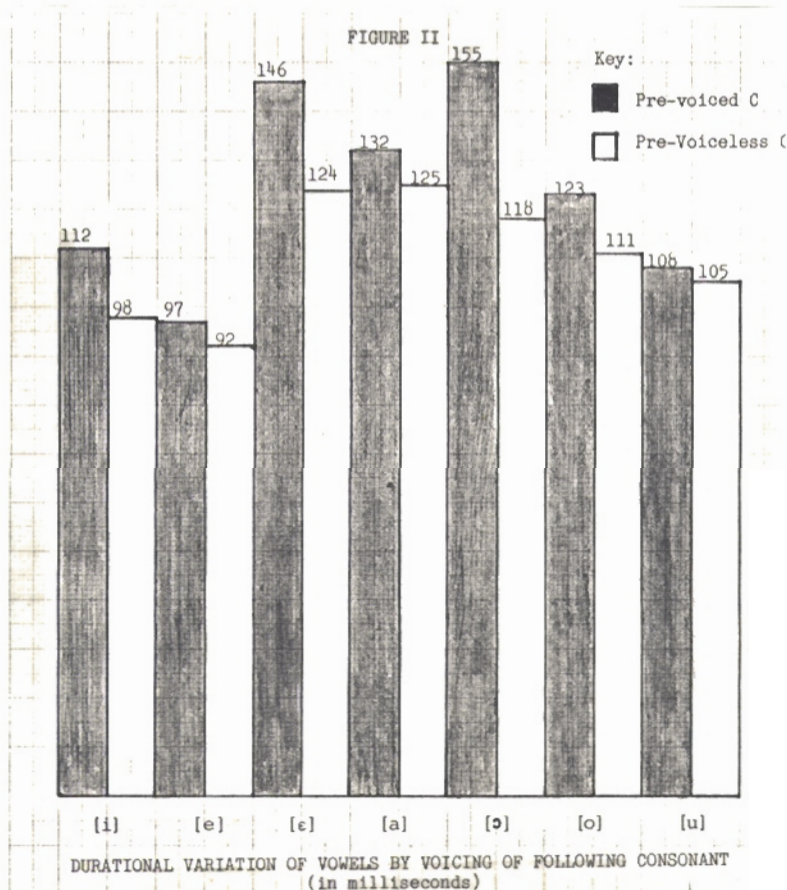


Historically, the mid open vowels [ɛ] and [ɔ] are reflexes of Classical Latin short  $\bar{e}$  and short  $\bar{o}$  respectively. The mid close varieties are the result of the collapse of Classical Latin short high vowels and long mid vowels:  $\bar{y}$  and  $\bar{e}$  collapsed to [e], and  $\bar{u}$  and  $\bar{o}$  collapsed to [o]. There is apparently no historical cause so far determined for the extreme length of the open mid vowels in modern day Brazilian Portuguese, although Williams (1962) states that even early in the 16th century double vowels 'came to be used (in orthography) to indicate the open sound of the vowel (a, e and o), the closed sound being indicated by a single vowel' (p. 25). Whether this orthographical convention reflects an actual length distinction, or was simply a tool to differentiate written minimal pairs, is not clear. It does, however, allow for the possibility of a lengthening of the open varieties in the early 1500's. There is still a contrast between close and open mid vowels in Brazilian Portuguese, and it is possible that this contrast is based not only on vowel quality but also on the perceived extra length of the open varieties. It would be interesting to investigate the extent to which quality and quantity differences operate in the perception of these two pairs of mid vowels.

Note that the back rounded vowels are longer than their front non-rounded counterparts.

The percentages of total sentence duration and of word duration composed by the vowel support the ranking given above, except in the case of [i] and [u], whose order is reversed for percentage of total duration of utterance.

Durational Variation Due to Post-Vocalic Consonant Voicing. Table I shows the mean duration of each vowel by voicing of the following consonant. Figure II graphs these values. It is clear that the mean vowel durations are all shorter before voiceless consonants (110 msc.) than before voiced consonants (126 msc.), which is to be expected based on previous studies of other languages (e.g. House 1961, Zimmerman and Sapon 1958, Elert 1964, Delattre 1962). Note, however, that the difference in duration is on a minor scale, with a 14 msc. mean differential. Even when we consider [ɛ] and [ɔ], where the differentials are 22 msc. and 37 msc. respectively, it is improbable that speakers of Brazilian Portuguese employ the length of the preceding vowel as a cue to consonant voicing, since the just-noticeable differences in duration are considered to be between 10 and 40 msc. (Lehiste 1970, p. 13). The durational variations found here must then be due to other factors.





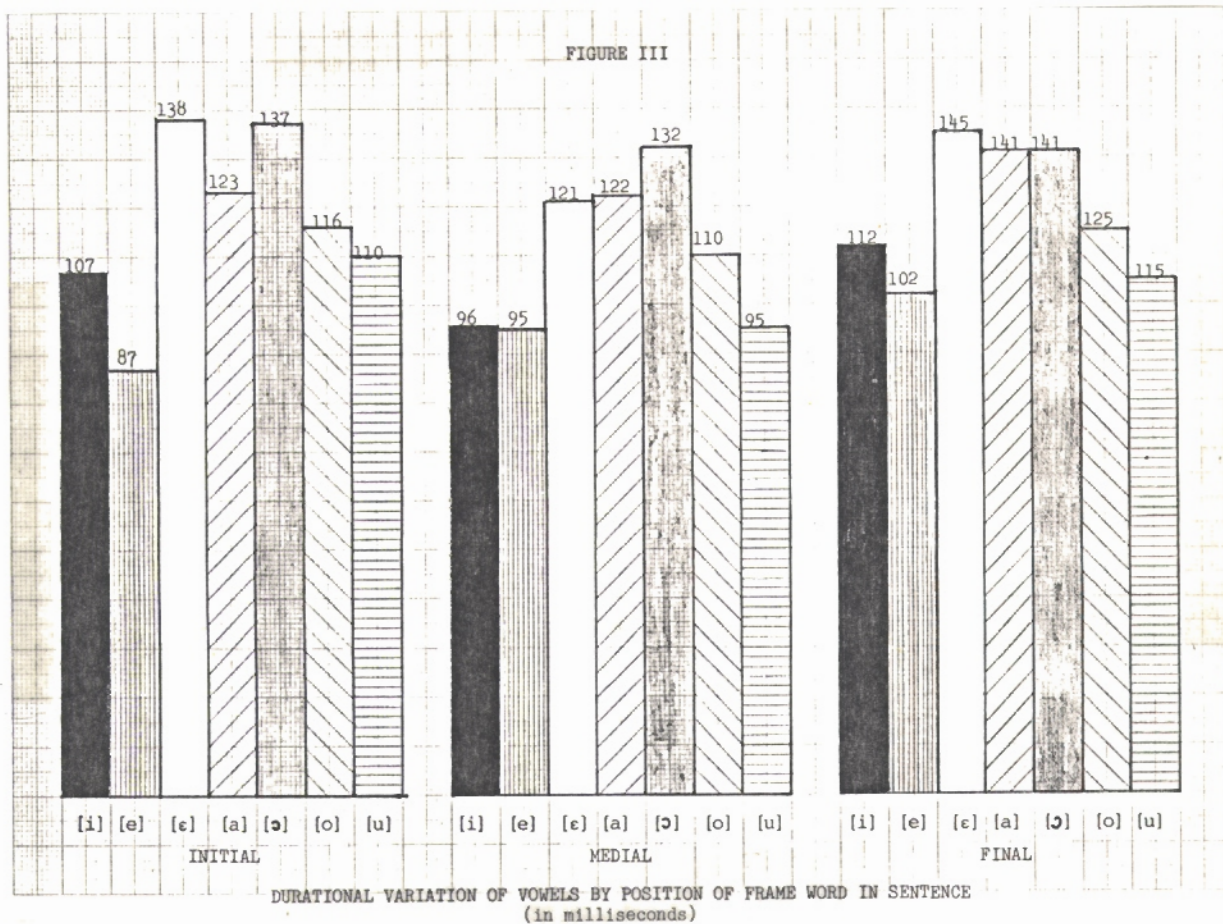
One possible explanation is discussed in Raphael (1974), in which he used electromyographic readings of the genioglossus muscle activity in speech production to investigate the physiological causes of the lengthening of vowels preceding voiced consonants. Raphael concluded that there is a sustention of the articulatory gesture for the vowel preceding voiced consonants, and that therefore motor commands cause the vocalic lengthening. This conclusion seems to be in keeping with the explanation that 'Vowels are lengthened before voiced stops to allow time for laryngeal readjustment needed if voicing is to be maintained during oral closure' (Lisker 1974, p. 239). At least the two are not contradictory, and Raphael's study does seem to provide some of the experimental support Lisker requires for the laryngeal readjustment theory.

Durational Variations in Relation to Position of Word in Sentence. Table II shows that stressed vowels occurring in the final word of the sentence were consistently found to be longer in duration than in any other position (mean = 126 msc.). When the word occurred in medial position, the stressed vowel was shorter than in other positions (mean = 111 msc.), with the exception of mid front close [e], which was found to be shortest in the initial word (87 msc.). In all other cases, the stressed vowel was found to be of intermediate length when occurring in the sentence-initial word (mean = 117 msc.).

TABLE II

MEAN DURATION OF STRESSED VOWEL									
BY POSITION OF FRAME WORD IN SENTENCE									
Vowel	Initial			Medial			Final		
	Mean Duration (msc.)	% of Word	% of Sentence	Mean Duration (msc.)	% of Word	% of Sentence	Mean Duration (msc.)	% of Word	% of Sentence
[i]	107	26.2	7.2	96	25.9	6.6	112	22.7	7.6
[e]	87	19.1	5.4	95	21.3	6.0	102	18.2	6.4
[ɛ]	138	30.9	8.8	121	29.2	7.8	145	26.5	9.3
[a]	123	28.7	8.0	122	30.7	7.9	141	26.3	9.2
[ɔ]	137	33.2	9.0	132	30.5	8.2	141	26.7	9.2
[o]	116	28.2	7.6	110	28.9	7.4	125	25.2	8.3
[u]	110	27.0	7.3	95	24.4	6.2	115	23.0	7.6
All Vowels	117	27.6	7.6	111	27.3	7.2	126	24.1	8.2





While the figures for the average percentage of utterance duration comprised by the test vowel reflect the rankings given here, those for average percentage of the word duration comprised by the test vowel do not. The latter figures, also given in Table II, show that the vowel in the final word comprises less of the word duration (24.1%) than in either sentence-initial (27.6%) or sentence-medial (27.3%) position. The figures for word duration shown in Table III indicate that the final word is by far the longest (524 msc. mean duration) when compared to initial (426 msc. mean duration) and medial (408 msc. mean duration). This implies that other segments in the final word are lengthened even more than the stressed word-medial vowel as a result of occurring in pre-pausal position. It is likely that the utterance-final unchecked vowel is the additional length factor.

TABLE III

MEAN DURATION OF FRAME WORD			
BY POSITION IN SENTENCE			
(in milliseconds)			
Words	Initial	Medial	Final
barriga/barrica	410	372	496
macedo/maceta	456	447	562
bodéga/botéco	449	419	553
babado/babato	429	398	536
pagóde/pacóte	416	436	526
do lódo/do lóto	412	397	496
rabudo/reduto	410	389	501
All words	426	408	524

### Conclusions.

The intrinsic duration of the Brazilian Portuguese vowels as determined by this study show that mid open [ɛ] and [ɔ] and low [a] are intrinsically longer vowels than the higher [i e o u], which supports the hypothesis that low vowels are longer than high vowels. The reason for this observed phenomenon is not clearly established. Lisker (1974) discusses several possible explanations, among which is the statement of Lehiste (1970) that 'the greater length of low vowels is due to the greater extent of the articulatory movements involved in their production' (p. 19). Lisker points out, however, that investigation into the glide and steady-state subsegments of the vowels indicates no systematic differences between high and low vowels. He states that if the additional length of the lower vowels were due to greater movement of jaw and tongue, there would be longer periods of glide to and from the steady-state interval of these vowels. Other explanations are no more satisfactory, according to Lisker: 'so far all we have is evidence that some sort of relation between duration and vowel height exists, none that this relation must be' (p. 238).

Regarding the variation of duration due to post-vocalic consonant voicing, the present study supports the observation that vowels are longer before voiced consonants than before voiceless, although as for other languages investigated in studies reported elsewhere (see references cited in the section Durational Variation Due to Post-vocalic Consonant Voicing), the differential is not nearly as great as in English (cf. Peterson and Lehiste 1960). Since there is a phonemic voicing contrast in the Brazilian Portuguese consonant system (cf. the word pairs used in this study, as well as such pairs as casa [kaza] 'house' and caça [kasa] 'hunt', doce [dosi] 'sweet' and tose [tosi] 'he coughs') much like that of English, there is some question as to the validity of the suggestion that the much greater differential between pre-voiced consonant vowels and those occurring preceding a voiceless consonant is a result, in English, of learned behavior due to the heavy load carried by the voicing distinction in English phonology. If the same cannot be said about Brazilian Portuguese, what might be the reason for the difference?

The durational variations due to position within the sentence show no surprising results. Final, or pre-pausal, position has previously been observed as the position of greatest lengthening, at least in English (Umeda 1975, Klatt 1975, Stetson 1928, 1951). The variations observed in the present study are somewhat suspect, however, due to the fact that one speaker, B, had extra-long stressed vowels in the sentence-final words, and also because the script was not randomized. The sentences of a single frame-type occurred in uninterrupted sequence, thus allowing a rhythmic pattern to be established and even exaggerated. A mixing of frame-types and the inclusion of dummy distractor sentences would have provided, perhaps, for more natural speech patterns and more reliable observations.

#### Suggestions for Further Research.

Two studies are suggested by the findings presented here. The first, and most immediately apparent, would look into the degree to which the length of the open mid vowels plays a role in the perception of the open/close distinction in Brazilian Portuguese, as compared to the role of vowel quality.

The second study might investigate the relationships among the vowel, the syllable, the word and the sentence in terms of durational variation, to establish ratios and determine the extent to which isochrony may be involved in explaining the variations reported in the present study.



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(with gloss)

Sentence and Gloss	Sentence Duration		
	A	B	C
1. Barrica não é o mesmo que barriga. 'cask is not the same as belly'	1554	1378	1422
2. Babado não é o mesmo que babato. 'damp with drool'.....'I hesitate'	1626	1422	1550
3. Rabudo não é o mesmo que reduto 'big-tailed'.....'fortress'	1536	1506	1452
4. Bodega não é o mesmo que boteco 'low-class bar'.....'small bar'	1718	1588	1511
5. Pacote não é o mesmo que pagode. 'parcel'.....'temple'	1635	1491	1535
6. Do loto não é o mesmo que do lodo. 'of Loto (a card game)....'of mud'	1545	1470	1480
7. Maceta não é o mesmo que macedo. 'stone mason's tool'....monotonous'	1749	1561	1612
8. Barriga não é o mesmo que barrica.	1600	1394	1588
9. Babato não é o mesmo que babado.	1714	1424	1510
10. Reduto não é o mesmo que rabudo.	1651	1438	1540
11. Boteco não é o mesmo que bodega.	1518	1504	1554
12. Pagode não é o mesmo que pacote.	1546	1460	1500
13. Do lodo não é o mesmo que do loto.	1511	1520	1584
14. Macedo não é o mesmo que maceta.	1568	1558	1604
15. Decoro não é o mesmo que maroto. 'decorum'.....'crook'	1546	1570	1493
16. Maroto não é o mesmo que decoro.	1436	1362	1439
17. Diga barrica mais uma vez, tá?	1360	1461	1417
18. Diga barriga mais uma vez, tá?	1519	1572	1440
19. Diga babado mais uma vez, tá?	1631	1575	1523
20. Diga babato mais uma vez, tá?	1599	1509	1448

21.	Diga reduto mais uma vez, tá?	1616	1516	1470
22.	Diga rabudo mais uma vez, tá?	1618	1550	1452
23.	Diga bodega mais uma vez, tá?	1665	1520	1436
24.	Diga boteco mais uma vez, tá?	1724	1505	1458
25.	Diga pacote mais uma vez, tá?	1680	1538	1506
26.	Diga pagode mais uma vez, tá?	1718	1638	1528
27.	Diga do lodo mais uma vez, tá?	1612	1567	1532
28.	Diga do loto mais uma vez, tá?	1538	1536	1471
29.	Diga maceta mais uma vez, tá?	1638	1576	1576
30.	Diga macedo mais uma vez, tá?	1660	1596	1532
31.	Diga decoro mais uma vez, tá?	1639	1554	1532
32.	Diga maroto mais uma vez, tá?	1528	1528	1471



APPENDIX 2  
SPECTROGRAPHIC MEASUREMENTS

Vowel/ Position	Speaker	VOICED CONSONANT					VOICELESS CONSONANT				
		Vowel Duration (in msec)	Word Duration (in msec)	Sentence Duration (in msec)	Vowel:Word (in %)	Vowel:Sentence (in %)	Vowel Duration (in msec)	Word Duration (in msec)	Sentence Duration (in msec)	Vowel:Word (in %)	Vowel:Sentence (in %)
[i] Initial	A	105	403	1600	26.1	6.6	92	396	1554	23.2	5.9
	B	116	406	1394	28.6	8.3	109	409	1378	26.7	7.9
	C	122	458	1588	26.6	7.7	100	385	1422	26.0	7.0
Medial	A	87	340	1519	25.6	5.7	95	367	1360	25.9	7.0
	B	110	387	1572	28.4	7.0	91	354	1461	25.7	6.2
	C	109	414	1440	26.3	7.6	86	368	1417	23.4	6.1
Final	A	118	472	1554	25.0	7.6	110	524	1600	21.0	6.9
	B	125	477	1378	26.2	9.1	100	500	1394	20.0	7.2
	C	120	475	1422	25.3	8.4	98	528	1588	18.6	6.2
[e] Initial	A	86	460	1568	18.7	5.5	84	459	1749	18.3	4.8
	B	100	450	1558	22.2	6.4	100	470	1561	21.4	6.4
	C	72	443	1604	16.3	4.5	80	456	1612	17.5	5.0
Medial	A	86	420	1660	20.5	5.2	102	470	1638	21.7	6.3
	B	104	414	1596	25.1	6.5	90	400	1576	22.5	5.7
	C	94	478	1532	19.7	6.1	92	498	1576	18.5	5.8
Final	A	107	639	1749	16.8	6.1	96	499	1568	19.2	6.1
	B	149	576	1561	25.9	9.6	106	592	1558	17.9	6.8
	C	79	538	1612	14.7	4.9	76	526	1604	14.5	4.7
[ɛ] Initial	A	156	449	1718	34.7	9.1	120	441	1518	27.2	7.9
	B	144	471	1588	30.6	9.1	134	494	1504	27.1	8.9
	C	144	398	1511	36.2	9.5	130	440	1554	29.6	8.4
Medial	A	144	426	1665	33.8	8.7	122	466	1724	26.2	7.1
	B	118	364	1520	32.4	7.8	112	376	1505	29.8	7.4
	C	133	420	1436	31.7	9.3	97	460	1458	21.1	6.7

Vowel/ Position	Speaker	/ _____ VOICED CONSONANT					/ _____ VOICELESS CONSONANT				
		Vowel Duration (in msec)	Word Duration (in msec)	Sentence Duration (in msec)	Vowel:Word (in %)	Vowel:Sentence (in %)	Vowel Duration (in msec)	Word Duration (in msec)	Sentence Duration (in msec)	Vowel:Word (in %)	Vowel:Sentence (in %)
[e] Final	A	151	488	1518	30.9	10.0	145	604	1718	24.0	8.4
	B	173	526	1504	32.9	11.5	147	588	1588	25.0	9.3
	C	147	557	1554	26.4	9.5	107	552	1511	19.4	7.1
[a] Initial	A	156	444	1626	35.1	9.6	120	496	1714	24.2	7.0
	B	116	416	1422	27.9	8.2	120	397	1424	30.2	8.4
	C	104	388	1550	26.8	6.7	120	430	1510	27.9	8.0
Medial	A	136	404	1631	33.7	8.3	123	392	1599	31.4	7.7
	B	116	368	1575	31.5	7.4	115	362	1509	31.8	7.6
	C	124	428	1523	29.0	8.1	116	434	1448	26.7	8.0
Final	A	144	582	1714	24.7	8.4	140	546	1626	25.6	8.6
	B	175	520	1424	33.7	12.3	157	528	1422	29.7	11.0
	C	118	492	1510	24.0	7.8	110	550	1550	20.0	7.1
[ɔ] Initial	A	180	398	1546	45.2	11.6	107	431	1635	24.8	6.5
	B	144	396	1460	36.4	9.9	124	445	1491	27.9	8.3
	C	154	408	1500	37.8	10.3	114	418	1535	27.3	7.5
Medial	A	150	392	1718	38.3	8.7	120	479	1680	25.1	7.1
	B	151	432	1638	35.0	9.2	120	400	1538	30.0	7.8
	C	145	459	1528	31.6	9.5	104	454	1506	22.9	6.9
Final	A	139	544	1635	25.6	8.5	118	514	1546	23.0	7.6
	B	178	537	1491	33.2	11.9	153	529	1460	28.9	10.5
	C	156	505	1535	30.9	10.2	100	528	1500	18.9	6.7
[o] Initial	A	125	366	1511	34.2	8.3	115	416	1545	27.6	7.4
	B	126	446	1520	28.3	8.3	110	423	1470	25.9	7.5
	C	119	425	1584	28.0	7.5	100	396	1480	25.3	6.8

Vowel/ Position	Speaker	/ _____ VOICED CONSONANT					/ _____ VOICELESS CONSONANT				
		Vowel Duration (in msec)	Word Duration (in msec)	Sentence Duration (in msec)	Vowel:Word (in %)	Vowel:Sentence (in %)	Vowel Duration (in msec)	Word Duration (in msec)	Sentence Duration (in msec)	Vowel:Word (in %)	Vowel:Sentence (in %)
[o] Medial	A	144	456	1612	31.6	8.9	113	393	1538	28.8	7.4
	B	126	376	1567	33.5	8.0	103	346	1536	29.8	6.7
	C	113	403	1532	28.0	7.4	88	408	1471	21.6	6.0
Final	A	116	493	1545	23.5	7.5	110	472	1511	23.3	7.3
	B	158	528	1470	29.9	10.8	149	516	1520	28.9	9.8
	C	107	450	1480	23.8	7.2	112	519	1584	21.6	7.1
[u] Initial	A	100	411	1536	24.3	6.5	126	433	1651	29.1	7.6
	B	127	426	1506	29.8	8.4	119	377	1438	31.6	8.3
	C	99	380	1452	26.1	6.8	90	430	1540	20.9	5.8
Medial	A	96	368	1618	26.1	5.9	92	369	1616	24.9	5.7
	B	96	388	1550	24.7	6.2	99	398	1516	24.9	6.5
	C	89	406	1452	21.9	6.1	97	407	1470	23.8	6.6
Final	A	117	500	1651	23.4	7.1	107	496	1536	21.6	7.0
	B	154	516	1438	29.9	10.7	120	546	1506	22.0	8.0
	C	95	490	1540	19.4	6.2	99	456	1452	21.7	6.8



## APPENDIX 3

## DURATION DATA FOR [o] TEST-WORD PAIRS

Sentence Position		Duration of Vowel		Duration of Word	
Speaker		Pre-voiceless consonant			
		do loto	maroto	do loto	maroto
Initial	A	115	102	416	365
	B	110	120	423	352
	C	100	108	396	377
Medial	A	113	126	393	444
	B	103	124	346	338
	C	88	116	408	408
Final	A	110	116	472	460
	B	149	158	516	550
	C	112	116	519	464
Pre-voiced consonant					
		do lodo	decoro	do lodo	decoro
Initial	A	125	103	366	406
	B	126	136	446	492
	C	119	104	425	412
Medial	A	144	119	456	427
	B	126	100	376	356
	C	113	103	403	416
Final	A	116	137	493	492
	B	158	162	528	501
	C	107	104	450	464