Pharyngalization in Cairo Arabic

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1. INTRODUCTION

This paper reports an investigation of pharyngalization in Cairo Arabic, one of the most important Arabic dialects.

A characteristic feature of Arabic is that it has few contrasting vowel phonemes, but a large number of consonants, Fig.1. Among the consonants there is another striking feature, which is typical of most Semitic languages, namely the forming of extra series of consonants by using different secondary articulations. In Arabic pharyngalization is used to form extra series of stops and fricatives, a very rare way to produce phonemic contrast in the languages of the world.

The Arabs themselves consider pharyngalization to be a very characteristic feature of the language and generally ascribe it to the consonant. There has been much discussion, however, about what segment is primarily pharyngalized, the consonant or the surrounding vowels. Surrounding vowels are namely strongly affected.

2. PROCEDURE

The investigation is based on six speakers who have recorded real words in a sentence frame with consonants in word initial position, surrounded by the vowel [a]. The pharyngalized and non-pharyngalized stops are disregarded in this context. The voiceless ones do not differ from each other in length of aspiration or duration. The voiced ones do not differ from each other in duration or wave-form.

3. ANALYSIS

1. For the investigation of the consonant segments FFT-spectra of each fricative to the limit of 10 kHz were made. These FFT-spectra in logarithmic scale were transformed to critical band spectra according to the method which has been worked out by

Manfred Schroeder el al. (1979). According to this formula, the spectrum is described as 24 bands. It is drawn as a histogram with each critical band as a bar with constant breadth where the heigth of the bar indicates the average intensity level in dB within each critical band. Each band corresponds to the same distance on the basilar membrane of the ear and gives a more correct auditory representation than the original FFT-spectra. For practical reasons only bands 2-24 were used. To differentiate between the fricatives three measures were used, namely the center of gravity in the critical band spectra, the dispersion in the same spectra and the average level of intensity. The center of gravity is a measure of the overall pitch level of the spectrum and the dispersion is a measure of its flatness.

2. Spectrograms were used to measure and compare formant transitions and vowel formants after /s/ and /ṣ/.

4. RESULTS FROM CRITICAL BAND SPECTRA

A comparison between critical band spectra of /s/ and /ṣ/ shows that both are characterized by a peak in the high frequency range with a sharp fall towards lower frequencies, with /ṣ/ having a more flattened peak than /s/, Figure 2.
/z/ and /ẓ/ both have a peak in the lowest bands in addition to the peaks in the high frequency range which characterize /s/ and /ṣ/ where the voiced pair has lower intensity as compared with the voiceless counterparts, Figure3 . Plotting the center of gravity in critical band spectra against dispersion shows that pharyngalized fricatives have a lower center of gravity and greater dispersion than their non-pharyngalized counterparts, Figure 4. Plotting center of gravity against level of intensity shows the pharyngalized fricatives to have lower intensity than the non-pharyngalized counterparts, Figure 5.

5. RESULTS FROM SPECTROGRAMS

The mentioned differences are based on average values of six speakers and in the individual case they do not need to be particularly great. In one case the relation between /s/ and /ṣ/ was even the opposite as compared with Figure 2. Therefore the difference does not always seem to be sufficient or reliable to allow a differentiation between pharyngalized and non-pharyngalized pairs of sibilants. As a consequence it is also necessary to look at the effects of pharyngalization on the following vowel. Measurements on spectrograms show strong influence on formant transitions of the following vowel, but there are also differences between pharyngalized and non-pharyngalized vowels in the steady state of the vowel. Regarding formant transitions, F2 in particular is affected and the beginning of F2 is rather drastically lowered for all vowels except /uu/, Figure 6. /uu/ is raised by 100-150 Hz instead, Figure 7. This is a consequence of the pharyngal tounge constriction. Uvular-pharyngal tounge constrictions have these effects on F2 as shown by Gunnar Fant (1968). The formant frequencies were also measured in their steady-states, however, to clarify the differences in vowel quality. A comparison between long pharyngalized and non-pharyngalized vowel pairs shows that /ạạ/ differs strongly in F2 and is further back than /aa/. /ii/ and /ịị/ overlap to a great extent, but t-test shows that the difference is significant. /uu/ and /ụụ/ overlap altogether and t-test shows that the difference is not significant, Figure 8. The short vowel pairs on the other hand are always different, where all short vowels are further back in pharyngalized surroundings, Figure 9.

6. DISCUSSION

In the end the picture of pharyngalization turns out to be rather complicated. On the one hand pharyngalized and non-pharyngalized sibilants differ, but not in an altogether clear way. On the other hand vowels also differ, but in a more complex way. Pharyngalized and non-pharyngalized low vowels show great difference in the F2 dimension with no difference between long and short vowels, with pharyngalized vowels further back. Long, high vowels show no or small difference, but short high vowels are always further back. Since pharyngalization is phonemic in Arabic it is only natural to ask what factor is the most important one in this connection. There are very few investigations done in this field, but one made with synthetic speech by Dean Obrecht (1968) shows that the formant transitions are the most important cue to perceive pharyngalization.

The conclusion is that the acoustic correlates of pharyngalization cannot be ascribed to one single segment. Its minimal domain is the syllable where formant transitions are the most important perceptual feature.

ACKNOWLEDGMENTS

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Obrecht, D.H. 1968. Effects of the second formant on the perception of velarization consonants in Arabic. The Hague, Paris: Mouton, p. 41.

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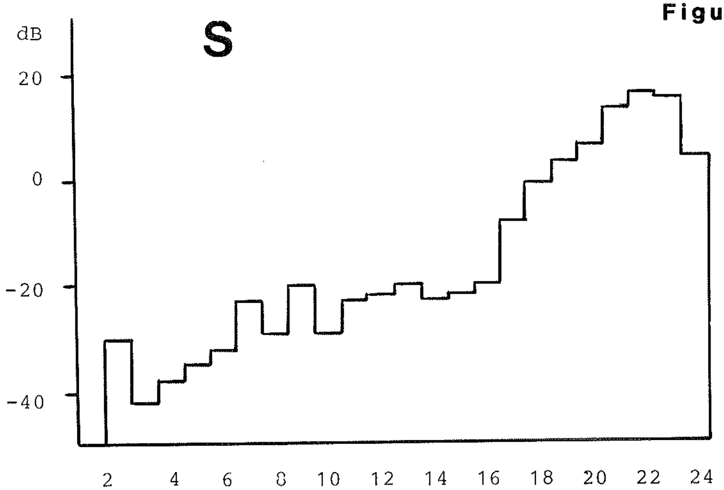
Figure 1

b	t d		k g	q		ʔ
	ṭ ḍ					
f	s z	š	x ɣ		ḥ ʕ	h
	ṣ ẓ					
m	n					
	l					
	r					
w		y				

ii	uu		
		i	u
ee	oo		
aa		a	

Figure 2


S
dB
20
0
-20
-40
2
4
6
8
10
12
14
16
18
20
22
24

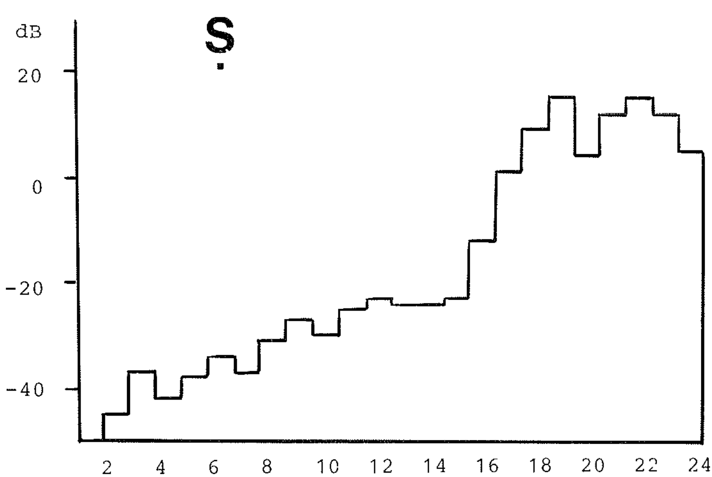
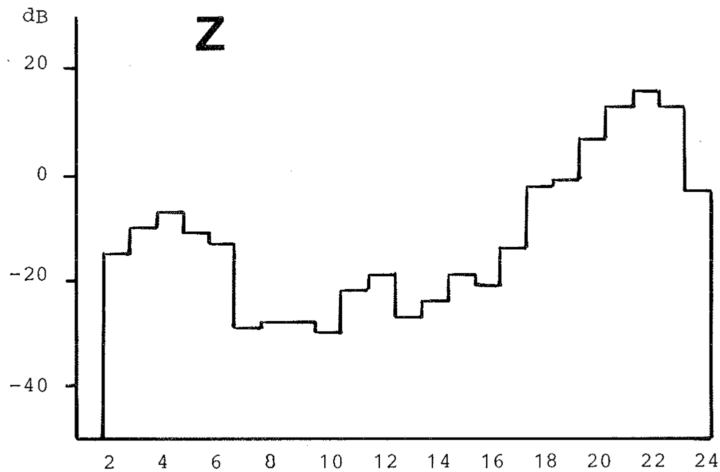
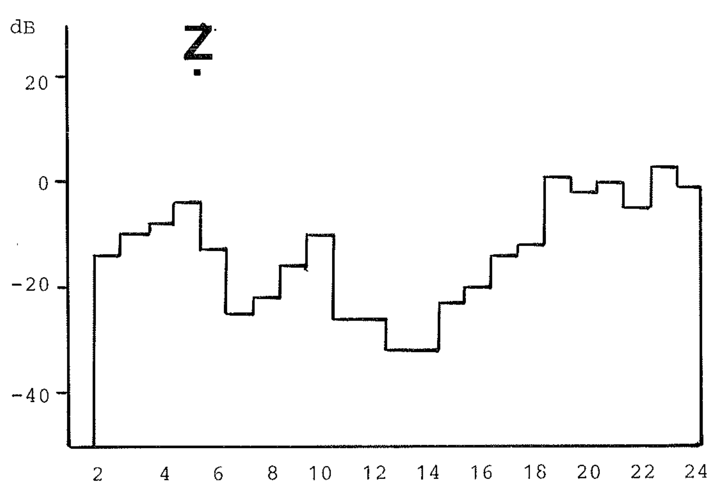

Ṣ
dB
20
0
-20
-40
2
4
6
8
10
12
14
16
18
20
22
24

Figure 3



dB
Z
20
0
-20
-40
2
4
6
8
10
12
14
16
18
20
22
24



dB
20
0
-20
-40
2
4
6
8
10
12
14
16
18
20
22
24

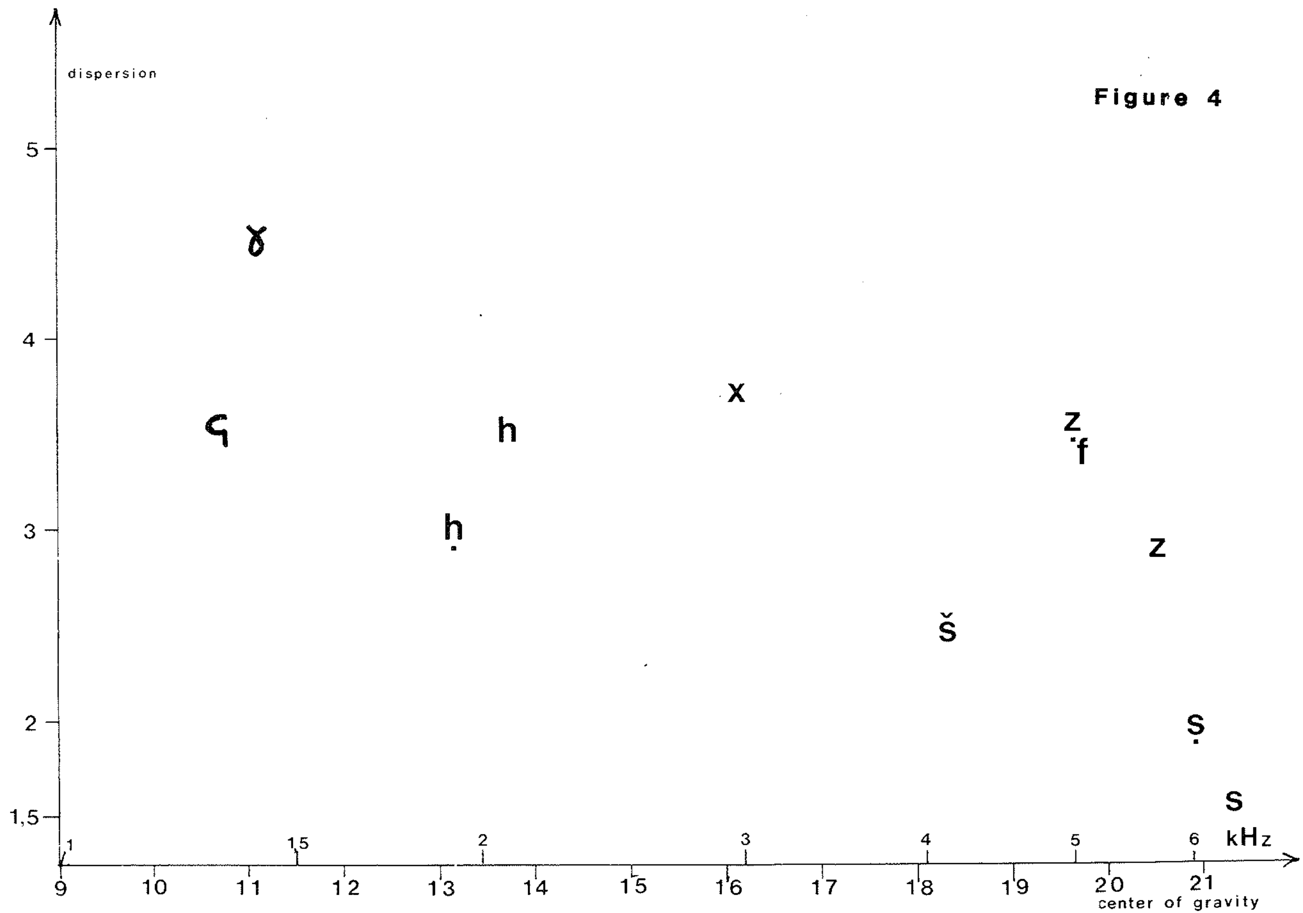

dispersion
5
4
3
2
1,5
ɣ
ʕ
h
ḥ
x
z
f
z
š
ṣ
s
9
10
11
12
13
14
15
16
17
18
19
20
21
center of gravity
1
1,5
2
3
4
5
6
kHz

Figure 4

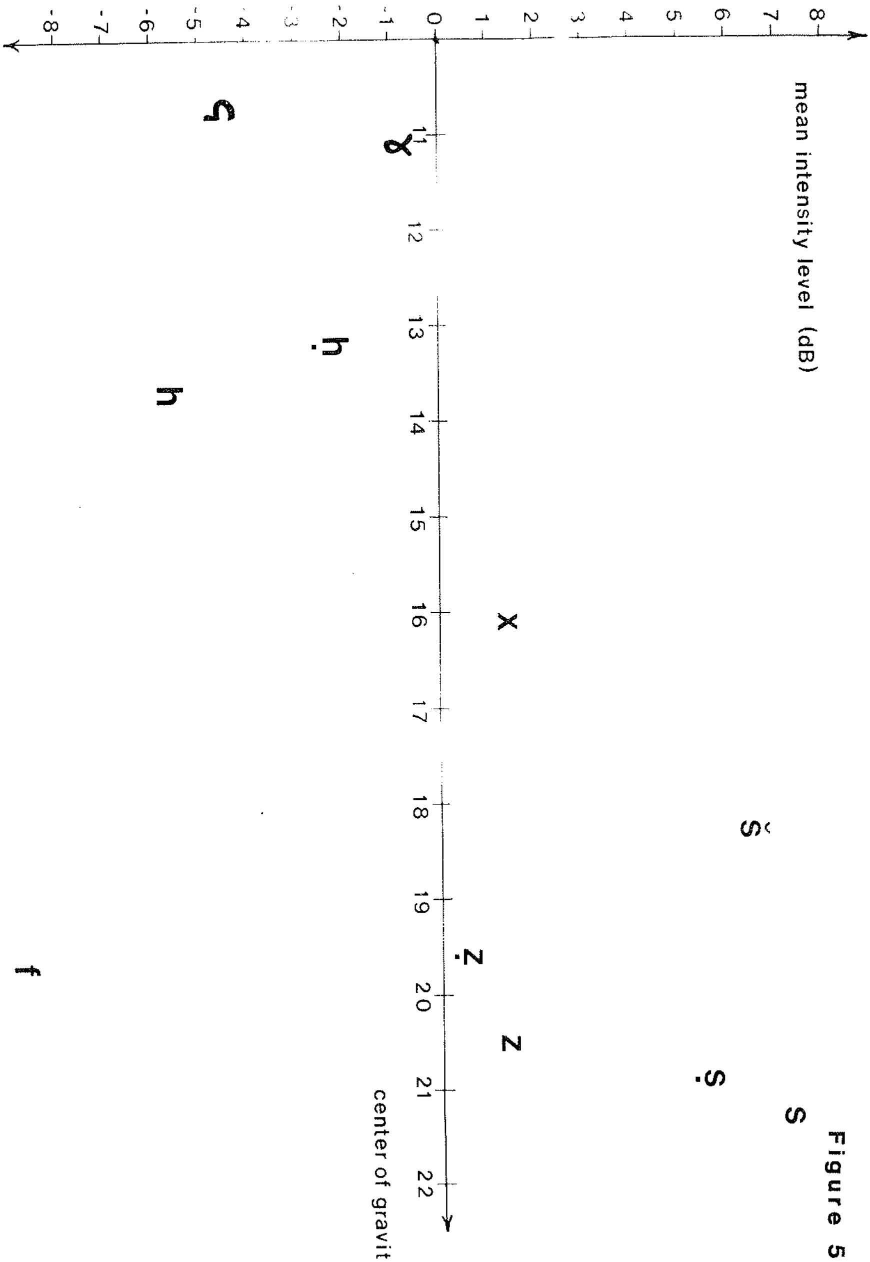

mean intensity level (dB)
center of gravity
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
11
12
13
14
15
16
17
18
19
20
21
22
x
š
ẓ
z
ṣ
s
f

Figure 5

Figure 6

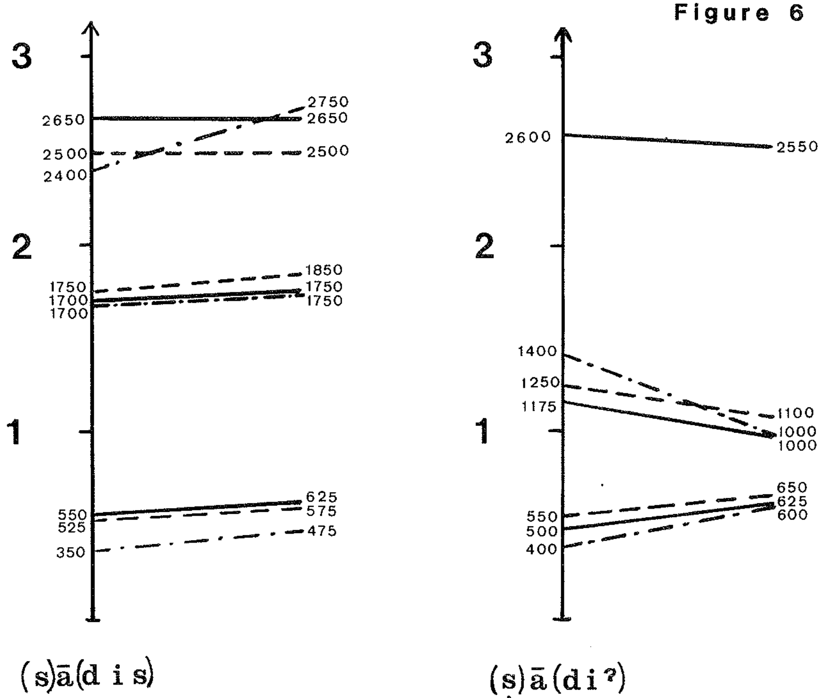
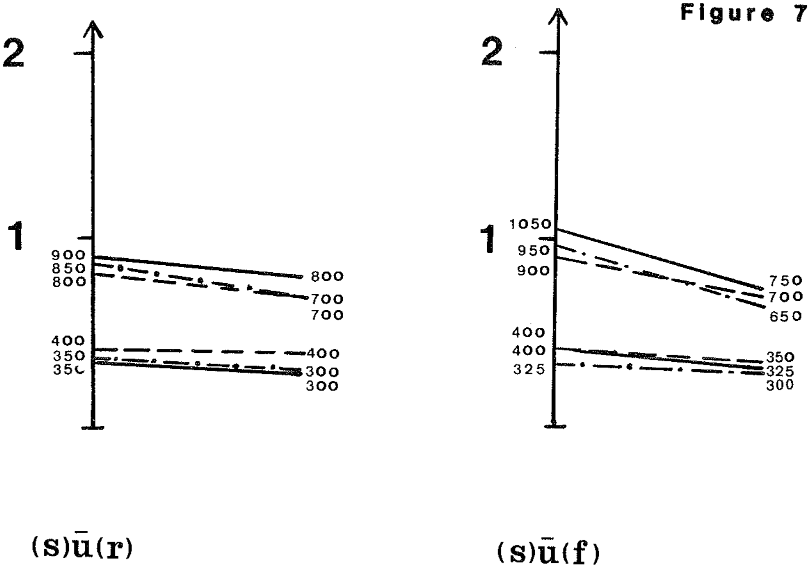


Figure 7



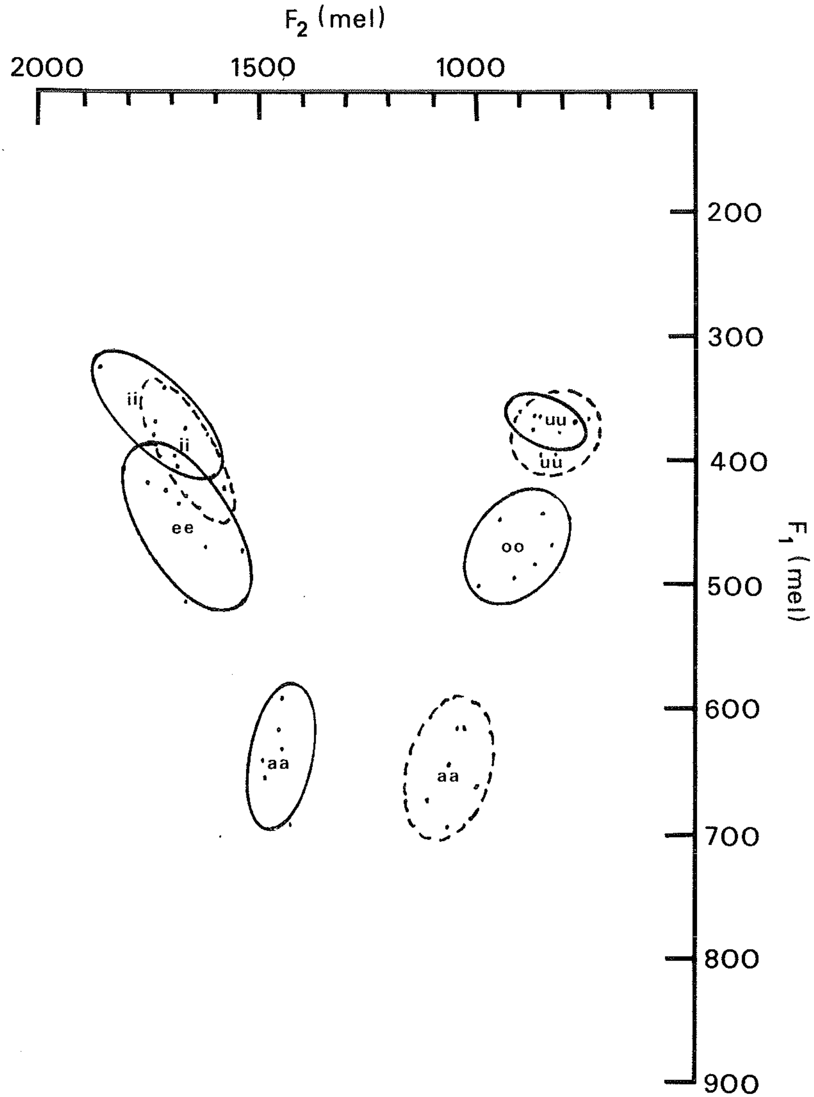


Figure 8. Long plain and pharyngalized vowels.

——— plain vowels

- - - pharyngalized vowels

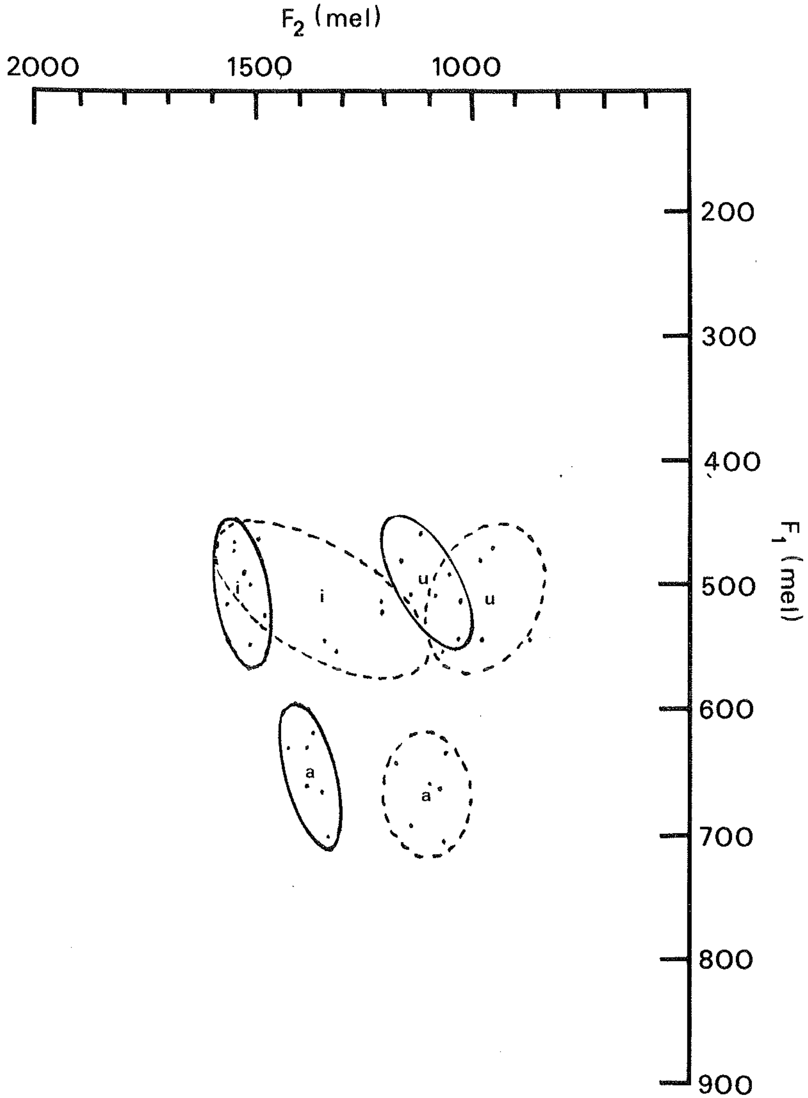


Figure 9. Short plain and pharyngalized vowels.

——— plain vowels

- - - pharyngalized vowels