An Acoustic Study of the place of articulation of Emphatic and non-Emphatic Voiceless Stops in Moroccan Arabic

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Abstract

This paper represents a part of an articulatory and acoustic study which was conducted on the voiceless stop /t/ and its corresponding emphatic /T/ in Moroccan Arabic (hereafter MA). The two types of consonants were studied in initial, intervocalic, and final position of syllables.
FFT and LPC Spectra shapes of the middle part of the burst and the frication noise showed a raising of amplitude in high frequencies for the emphatic and the non-emphatic. This raising becomes more important after 4000 Hz, and the amplitude's prominence takes place between 5000 Hz and 6000 Hz. This fact is one of the acoustic cues indicating the alveolar place of articulation.

Another cue of consonants place of articulation is adjacent vowels. Spectra shapes of the initial, middle, and final part of vowels adjacent the emphatic and the non-emphatic showed that F4 and F5 frequencies are about 5000 Hz and 6000 Hz, respectively, which corresponds to the frequency of consonants amplitude prominence seen above. This can also help to deduce the alveolar place of articulation of voiceless stops in MA.

1 Introduction

It is known that emphatics, in comparison to non-emphatics, are produced with an additional secondary back articulation on the pharynx. This backward movement of the root of the tongue could posteriorize the whole tongue mass, and consequently the principal place of articulation. The aim of this research is to complete palatographic and linguographic data [4] through which we found out that emphatics and non-emphatics are alveolars or dento-alveolars, but the first are apicals and the second are laminals.
For this acoustic study, the burst and the frication noise will be first dealt with, and then vowels adjacent to consonants. Spectrograms and spectral cuts were used to detect a difference between these noises in an emphatic and a non-emphatic context. Then transitions of the first four formants of vowels adjacent to consonants were measured. These measures allow to check formants behaviour on one hand, and to make the relationship between acoustics and the articulation findings on the other hand.

2 Material and procedure

Three Moroccan speakers aged between 26 and 36 years, none of them suffered from articulatory disorders, have been invited to participate in the experiment. They were instructed to pronounce three times, randomly, syllables /#Cab/, /aCa/, and /baC#/ where /C/ is the non-emphatic /t/ or the emphatic /T/. The bilabial /b/ was chosen to minimize the effect of coarticulation, while the /a/ vowel was selected among the other two vowels of Moroccan Arabic, /i/ and /u/, since it is produced with a minimal linguo-palatal contact.
For this acoustic study the items were pronounced three times randomly in an anechoic room before doing a digitization on 'Sound Forge' by a sampling of 25000 Hz on a 16-bits dynamic. Spectrograms and spectral (FFT and LPC) cuts were used to detect differences between noises within the burst and the frication noise in the emphatic and the non-emphatic

context, then to measure transitions of formants values.

3 Results and analysis

3.1 Spectrograms

An observation of consonants spectrograms shows that the frication noise (situated between the end of the burst and the end of the compact part of the noise) is longer for the non-emphatic /t/ (46 ms. on average) than for the emphatic /T/ (8 ms. on average). This can be illustrated through the figures 1 and 2.

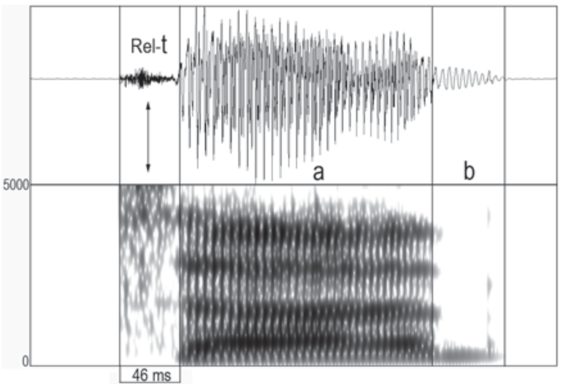

Fig. 1 Spectrogram of /t/ in /tab/.

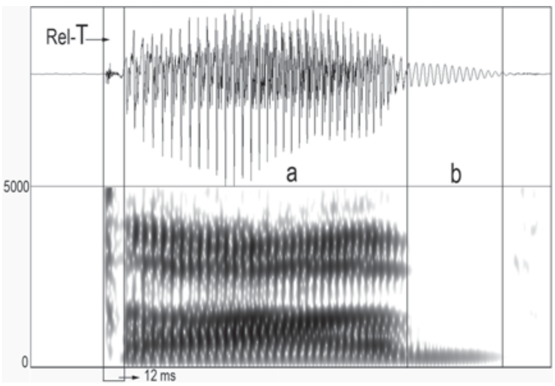

Fig. 2 Spectrogram of /T/ in /Tab/.

The frication noise occurs more easily at 4000 Hz frequency, then its duration for the non-emphatic /t/ (see figure 1) may cause a confusion with the affricate /ts/. The relationship between the non-emphatic and the affricate can be explained by [3] who pointed out that «*if a language has both an apical and a laminal stop consonants, then the laminal consonant is likely to be more affricated.*»(p. 23). Bearing in mind that /t/ is laminal and /T/ is apical from our articulatory findings, we can agree with Ladefoged and Maddieson's point of view.

3.2. Formants values

It is known that emphasis increases F1 value and lowers F2 value for vowels neighbouring emphatics [1]. We measured the values of formants in question by considering the beginning of vowels part represented by the first appearance of F2 for vowels following the studied consonants. Then the end of vowels was represented by the last appearance of F2 for vowels preceding consonants. We obtained the average values given in table 1.

	F1	S.D	P	F2	S.D	P
tab	449	46	<,0001	1704	105	<,0001
Tab	466	41		1269	44	
ata	489	58	=,002	1612	103	<,0001
aTa	549	50		1289	81	
bat	466	35	<,0001	1538	62	<,0001
baT	572	28		1339	62	

Tab.1 Average values of F1 and F2 (3 speakers, 3 repetitions).

A paired-t test indicated that each time there is a significant difference between F1 values, on the one hand, and F2 values, on the other hand. If the raising of F1 and the lowering of F2 may be due to pharyngealization for the emphatic, it can also be explained by the difference in anterior articulation (laminal / apical) between consonants. It was suggested that laminal articulation «*can be attributed to a somewhat higher and fronter tongue body position of the consonant.*» [2] which is the case for the non-emphatic. Furthermore, the expanded back of the tongue towards the pharyngeal cavity as it is the case for the emphatic would result in a decrease of F1.

3.3. Spectra

[5] and [6] have studied the place of articulation of consonants through their spectral realisation. They found out that the form of spectra is raised at high frequencies for alveolar consonants. In addition, according to [7] alveolar stops are characterized by an anterior cavity causing high amplitude frequencies corresponding to F4, F5 frequencies or more for adjacent vowels.

We checked these theories for both /t/ and /T/. We studied these consonants in initial, intervocalic, and final position. Once we had spectrograms, we put the cursor in the middle of the burst to get LPC and FFT spectra as presented in the following figures.

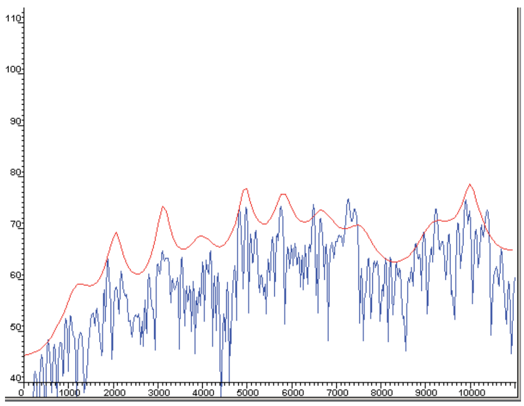

Fig.3 Spectrum of /t/ burst.

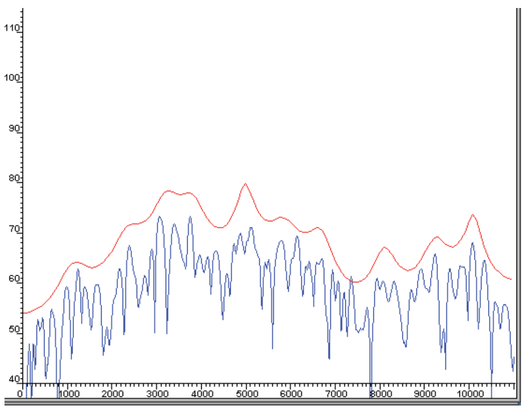

Fig.4 Spectrum of /T/ burst.

As it is shown in spectra above, all speakers produced /t/ and /T/ with a raising amplitude in high frequencies confirming the alveolar or dento-alveolar articulation [6].

The same spectra indicate that their last halves reflect a higher amplitude for the non-emphatic /t/ compared to the emphatic /T/ and thus a less anterior articulation for the latter consonant. This finding confirms the apical articulation of the emphatic and the laminal articulation of the non-emphatic.

After consonants, we dealt with adjacent vowels. To do so we examined whether the frequency of the highest amplitude for consonants corresponds to F4 or F5 or more for adjacent vowels. To do this, we considered the closest part of vowels to consonants (10 ms. as duration) to get the following spectra.

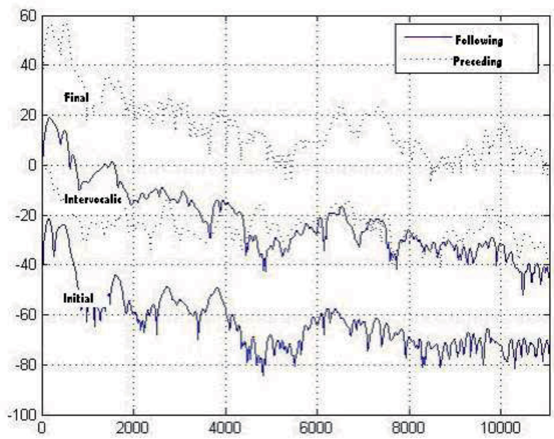

Fig.4 Spectrum of /a/ adjacent to /t/.

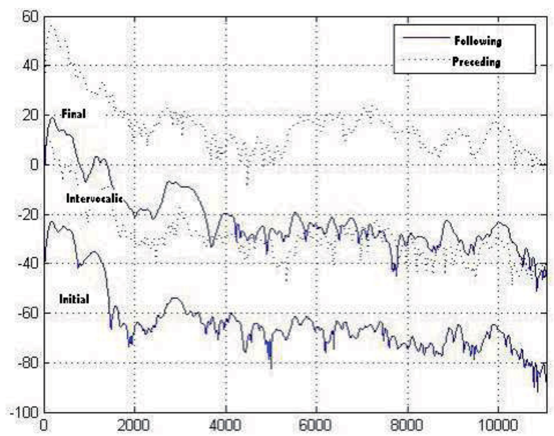

Fig.5 Spectrum of /a/ adjacent to /T/.

We can see through vowels spectra that the value in 5000 Hz or 6000 Hz, which corresponds to the highest amplitude for /t/ and /T/ is the one that lies between the fourth and fifth formants. This fact is another acoustic cue indicating the alveolar articulation of our consonants.

Conclusion

Acoustic results confirm those of the articulatory study. Indeed, we found that the non-emphatic /t/ (which is laminale) is produced with a frication noise more important than that of its corresponding emphatic /T/ (which is apical). Spectral shapes revealed a raising of amplitude in high frequencies which confirms the alveolar articulation of consonants.

The raising of F1 and the lowering of F2 for vowels adjacent to the emphatic /T/ is due not only to pharyngalisation but also to the apical articulation.

References

[1] S. Ghazeli. *Bak consonants and backing coarticulation in Arabic*. PhD dissertation. University of Texas Austin, 1977.

[2] H. Kim . The place of articulation of the Korean plain affricate in intervocalic position, an articulatory and acoustic study. *Journal of the International Phonetic association*, 31, 229-257, 2001.

[3] P. Ladefoged, I. Maddieson.. *The sounds of the world's languages*. Cambridge, USA and Oxford, UK: Blackwell, 1996.

[4] K. Shoul. *Etude physiologique, articulatoire, acoustique, perceptive de l'emphase en arabe marocain oriental*. P.h.D. Thesis, Sorbonne Nouvelle University, 2007.

[5] K. Stevens. Acoustic correlates of some phonetic categories. *Journal of the Acoustical Society of America*, 68, 836-842, 1980.

[6] K. Stevens, S.E. Blumstein. The search for invariant acoustic correlates of phonetic features'. In *Perspectives on the study of speech.* Eimas. P.D., Miller, E. (ed.). 1-38. New Jersey. Lawrence Erlbaum Associates, 1981.

[7] K. Stevens. On the quantal nature of speech. *Journal of phonetics*. 17. 3-45, 1989.