# THE ROLE OF COARTICULATION IN THE PERCEPTION OF VOWEL QUALITY IN MODERN STANDARD ARABIC

*Imad Znagui & Mohamed Yeou*

Laboratoire de Phonétique de Paris, CNRS, URA 1027, Université Paris VIII

## ABSTRACT

In Znagui (1995), on investigation was made of the coarticulatory influence of lingual consonants differing in place of articulation (interdental /ð, θ/, alveolar /s, z/, palatal /ʃ, ʒ/, postpalatal /k/, uvular /χ, ʁ, q/, pharyngeal /ħ, ʕ/ and pharyngealized /tˤ, sˤ, dˤ, ðˤ/ on the adjacent vowels /a, a:, i:, i:, u, u:/ in Modern Standard Arabic (MSA). Measurements were taken of the distance between the frequency of F1 and F2 in the vowel steady state. The results showed that two categories of vowels could be distinguished as a function of the distance between F1 and F2. The objective of the present study is to investigate the perceptual significance of this acoustico-phonetic classification. One question of interest is to see if native speakers of Arabic can discriminate between these categories of vowels.

## 1. INTRODUCTION

Badreddine (1977) and Ghazeli (1977) showed that the forward and backward horizontal displacement of the tongue during the production of arabic consonants (interdental /ð, q/, alveolar /s, z/, palatal /ʃ, ʒ/, postpalatal /k/, uvular /χ,ʁ,q/, pharyngeal /ħ, ʕ/, and pharyngealized (from now on emphatic) /tˤ, sˤ , dˤ , ðˤ / had different and important influences on the articulation and the formant structure of the adjacent vowels. This observation has not been verified in perception.

Previous acoustic studies indicated that the realization of arabic vowels in consonantal context shows a great acoustic dispersion relative to the 3 phoneme qualities /a, i, u/ (Rajouani et al., 1987; Belkaid, 1984, Kiel, 1987; Metoui, 1989). These studies, however calculated the vowel formant frequencies (F1 and F2) in terms of absolute values without undertaking perceptual analyses. To our knowledge, the vocalic space of arabic has not been exhaustively investigated from a point of view of both production and perception .

## 2. OBJECTIVE

The objective of this study is to test by perceptual analysis the validity of a phonetic classification of vowels (in CV syllables) of Modern Standard Arabic (MSA) : vowels into two groups : (a), G1, vowels in the contact of anterior consonants; and (b) , G2, vowels in the context of posterior and emphatic consonants. One question of interest is to examine if arabic subjects can discriminate these two vocalic categories. Another question concerns the degree of CV coarticulation : in which consonantal context vowels change their quality ? Results of this study are discussed with reference to two different theories : Motor Theory (Liberman & Mattingly, 1985) and Auditory Theory (Chistovich & Lublinskaya, 1979; Schwartz, 1987 ...).

## 3. METHOD

### 3.1. Corpus

90 stimuli were constructed on the basis of a corpus consisting of 12 words and non-words produced by a Moroccan speaker. In order to keep a certain homogeneity the following criteria were used:

- only bisyllabic words (CV:CV, CV:CVC) were used
- long vowels /a:, i:, u:/ appeared in CV; open syllables

- only the following consonants were chosen, alveolar /s/, emphatic /sˤ/, uvular /χ/ and pharyngeal /ʕ/

- alveolar /s/ in context of /a: i: u:/ was taken as a representative of anterior and central consonants. Vowels following /s/ present a lesser acoustic variability in comparison with posterior and emphatic consonants (Znagui, 1995)

- only long stressed vowels were taken into consideration, since acoustic analysis showed that neither duration nor stress plays a role in the characterisation and perception of arabic vowels (Znagui, 1995)

- the consonant which follows the vowels in the corpus was always labial.

[a:] of [sa:]+ [a:] of [sˤa:]

[a:] of [sa:]+ [a:] of [χa:]

[a:] of [sa:]+[a:] of [ʕa:]

### 3.2. Material and procedure

The corpus was recorded in anechoic room using a Revox A71, and an ECM 265 microphone which was at a distance of 25 cm from the speakers' mouth. Corpus items were written in arabic orthography and read 3 timbres by a Moroccan speaker. Only one realisation was retained for the experiment. For signal editing, Audiomedia software on Macintosh II was used. The steady state portion of the vowels without transition was edited, since our objective was to test the effect of consonant on vowel target. Stimuli of 300ms-duration were constructed by duplicating periods of the vowel signal taking into consideration zero crossing. Five Arabic listeners judged the stimuli to be of an acceptable quality. The latter were arranged in three blocks of 30 stimuli: the first block contains stimulus with [a:], the second with [i:] and the third with [u:]. The discrimination test (a fixed AX) was a randomized sequence of all possible stimulus comparisons. Intervals between pairs were 0.5 s, between stimuli 2 s, and between ten-stimuli blocks 10 s. The subjects were 10 Arabic and 10 French subjects (aged between 30 and 45). They reported having normal hearing.

## 4. RESULTS

Figure 1 shows that Arabic subjects were capable of distinguishing two vocalic qualities for /a, i, u/ only in the alveolar/emphatic comparison but not in the alveolar/uvular and the alveolar/pharyngeal comparisons. An Anova with types of comparisons X Scores was conducted on the results. Overall differences between types of comparison were significant. [$F(2,9)=46$, $p<0.0001$] for /a:/, [$F(2,9)=45$, $p<0.0001$] for /i:/ et [$F(2,9)=34$, $p<0.0001$] for /u:/. Post-hoc comparisons showed that there were no significant differences between the alv-uvu comparison and the alv-phar one [Scheffé F-test, $p=0.05$] for /a:, i:, u:/. This result seems to be surprising since the discriminated vocalic qualities in the alv-emph comparison do not have a phonological status in ASM, a language which has three short vowels and three long vowels /a, i, u, a:, i:, u:/. We suspect that subjects' ability to discriminate has a psychoacoustic explanation: the important distance betwen F1 and F2 in the perception of vowels (Amerman & Daniloff, 1977). To further investigate this hypothesis, a control experiment was conducted with French subjects.

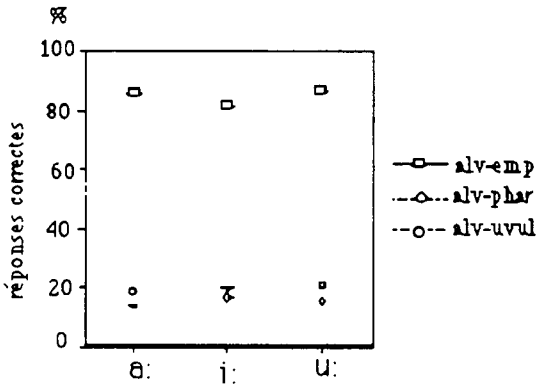


**Figure 1:** Discrimination scores for /a:, i:, u:/ in the three comparisons (alv-emp, alv-phar alv-uvu) calculated on 10 Arabic subjects.

Results indicate that the distribution scores in the alveolar/emphatic comparison were 98%, 87%, and 100% for /a:, i:, u:/ respectively, and 27%, 24%, 15% in the alveolar/pharyngeal comparison, and 28%, 26%, 20% in the alveolar/uvular comparison.

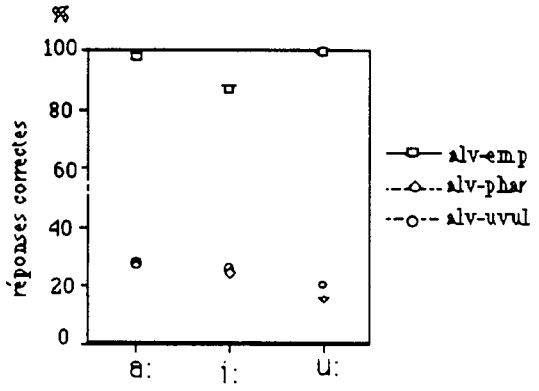


**Figure 2:** Discrimination scores for /a:, i:, u:/ in the three comparisons (alv-emp, alv-phar alv-uvu) calculated on 10 French subjects.

A repeated-measure ANOVA shows that discrimination scores differ significantly between the three types of comparisons [$F(2,9)=7$, $p<0.0001$] for /a:/, [$F(2,9)=76$, $p<0.0001$] for /i:/ et [$F(2,9)=207$, $p<0.0001$] for /u:/. Post-hoc comparisons showed that there were no significant differences betwen the alv-uvu comparison and the alv-phar one [Scheffé F-test, $p=0.05$] for /a:, i:, u:/. Comparison of the arabic subjects' performance with that of French subjects indicate that they differ significantly [$t(9)=4.3$, $p<0.0001$]. French subjects have the best discrimination scores in the alv-emp comparison, probably thanks to French rich vocalic system. Still the psychoacoustic explanation withholds. This is confirmed by the fact that both arabic and French subjects were able to discriminate the two vocalic qualities for each of the three vowels /a:, i:, u:/ in the alv-emphatic comparison.

## 5. DISCUSSION

It seems that the coarticulatory effects of posterior consonants (pharyngeal and uvular) in contrast to alveolar consonants on the three vowels /a:, i:, u:/ are not sufficient in producing different vocalic percepts. This suggests that the forward/backward horizontal displacement of the tongue during the production of ASM consonants has no significant effect in the perception of adjacent vowels.

The anterior/posterior binary feature should not be used as a distinctive feature for the phonological description of these vowels. Only emphatic consonants, which have a double articulation (alveolar/pharyngeal) are capable of producing an acoustico-perceptual effect on the adjacent vowels. A psycho-acoustic classification in terms of the following categories based on the distance between F1 and F2 (see Figure 3) would be very pertinent:

- a category of short vowels in the context of emphatic consonants, characterized by F1 and F2 being very close;
- a category of short and long vowels in the contetxt of non emphatic consonants with F1 and F2 distant apart.

A binary classification of vowels in terms of two groups, one preceded by anterior consonants and the other by posterior consonants and emphatic consonants is not confirmed by the present perceptual experiment. There is then a certain lack of correspondance betwen the perception and production of ASM vowels. It is important to signal the fact that arabic subjects "benefit" from an important articulatory free variation in the production of /a:, i:, u:/ which is correlated with important acoustic variations due to different consonantal contexts (labial, interdental, alveolar, palatal, uvular, pharyngeal, pharyngealized, glottal). Results of the present study indicate that it is possible to distinguish two vowel categories within the vocalic space on the basis of their adjacent consonanatal basis: emphatic and non emphatic.

On the phonological level, it is postulated that each vowel phoneme /a:, i:, u:/ has two variants in function of the emphatic/non emphatic context.

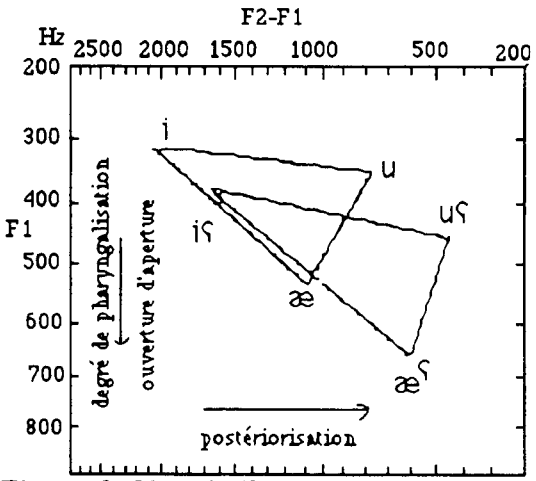


**Figure 3:** Vocalic Triangle of short vowels: emphatic and non-emphatic of MSA produced by 6 Maghrebi speakers.

## 6. BIBLIOGRAPHY


Amerman, J.D. & Daniloff, R.G. (1977) "Aspects of lingual coarticulation,"*Journal of Phonetics* 5, 107-13.

Badreddine, B. (1977) *Analyse phonologique et Phonétique du Parler de Kairouan*. Thèse de 3ème cycle. Paris X.

Belkadi, Y. (1984) Les voyelles de l'Arabe Standard Moderne: analyse spectrographique, *Travaux de l'Institut de Phonétique de Strasbourg*, 16, 217-240.

Chistovich, L. A. & Lublinskaya, V. (1979) "The center of gravity effect in vowel spectra and critical distance between formants: Psycho-acoustical study of the perception of vowel-like stimuli." *Hearing Research* 1, 185-195.

Ghazeli, S. (1977) *Back Consonants and Backing Articulation in Arabic*. Ph.D. Dissertation, University of Texax, Austin.

Kiel, N. (1987) A phonetic study of emphasis and vowels in Egyptian arabic, *Working Papers Lund University*, 30, 1-119.

Liberman, A. M & Mattingly, I. G. (1985) "The motor theory of speech perception revised," *Cognition*, 21, 1-36.

Metoui, (1989) *Contribution à la phonologie et la phonétique arabe : Etudes articulatoire et acoustique des voyelles du Parler de Tunis*, Idstein Schult-Kircher,Verlag.

Rajouani, A., Najim, M. and Chiadmi, D. (1987) "Synthesis of the pharyngealisation feature in arabic," *Speech Communication* 6, 261-268.

Schwartz, J.L. (1987) "A propos des notions de forme et de stabilité dans la perception des voyelles," *Bulettin du Laboratoire de la Communication Parlée*, Vol. 1A, 159-190.

Znagui, I. (1995) *Etudes phonétique et perceptive des voyelles de l'Arabe Standard Moderne*. Thèse de Doctorat, Université Paris III, Paris, 1-250.