Phonetic variation in production and perception of speech: a comparative study of two Arabic dialects

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ABSTRACT

This paper presents a preliminary study of intra-speaker and inter-speaker variability in speech production and perception with an inter-dialect investigation of acoustic vocalic space according to different phonological systems. This work aims at providing an analytic study based on individual data that might account for individual strategies. We have studied variability in vowel production and perception for 20 speakers of two Arabic dialects: Jordanian Arabic and Moroccan Arabic. Results show on the one hand, that vocalic spaces larger for perception than for production for speaker of both Arabic dialects; and on the other hand that the vocalic space in production for Moroccan Arabic seems more centralized than for Jordanian Arabic.

1. INTRODUCTION

Speech variability is a phenomenon that is fairly studied. Despite of speech variability, communication is still possible between speakers speaking different dialects of the same language We will study here the phonetic variability in production and perception of vocalic segments, in two Arabic dialects: Jordanian Arabic (henceforth JA) and Moroccan Arabic (hencefort MA) attesting respectively 5 and 8 vocalic segments. This work is part of a larger research project (Projet Cognitique : *"Variabilité phonétique en production et en perception de parole : rôle et limites des stratégies individuelles",* directed by René Carré, ENST Paris) which aim is to study inter-speakers' variability, so as to find possible individual strategies (*Hombert* 1999). We formulate the hypothesis that vocalic space distribution depends on the number of vocalic segments attested in the language. In this paper, we will try to understand the relation between production and perception in speech. We think that perceptual vowel space is different from that of production. Indeed if the position in the vocalic 'triangle' of produced vowels is different from the position of prototypic perceived vowels will correspond to 'hyper-articulated' produced vowels (*Johnson* 1993). In this paper, we intend to (i) understand the relation between production and perception of vowels, (ii) study speech variability in production and perception of vowels in two Arabic dialects: JA and MA, (iii) observe the differences between vocalic realizations of male and female, (iv) study the distinction between long and short vowels within Arabic dialects, (iv) examine the effect of pharyngealization on the adjacent vowels both in JA and MA. Each of these different points being analysed for both production and perception.

2. RELATION BETWEEN PRODUCTION AND PERCEPTION

Many linguists have tried to explain the relationships existing between production and perception. Some theories were based on the articulation, such as the Motor Theory of Speech Perception revised by *Liberman & Mattingly* [1] According to the authors, hearers use their phonetic knowledge in order to recognize the gesture model corresponding to the acoustical reality of a specific stimulus. *Twadell* [2] *Hockett* [3] and *Delattre* [4] described speech perception as depending on speakers' articulatory habits. *Kluender & al.* [5] proposed that categorical perception does not depend on speakers' articulatory attitudes but on memorization processes. *Fry* [6] developed the notion of '*categorical perception'*. The author showed there are differences between the categorical perception of consonants and vowels. According to *Fry* speakers were able to categorize limits between /b d g/ while they were not able to establish exactly the limits between /i e a/. Indeed, vowel categories merge due to the continuum space from which they proceed. This is not the case for consonants that are formed in a discontinuous space. As mentioned earlier, *Johnson* [7] demonstrated prototypic representations of vowels may correspond to a 'hyper-articulated production'. These experiences were based on a MOA experiment (Method of Adjustment) which revealed hearers' expectations for the sounds of their mother tongue. In this method, speakers manipulate a vocal synthesizer until the machine produces the 'best vocalic target'. *Johnson* compared the vocalic spaces obtained in production and in perception. They found vocalic space in perception is larger than productions' corresponding to a 'hyper-articulated production'.

3. DIALECTAL VARIABILITY IN ARABIC

Arabic language has a variety of regional and dialectal differences. Besides, it is commonly accepted the Arabic speaking world can be divided into two main dialectal areas: the Western area vs. the Eastern area (figure 1). The part including the South East of Tunisia, the West of Egypt and Libya being considered as an intermediate dialectal area

where one can find mixed-languages [8].

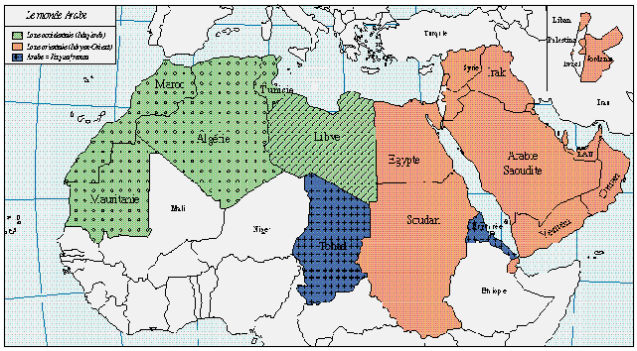

Figure 1: In green with dots: Western area; in plain pink Middle–Eastern area; hatched green area refers to a small part of the dialectal intermediate area whereas crossed section in blue corresponds to the countries where Arabic is spoken as a lingua franca.

4. MATERIAL AND METHOD

In this paper two dialects are studied: Jordanian Arabic spoken in Amman and Irbid and Moroccan Arabic spoken in Casablanca. Vocalic systems of these two dialects are slightly different in terms of number of items: 5 vowels are attested in MA /iː u uː ə a/, 8 vowels in JA /i iː u uː ːe oː a aː/ (figure 2).

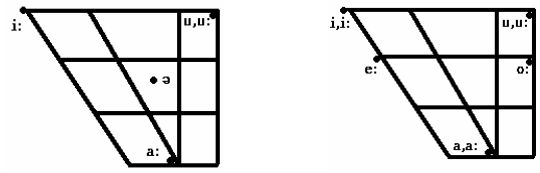

Figure 2: Vocalic systems of Moroccan Arabic (on the left) and of Jordanian Arabic (on the right)

In our corpus, vowels of JA and MA are preceded by 9 consonants /b, d, k, tˁ, dˁ, q, sˁ, w/ in production and by /d/ and /dˁ/ in perception. In production, 51 items for JA and 35 for MA were presented 5 times in random order to 10 male native speakers of JA as well as 10 male native speakers of MA (i.e. 51*5 items for JA i.e., 255 item-corpus and 35*5 i.e., 175 item-corpus for MA). Subjects' realizations were recorded on PC Computer, at 22 KHz, 16 bits, mono. In perception, the experiment was based on a method of formant adjustment (i.e. MOA) of isolated synthetic vowels with F_0 = 120 Hz. Subjects' task was to determine the best prototypic vocalic representations for 16 items (for JA) and 10 (for MA). Each item being presented 10 times (i.e. 16*10 i.e., 160 items for JA and 10*10 i.e., 100 items for MA).

4. DATA ANALYSIS

In production, we extracted values of F1 and F2 at the middle part of the vowels using *Winsnoori*® [9] within two consonantal contexts i.e., /d dˁ/. We converted our data into Barks applying Henton's formula[1] [10] before calculating the average and the standard deviation for all vowels' formant values. In perception, we converted vowel formant values from Hertz to Bark and calculated the average and the standard deviation of F1 an F2 values for all vowels.

5. RESULTS

Results will be presented below both for JA and MA in production as well as in perception: (1) distribution of long vs. short vowels and cross-dialectal comparison of vocalic dispersion, (2) effect of pharyngealization on vocalic distribution, (3) comparison of production vs. perception vocalic spaces. Our hypotheses were: (i) short vowels are more centralized than long ones; (ii) adjacent vowels in pharyngealized context are posteriorized; (iii) vocalic perceptual space corresponds to a hyper-articulated space**.** We think *a priori* results would follow the same patterns both in production and perception. Several works deal with the opposition between long and short vowels in Arabic among them [11] [12] [13] [14] [15]. Authors regularly noticed short vowels are reduced as compared to long ones confirming Lindblom's finding [16] Our analysis reveals the same pattern of distribution for production as well as for perception both in JA and MA, short vowels centralization being significant on the statistical level ($p<0.0001$) (figures 3 to 6).

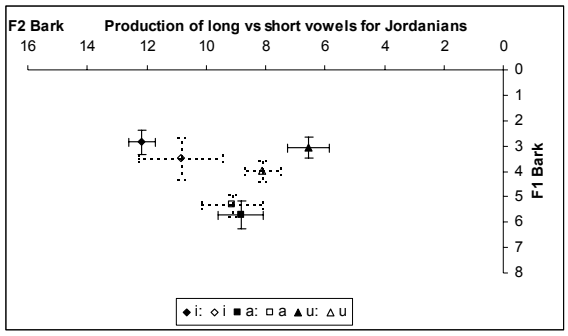

Figure 3: long vs. short vowels distribution for JA in production.

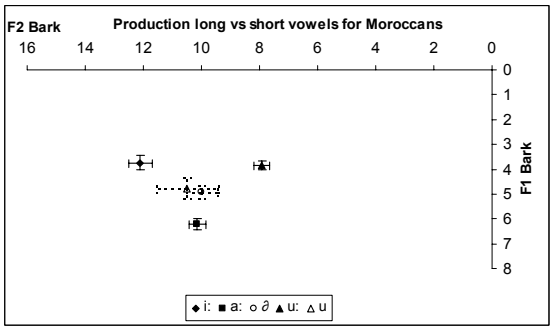

Figure 4: long vs. short vowels distribution for MA in production.

[1] *6*ASINH*(Data/600) – 1 where ASINH* corresponds to the reversed hyperbolic Sinus of a number; *Data* is the formant value of F1 and/or F2 in Hz.

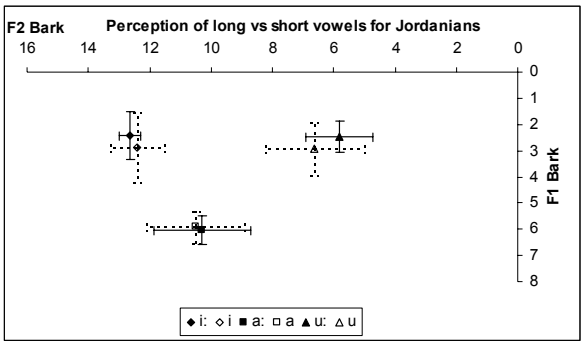

Figure 5: long vs. short vowels distribution for JA in perception.

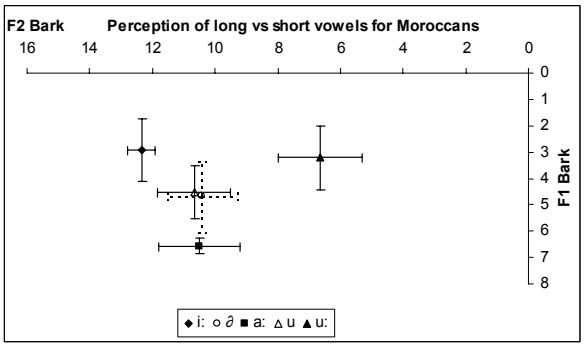

Figure 6: long vs. short vowels distribution for MA in perception

In order to see if the size of vocalic inventory affects its organization in terms of distribution, we compared the organization of vocalic space in JA vs. MA. Our claim was that the fewer segments are attested in a language the larger the distribution for each vowel could be observed. In other words, a great amount of variability for the realization of one segment could be observed without leading to categorization mistakes. Graphical representation below show the fewer vowels are attested in a language the greater variation for the realization of each vowel is observed: largest ellipses corresponding to Moroccan long vowels /iː uː aː/ as compared to their Jordanian counterparts (figure 7).

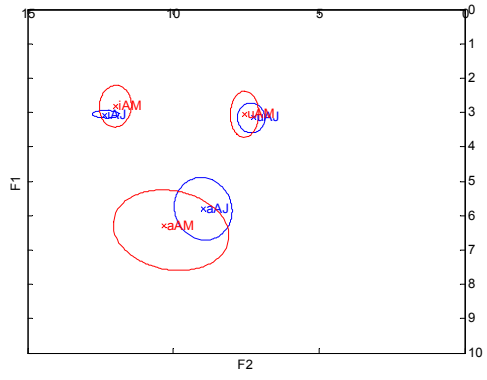

Figure 7: Long vowels dispersion for Moroccan Arabic (in red) vs. Jordanian Arabic (in blue).

Besides, statistical analyses show us on the one hand there are differences in the dispersion of vowels in the Arabic dialects. MA vocalic space, for long and short vowels, is more centralized than JA's ($p<0.0001$). The central open vowel /aː/ in JA is significantly more posterior than its Moroccan equivalent ($p<0.001$). In dental context, MA /u/ and /ə/ merge in MA ($p<0.001$) (cf. figure 8 and 9) leading to a simplification on the phonological system.

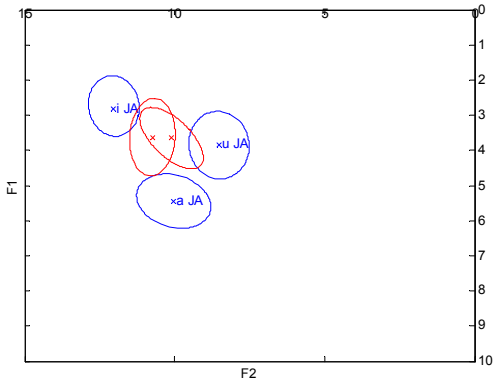

Figure 8: Short vowels dispersion for Morrocan Arabic (in red) vs. Jordanian Arabic (in blue).

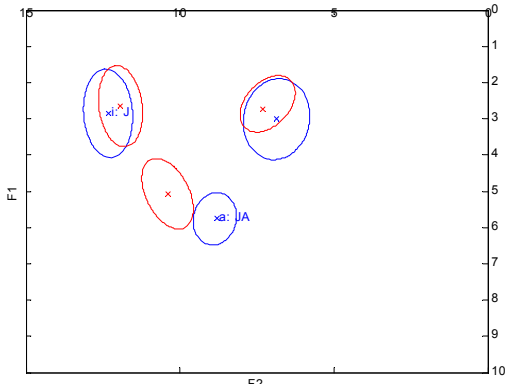

Figure 9: Long vowels dispersion for Moroccan Arabic (in red) vs. Jordanian Arabic (in blue).

The effect of pharyngealization on adjacent vowels is also fairly studied [11] [12] [13] [17]. Authors found that adjacent vowels are posteriorized in pharyngealized context (i.e. lowering of F2 values). Nevertheless there is no cross-dialectal comparative study of pharyngealization effect on adjacent segments. Statistical analysis on data obtained in production in JA and MA showed pharyngealized vowels are posteriorized (i.e. figures 10 & 11) confirming the literature. We observed as well an effect of pharyngealization both on F1 and F2 axis in MA ($p<0.0001$) (cf. figures 12 & 13). In perception, JA vowels in pharyngealized context attest a significant difference on F1 axis only ($p<0.0001$). Indeed we did not find any effect of contextual pharyngealization on F2 as expected *a priori*. This result may be interpreted in the light of Barkat's perceptual experiments (2000) where Jordanian dialects were said to be easily discriminated from other Arabic dialects thanks to '*a higher degree of pharyngealization'* which may be linked to a more important opening of the jaw. Articulatory measures should be taken so as to answer this question.

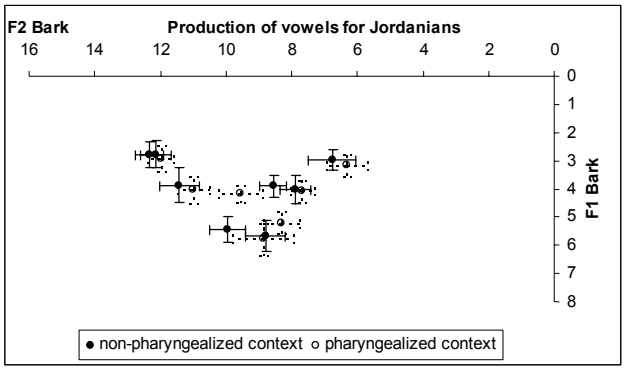

Figure 10: Effect of pharyngealization on vowels in production (JA)

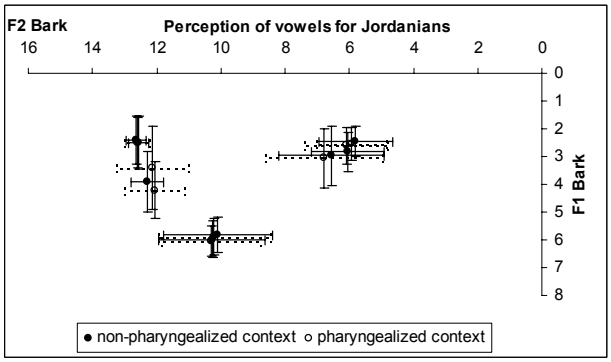

Figure 11: Effect of pharyngealization on vowels in production (MA)

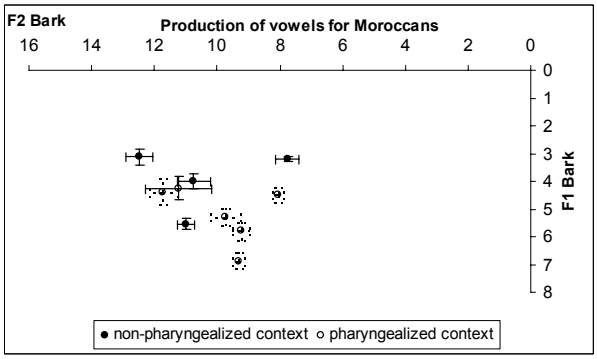

Figure 12: Effect of pharyngealization on vowels in perception (JA)

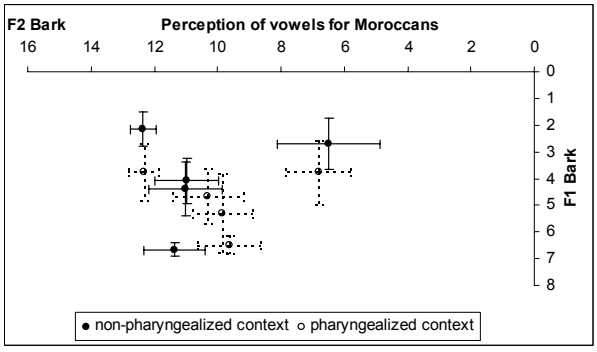

Figure 13: Effect of pharyngealization on vowels in perception (MA)

Eventually, as done in *Johnson* (1993), we compared production and perception vocalic spaces. If the perceptual vocalic space is larger than the one observed in production then, we could confirm that the perceptual vocalic space corresponds as a matter of fact to a hyper-articulated space.

We applied different statistical analysis (ANOVAs and T-tests) in order to compare: the global vocalic distribution in production vs. perception then for each vowel separately. Both in Jordanian and Moroccan Arabic, the perceptual vocalic space is larger that it is in production ($p<0.0001$). Back vowels are backed in perception whereas front vowels are As for F1 axis it appeared that closed vowels are significantly more closed in perception whereas open vowels are more open and more posterior ($p<0.0001$ (figures 14 & 15).

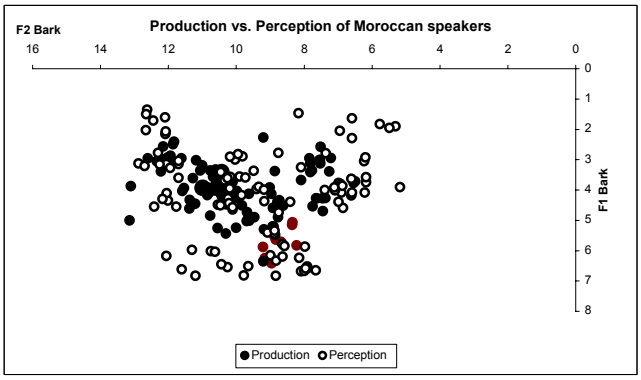

Figure 14: production vs perception for MA speakers

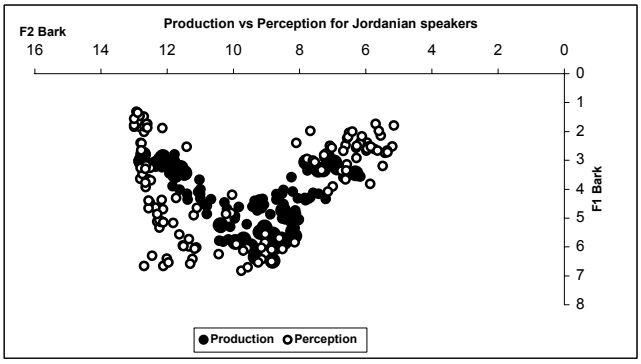

Figure 15: production vs perception for JA speakers

5. CONCLUSION

Results revealed that for some of the issues mentioned one can observe the same pattern of realization both in speech production and perception modality (i.e., reduction of short vowels as compared to their long counterparts both in JA and MA leading to a centralized vocalic distribution in Moroccan Arabic as opposed to a peripheral dispersion in Jordanian Arabic; backing co-articulation both in JA and MA in pharyngealized context due to the inertia of articulators and the lowering of velum for the articulation of pharyngealized consonants ; a greater variability for the realization of vocalic segments when the system attest few vowels and last but not least, our study confirms Johnson's work since we were able to observe perceptual vocalic space corresponds to a hyper-articulated vocalic triangle so as to integrate speech variability without any risks for speech comprehension.

6. REFERENCES

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