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ULTRASOUND STUDY OF MOROCCAN ARABIC LABIOVELARIZATION

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ABSTRACT

In this survey, we analyze acoustic and ultrasound data from two subjects in order to characterize a secondary articulation generally analyzed as labialization in Moroccan Arabic. Our results show that the so-called labialized consonants are rather labiovelarized. They also show that the vowel [a] adjacent to the labiovelarized consonants is velarized.

Keywords: labialization, velarization, ultrasound, Arabic, velar, labial

1. INTRODUCTION

Several phonological studies [5, 6, 8] have underlined that Moroccan Arabic (MA) has, in addition to pharyngealization, another secondary articulation generally characterized as a labialization, which they associate with dorsal (/k g χ ʁ q/ = /K/) and labial (/b, m, f/ = /B/) consonants. However, recent studies have demonstrated that this characterization is a cover feature which hides more complex phonetic details [11].

Phonological descriptions mention that this pronunciation is attested in initial clusters #CKV and #KCV where /K/ is a dorsal consonant and /V/ different from /u/. For these reasons, it has often been analyzed as labialization anchored phonologically to the dorsal consonants in the segmental string #K^{w}CV and #CK^{w}V. However, at the phonetic level and according to several phonological descriptions, segments in the vicinity of these labialized dorsals and labials are also affected by this secondary articulation. Indeed, C_1 is always labialized in C_1K^{w}V [6], C_2 is labialized in K^wC_2V only if it is labial #K^{w}B^{w}V [8], and /a, i/ are velarized in CK^{w}V and #K^{w}BV [5].

MA also exhibits labialized labials /BB^w/ as a consequence of coalescence between underlying labial /b, m, f/ and a glide /w/ (#BwV→ BB^{w}V). For Heath [6] these geminate labials are not only labialized, but also velarized. For Mitchell, [8] they are "usually realized as emphatic", while Elmedlaoui [5] considered these labialized labials as merely velarized.

To our knowledge, only one published study has investigated the articulatory correlates of this MA labialization [11]. Based on acoustic and EMA data, this study demonstrated that, in #K^{w}Ca and #CK^{w}a contexts, the labialization is always aligned with the initial consonant and /k/ is more back than in #KCa and #CKa. /k^w/ seems to be mainly velarized in CK^{w}a and labiovelarized in #K^{w}Ca. This same articulatory survey showed that in BB^{w}V, BB^w are velarized and the maximal target of their secondary articulation is aligned with the onset of [V]. It also confirms that the vowel /a/ is velarized in #CK^{w}a, #K^{w}ba and BB^{w}a.

Notice that this published articulatory analysis of labialization in MA [11] was based on EMA and acoustical data from only one speaker. EMA does not provide a complete representation of the tongue articulator shapes. To further characterize the nature of the tongue dorsum involvement during this secondary articulation of (labio)-velarization, we conducted an exhaustive ultrasound experiment in which five MA speakers participated. In this paper, we discuss results from two speakers. To simplify our analyses, we adopt at first broad phonological representations (#K^{w}CV and #CK^{w}V) to which we try to associate a more narrow phonetic characterization.

2. METHOD AND MATERIAL

2.1. Subjects

5 MA native speakers (4 males and 1 female, aged between 30 and 40 years) with no history of speech or hearing disorders participated in an ultrasound experiment. Only the data of two speakers S1 and S2 (males), are discussed in this survey. In fact,

their tongue contours are more distinct and clearly visible compared to the other speakers.

2.2. Material

During this experiment, 5 words and 1 nonsense word containing emphatic, back, and labialized consonants and their non-emphatic and non-labialized cognates were produced in different phonetic contexts to test several hypotheses. For this present paper, only the subset of items presented in the Table 1 were selected in order to compare the position of tongue dorsum during /k/ in different vocalic contexts and /f/ before /a/, with their labialized cognate /k^w/ and /ff^w/. These items were pronounced more than five times without a carrier phrase. Only the 5 tokens with the clearest ultrasound contours were analyzed statistically.

Table 1: List of the subset of items pronounced during the ultrasound experiment.

Item	Glosses
/kan/	To be
/kul/	To eat
*/kis/	nonsense word
/sk^wat/	Silence
/fad/	To interest
/ff^wad/	Trips

2.3. Method and ultrasound measures

Ultrasound video data were recorded in a sound-attenuated room using the Mindray portable Ultrasound system DP-6600 (scan rate of 30frames/sec) and the software Articulate Assistant Advanced 2.12 (AAA 2.12 [1]). Ultrasound video and audio signals were captured into an avi file. To increase the accuracy of the synchronization between these two signals, we invite our subjects to start the recording of each sample with the sequence /kakaka/.

For a more reliable comparison between images extracted from different ultrasound recording sessions (of the same speaker), the probe was fixed underneath the speaker's chin in a position where the recorded images are between the (acoustic) shadows of the hyoid bone and the mandible (Fig. 1). To keep this position constant, the probe was supported by a moldable head stabilizer fixed on the head of our speakers.

For each speaker, using the AAA program, we identified within each of the 6 items three frames. The first one corresponds to the midpoint of the prevocalic consonant /f ff^w k, k^w/. The second and the third ones are at the onset and the midpoint of /V/ (Fig. 2) respectively. A fan grid was placed over these frames and the contours of the tongue were drawn manually: five times for each item (for more technical details and recommendations see [10]). Then, x and y values were exported to the Excel program for statistical analyses.

Figure 1: Example of ultrasound frame extracted from our video recording with a fan grid. TD: Tongue dorsum, TB: Tongue blade, AS: acoustic shadows of the hyoid bone (left) and the mandible (right).

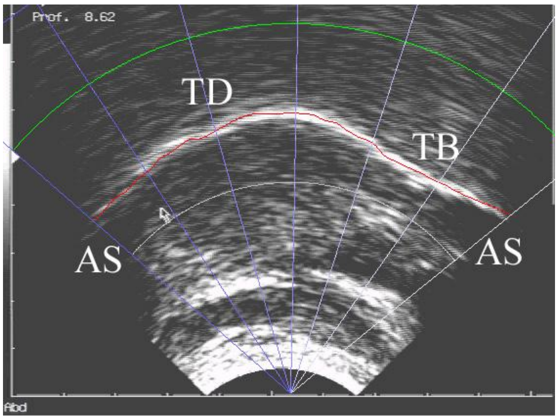
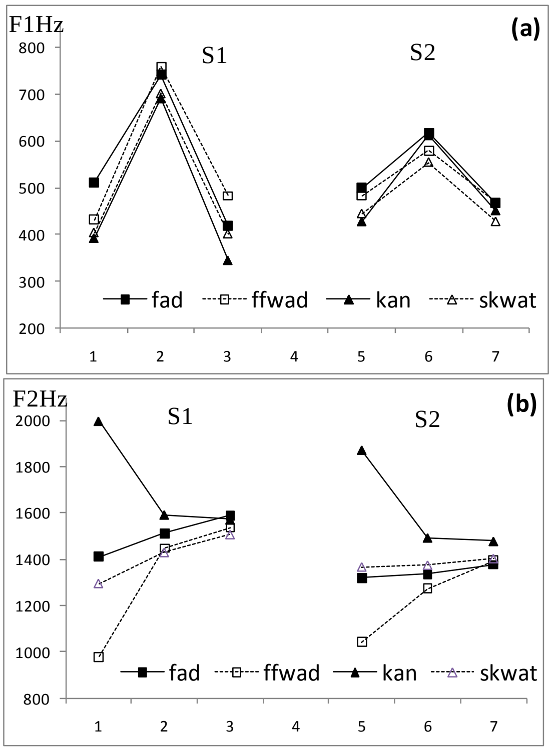


Figure 2: Onset, mid, and offset mean values of F1 (a) and F2 (b) of the vowel [a] produced in the words /fad/, /ff^wad/, /kan/, and /sk^wat/ (5 tokens) by the speakers S1 and S2.



2.4. Acoustic measures

In these items, we also measured F1 and F2 frequency values of the vowels (5 tokens x 2 speakers) using Praat.

3. RESULTS AND DISCUSSION

3.1. Acoustic data

Our statistical analyses (separate ANOVA tests) compare F1 and F2 of /a/ produced in a labialized context (i.e. in /sk^{w}at/ and /ff^{w}ad/) with their values in the non labialized one (i.e. /kan/, /fad/: Table 2).

Table 2: Significance of acoustic differences between paired values of F1 and F2 at the onset, midpoint and offset of /a/ in /ff^{w}ad/ vs /fad/ and /sk^{w}at/ vs /kan/: *** = p<0.001, ** = p<0.01, * = p<0.05, ns = not significant.

Paired items	S	Paired /a/					
		F1			F2		
		Ons	Mid	Off	Ons	Mid	Off
/ff^{w}ad/ vs. /fad/	S1 S2	ns ns	ns **	ns ns	*** ***	ns **	ns ns
/sk^{w}at/ vs. /kan/	S1 S2	ns ns	ns **	* ns	*** ***	** ***	* **

In general, F1 values of /a/ in /ff^{w}ad/ are not significantly different (Table 1 and Fig. 2a) than in /fad/, except at its midpoint for the subject S2 where F1 is lower in the former than in the latter context. For the two subjects, F2 at the onset of /a/ is substantially lower in /ff^{w}ad/ than in /fad/ (Table 1 and Fig. 2b). No such differences were observed at the midpoint and offset of /a/ produced by S1 and at the offset of /a/ produced by S2. These first observations show, contrary to Mitchell's hypothesis, that the coarticulatory effect of /ff^w/ on /a/ is not similar to the one induced by an emphatic consonant. The latter induces a rising of F1, and its F2 lowering is more substantial and affects the whole length of the vowel /a/.

F1 of /a/ produced in /sk^{w}at/ and /kan/ are not significantly different at the onset and the midpoint, while for S2 this difference is significant only at the midpoint of /a/. However, for S1 and S2, F2 is significantly lower in /sk^{w}at/ than in /kan/; this difference is more pronounced at F2 onset (Fig. 2b). The interpretations of these results are given in the following section.

3.2. Ultrasound data

Visual inspections of Fig. 3 show that, for the two speakers S1 and S2, [k] has a more forward place of articulation in [ki] than in [ku]. Tongue contour of [k] is also more fronted in /kan/ than in /kul/, especially for S1 where its form is very similar to the one of /kis/.

To compare statistically between tongue contours of these dorsal consonants in different vocalic contexts, we calculated the average x-values of the 5 repetitions of /k/ in /kan, kun, kis/ and /k^w/ in /sk^{w}at/. Then, we calculated the difference along the length of these averaged curves (see Table 3) between these contours (see [4] for a different statistical method). Separate ANOVA tests show that the mean difference between /k/ in /kis/ and /k/ in /kul/ is significantly greater than that between /k/ in /kis/ and /k/ in /kan/ (Table 3). This result confirms that /k/ is fronted before /i/ and even before /a/ compared to its more posterior position in /kul/. The more forward position of the tongue dorsum during /k/ in /kan/ is responsible for the high value of F2 at the onset and midpoint of /a/ (Fig. 2b).

Boff [2] had also shown, using cineradiography, that standard Arabic /k/ pronounced by MA speakers before /i/ is slightly more forward than before /a/. According to Boff [2], /k/ is dorso-palatal. In fact, allophonic variations of /k/ seem language specific. For example, French /k/ is velar before /u/, palato-velar before /a/ and palatal before /i/ [9]; while English /k/ is dorso-velar even before /a/ (e.g. in /kar/) [3]. The fact that MA /k/ seems to be velar only in [Cu] can be attributed to the phonetic nature of its low vowel which is a front one and should be transcribed [æ]. MA /k/ has a more forward place of articulation probably to enhance its contrast with /q/, which is also attested in MA as a phoneme.

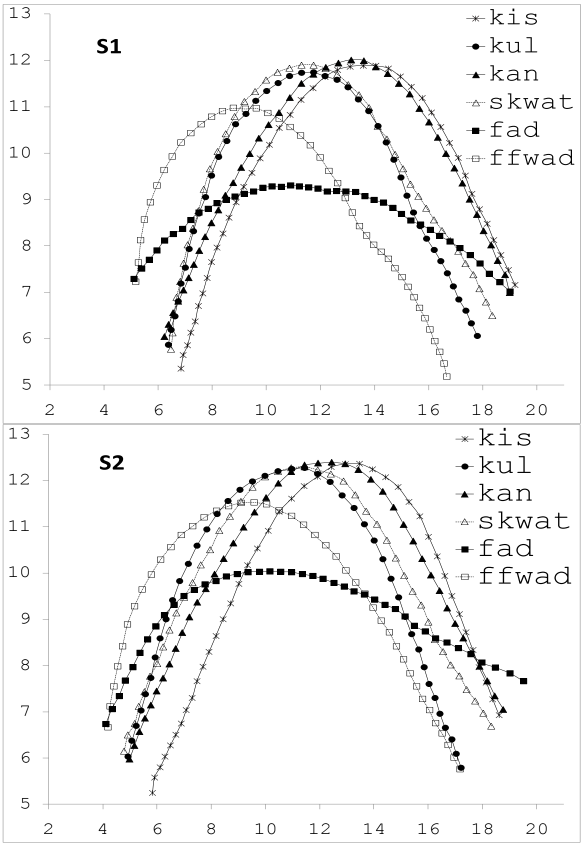
Table 3: Significance of paired comparisons between mean x-value difference of tongue contours in ($k_{[kis]}$ - $k_{[kul]}$) with ($k_{[kis]}$ - $k_{[kan]}$) and with ($k_{[kis]}$ - $k^w_{[sk^wat]}$): *** = p<0.001, ** = p<0.01, * = p<0.05, ns = not significant.

Paired mean x-value comparisons	S	Sig.
($k_{[kis]}$ - $k_{[kul]}$) vs. ($k_{[kis]}$ - $k_{[kan]}$)	S1 S2	*** ***
($k_{[kis]}$ - $k_{[kul]}$) vs. ($k_{[kis]}$ - $k^w_{[sk^wat]}$)	S1 S2	ns. ns.

Visual inspections of Fig. 3 also show that the place of articulation of /k^w/ in /sk^{w}at/ produced by S2 and especially by S1 seems as back as during /k/ in /kul/. This tendency is confirmed by statistical analyses (Table 3) showing that the mean difference between tongue contour of /k/ in /kis/ and /k/ in /kul/ is not significantly different from the mean difference between /k/ in /kis/ and /k^w/ in /sk^{w}at/. The backed (raised) position of the tongue dorsum during /k^w/ also explains why F2 at the onset and midpoint of /a/ in /sk^{w}at/ is substantially lower than in /kan/ (Fig. 2b).

Fig. 3 clearly shows that the tongue dorsum during /ff^w/ in /ff^{w}ad/ is substantially higher compared to its position during its non labialized cognate /f/ in /fad/. This ultrasound data confirm that /ff^w/ is velarized and explain why this consonant induces an F2 lowering of its adjacent vowel /a/, which can also be characterized as velarized (Fig. 2b).

Figure 3: Tongue contours at the midpoint of /k k^w f ff^w/ in /kis, kul, kan, sk^{w}at, fad, ff^{w}ad/ pronounced by S1 and S2. For S2 all the tongue contours are mean values of 5 tokens; while for S1, we have 5 tokens for / kis, kul, kan, sk^{w}at/ and 4 for /fad, ff^{w}ad/.



4. CONCLUSION

This survey confirms that the secondary articulation found in Moroccan Arabic, in addition to pharyngealization, and generally characterized as labialization, is in fact a labiovelarization. It also shows that [a] adjacent to the labiovelarized consonants is velarized.

Our present phonetic observations from MA seem to be in accordance with an assumption made by Ladefoged & Maddieson [7] according to which "in the great majority of cases where lip rounding is employed as a secondary articulation, there is also an accompanying raising of the back of the tongue, i.e. a velarization gesture. […] This double secondary articulation type is sometimes called labiovelarization".

Extending the general line of analyses adopted in this study to the rest of our ultrasound data, will help us to further elaborate our view of the phonetic implementation of this MA labiovelarization in different phonetic contexts.

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