A FIBERSCOPIC AND ACOUSTIC STUDY OF « GUTTURAL » AND EMPHATIC CONSONANTS OF MOROCCAN ARABIC

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ABSTRACT

In this study, we have observed the movements of the back of the tongue and the top of the larynx during the production of the « guttural » and « emphatic » Moroccan Arabic (henceforth MA) consonants. We found different shapes of the pharyngeal cavity in these consonants, and an anterior-posterior compression of the aryepiglottic sphincter occurring solely in the pharyngeal consonants. Acoustical analysis confirms that the VOT in emphatic stop is much shorter than in its non emphatic counterpart, and showed that only the F1 of /a/ (and not of /i/) is higher after a guttural than after plain (nonguttural) consonants.

1. INTRODUCTION

Though there are several phonetic (physiological and acoustical) descriptions of the guttural and emphatic consonants of many Arabic dialects, many questions concerning the phonological level of analysis remain open. In our present experiments we have tried to identify the secondary articulation involved in emphatic consonants (pharyngealisation vs. uvularisation) and to determine what phonetic property motivates the phonological unity of the guttural consonants. We first provide some details about the experimental procedures (section 2). In section 3 we present our results, classified into four parts. Each one deals with a set of consonants which share several phonetic properties.

2. METHOD

In the physiological experiment, a fiberscope was inserted through the nostril of a male native speaker of MA. The internal tip of the fiberscope was stabilized in two different positions:

-At the top of the pharynx just below the uvula in order to observe the mouvements of the back of the tongue. The subject uttered the following ten items: /isil/, */itir/, /ihiʒ/, /iħil/, /iœif/; /iχis/; /ī̄is/, /iqis/, /iTir/, /iSib/. (/T/ are /D/ emphatic stops, /S/ an emphatic fricative, and * a nonsense word)

-At the bottom of the pharynx a bit above the larynx to observe the state of the glottis and the aryepiglottic sphincter. The same list of items was uttered, by the subject, as well as the four following words: /idir/, /igis/, /izid/, /iDim/.

Each item was pronounced at least three times in isolation. A camera was fixed on the external side of the fiberscope which enabled us to record a video film on a « umatic » magnetoscope (25 frames/s). This film was analyzed by means of a Macintosh (PowerPc 9600/200), using the programs Adobe Premiere, and Adobe Photoshop.

For the acoustic analysis, two lists of nonsense syllables of the form /Cab/ and /Cib/, where /C/ stands for any MA consonant, were uttered by several subjects (6 male adult MA native speakers). Each item was uttered at least five times. The spectrographic analysis involved the measurement of F0, F1, F2, F3 and VOT.

3. Results and discussion

3.1. /isil/, /itir/, and /ihiʒ/ [IMAGE 0416.TIFF]. We observed a forward movement of the epiglottis during the production of these items. This movement begins just before the production of the first vowel and continues until the middle of the vowel where the epiglottis reaches a more fronted position, touching the base of the tongue. Generally, the epiglottis begins to move backward in a progressive manner at the begining of the consonant /s h t/. It comes to a maximally backed position at the middle of the consonant, where the epiglottis is midway between the base of the tongue and the back wall of the pharynx. Usually the epiglottis starts to move forward towards the base of the tongue at the end of the consonant. This movement continues during the production of the second vowel. The epiglottis reaches a more fronted position at the middle of the following vowel, where it approaches or even touches the base of the tongue.

Since we find a backward movement of the epiglottis when producing /h/ just as when uttering /s/ and /t/, we deduce that we are dealing with a passive movement of the epiglottis from a more fronted position during the preceding /i/ towards a neutral one during /h/.

Shahin [17] found that the F1 of a vowel is higher following a laryngeal consonant in Palestinien Arabic, and supposed that laryngeal consonants in Arabic involve the movement of the tongue root. This hypothesis is not confirmed by our observations of the MA laryngeal consonant /h/.

Our physiological observations are in accord with those of Zawahdeh [19], who found that in the Jordanian dialect of Arabic the width of the pharyngeal cavity in /h/ and /ʔ/ is not significantly different from that of /s t k/. Zawaydeh provides acoustic data showing that the F1 extracted at the temporal centre of a vowel V (= /a/ or /i/) in the sequence ?aCV is significantly higher after the guttural and laryngeal consonants compared to its value after an oral consonant /s t k/. Since in Classical Arabic and many modern dialects the laryngeal consonants behave phonologically like the guttural ones, especially the pharyngeal consonant /ħ œ/ (see McCarthy [13, 14] and Herzallah [8]) Zawaydeh [19] proposes that this phonological grouping is motivated by an acoustic property (Higher F1) shared by all the guttural consonants.

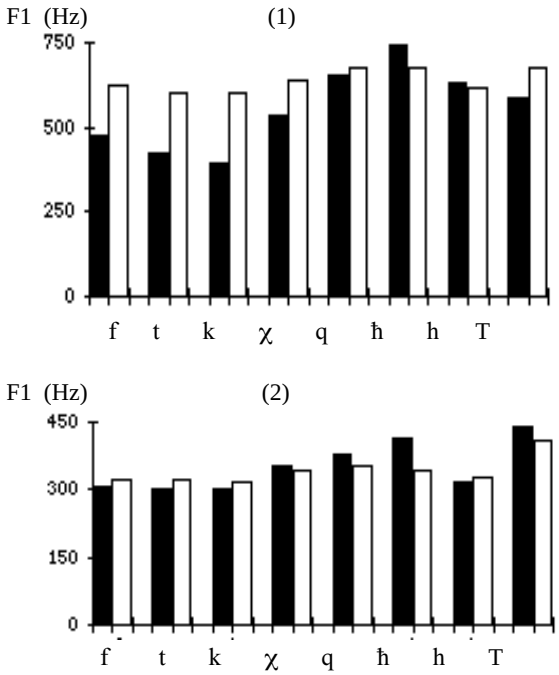

Figure 1. Mean value of F1 of /a/ (1) and /i/ (2) at the onset ■ and the centre □ of these vowels uttered after eight diffrent consonants.

Our statistical analyses of the Cab/Cib monosyllables were based on four single-factor ANOVA tests conducted separately on F1 values taken at the onset of the vowel /a/ (first test) and /i/ (second test) and at the middle of these same vowels (third and fourth tests). In each test, we gathered the F1 values into six groups according to the nature of the preceding consonant: oral [f, t, k], emphatic [T], uvular fricative [χ], uvular stop [q], laryngeal [h], and pharyngeal [ħ].

The four tests show that, in general, F1 varies with the nature of the preceding consonant both at the middle of the vowel (for [a], $F(5, 229) = 13{,}36$, $p<0{,}001$; for [i], $F(5, 235) = 46{,}55$, $p<0.001$) and at the onset of the vowel (for [a] $F(5, 231) = 147{,}17$, $p<0{,}001$; for [i] $F(5, 235) = 91{,}34$, $p<0{,}001$). Notice that the mean values of the /a/ and /i/ durations are respectively 206msec. (6) and 192msec. (8). Post-hoc analysis shows that the mean value of F1 taken at the onset of the vowel /a/ is significantly higher after the [laryngeal] consonant than after the [oral] consonants. However, F1 is significantly higher at this point after the pharyngeal consonant [ħ] and the uvular stop [q] than after [h]. At the middle of the vowel [a], the mean value of F1 is not significantly different after a laryngeal consonant than after an [oral] consonant. Moreover, the value of F1 at the onset of /i/ is not significantly different after a [laryngeal] consonant than after an oral consonant, and is significantly lower than following [T], [q], [χ] or [ħ]. So in MA, we cannot say that all guttural consonants induce the same effect on the F1 of the following vowel.

Hess [9] and Nolan [15] argue in favour of the implication of the aryepiglottic sphincter in the production of the laryngeal consonants in languages where they behave phonologically like pharyngeal consonants.

Our fiberscopic observations showed no anterior-posterior compression of the aryepiglottic sphincter during /h/. The consonant /h/ was produced by our subject with an opening of the posterior portion of the glottis. Spectrographic analysis showed that this consonant is produced with voicing and a higher amplitude of the first harmonic (H1), confirming that it is produced with breathy voice. Our observations are in accord with the photographs taken by Ohala & Vanderslice (reportedby Ladefoged [10]), who showed that breathy voice requires an opening of the posterior portion of the glottis only. The same posture of the aryepiglottic sphincter (i.e. with no compression), but with a full opening of the glottis, was observed by Esling [6] during his production of /h/ in the sequence /ihi/. For Esling, this segment was a voiceless laryngeal fricative.

Accordingly, we can say that the Moroccan Arabic consonant /h/ is not an aryepiglottal but a laryngeal consonant.

3.2. /iħil/, /iœif/ [IMAGE 0416.TIFF]**.** During the production of the first vowel in these items, the epiglottis and the base of the tongue maintain a quasi-stable position in which the epiglottis is midway between the back of the pharyngeal wall and the base of the tongue. Generally it is at the end of this vowel that the epiglottis first starts moving quickly backward to approach the back wall of the pharynx. At the begining of the following consonant, the base of the tongue moves progressively backward. At the middle of the pharyngeal consonant, the epiglottis and the base of the tongue (as well as the larynx) rise up slightly and then remain stable. At the begining of the following vowel, the epiglottis and the base of the tongue move quickly forward and slightly downward. They reach a more fronted position at the midddle of the second vowel, where the epiglottis touches the base of the tongue, maintaining this position until the end of this vowel. Generally, /ħ/ and /œ/ share the same articulatory pattern, except that the back of the tongue is more retracted in /ħ/ than in /œ/. Ghazeli [7] also found that the pharyngeal constriction is narrower in /ħ/ (3 mm) than in /œ/ (4 mm).

Concerning the place of articulation of the pharyngeal consonants, basing themselves on the fiberscopic observations of Laufer & Baer [12] and the X-ray study of Boff [1], Ladefoged & Maddieson [11] consider that the pharyngeal consonants of Arabic are actually epiglottal consonants, meaning that the major articulator is the epiglottis. While confirming the movement of the epiglottis, we note that the base of the tongue is also involved during the production of these consonants.

Our observations show that in /ħ/, the glottis is wide open, the arytenoid cartilages are mostly apart, and the top of the arytenoids and the base of the epiglottis are very close together. The same phenomenon (compression of the laryngeal vestibule) occurs in /œ/ except that in this case the glottis is closed. In /ħ/ we observed no vibration of any component of the laryngeal vestibule (vocal folds, aryepiglottic folds). During /œ/, though only a small part of the glottis is visible, we observed that only the vocal folds and not the ventricular folds are adducted.

Esling [6] has carried out a fiberscopic study where he observed the different postures of the laryngeal and pharyngeal cavities during his production of several different types of pharyngeal consonants. He observed that in the pharyngeal consonants /ħ œ/ just as in the epiglottal /ʜ ħ/ consonants, there was an anterior-posterior compression of the aryepiglottic sphincter, more important in the latter (in the epiglottal consonants he also observed « rapidly vibrating aryepiglottic folds »). Thus we can say that the position of the aryepiglottic sphincter in the MA pharyngeal consonants is very similar to those analysed by Esling.

3.3. /iχis/, /ī̄is/ and /iqis/ [IMAGE 0416.TIFF]. During the production of the first vowel in these items, the epiglottis and the base of the tongue move slightly forward, the epiglottis reaching a maximal position far from the base of the tongue. At the begining of the consonant, both the epiglottis and the tongue start moving simultaneously backward. At the middle of the consonant, the epiglottis and a much more important part of the tongue base reach a maximally backed and raised position. The magnitude of this movement is much more important in /q/ than in /χ̄/. At the end of the consonant, the back of the tongue and the epiglottis start to move simultaneously forward and downward again. This movement continues into the beginning of the following vowel /i/. The base of the tongue and the epiglottis reach a more fronted position just before the middle of this vowel, where the epiglottis touches the base of the tongue and keeps this position until the end of the vowel.

We can say that, in contrast to /ħ œ/ a higher part of the tongue retracts and rises in /q χ̄/. Moreover, it seems that in /q χ̄/, the epiglottis is not actively involved, as its backward movement is only a consequence of the movement of the tongue. The maximally backed position of the epiglottis in /q/ and especially in /χ̄/ is far from the back wall of the pharynx compared to its position in /ħ œ/. These observations are not in accord with those of Laufer & Baer who state: « Our own data [...] does not show a different place of articulation in the pharynx. [...] the constriction associated with all of these sounds [emphatics, /q/ and pharyngeals /ħ œ/] is in the lower part of the pharynx. » [12].

Concerning laryngeal movements, our observations show no compression of the laryngeal vestibule during the production of /q χ̄/. The glottis is more open in /χ/ than in /s/, probably to produce a higher air flow in /χ/ than in /s/ (588cm^3/s and 287cm^3/s respectively, according to Yeou [18] for MA subjects). At the end of χ̄/, we observed a slight opening of the glottis. Our spectrographic analysis, like that of Yeou [18], showed that in χ̄/ we have a vowel-like formant structure with an occasionally more important frication noise component at its end.

The description of the shape of the glottis in /q/ is given, below, with that of the consonant /T/.

3.4. /iSib/, /iTib/ [IMAGE 0416.TIFF]. Before and during the beginning of the first vowel we have, as in uvular consonants, a slight forward movement of the epiglottis and the base of the tongue. Just after the middle of the vowel, the epiglottis reachs a maximal position far from the base of the tongue.

At the beginning of the consonants /T/ and /S/, we first observe a slight backward horizontal movement of the base of the tongue, pushing the epiglottis with it. Just after this, a larger and higher part of the tongue moves backward and upward to reach a maximally backed position at the end of the consonant. At this point the epiglottis is near the tongue in /S/, and touches it in /T/. In /iSib/, at the beginning of the second vowel, the base of the tongue and the epiglottis move slightly forward and upwards. Then these structures begin to move forward and downward to reach a maximally fronted position at the middle of the second vowel, where the top of the epiglottis touches the back of the tongue, which is slightly retracted. At the begining of the second vowel of the item /iTib/, the back of the tongue and the epiglottis rotate and rise to a stable position. Immediately after the middle of this vowel, the back of the tongue and the epiglottis move slightly forward and downward, still maintaining a very retracted and raised position until the end of the second vowel, perhaps because the following consonant /r/ is produced by our subject as an emphatic.

Our main observations show that the pharyngeal constriction is narrower in /T/ than in /S/. In both consonants, this constriction is higher than it is in /ħ œ/. The general articulatory patterns observed in /T/ and /S/ are very similar to those seen in /q/ and /χ/, respectively. For these reasons, we agree with Herzallah [8] that the secondary articulation of the emphatic consonants is best regarded as uvularisation.

Our fiberscopic observations also show that there is no anterior-posterior compression of the aryepiglottic sphincter during /T/ and /S/.

Concerning glottal gestures, we have observed that the glottis is more open in /t/ than in /T/, both before and at the point of release. Recall that it is widely attested that in many Arabic dialects, /t/ and /k/ have a much higher VOT than do /T/ and /q/ respectively. This pattern is confirmed by our acoustical data for MA consonants (/t/: 63 (13), /T/: 24 (6), /k/: 57 (17), /q/: 35 (1); mean values before /a/ and /i/). Based on such differences, Odisho supposed that « /k/ correlates with an open glottis at the time of the release of the supraglottal gesture and for a while after it, whereas [q] is correlated with a closed glottis at the time of the release of the supraglottal stricture and possibly for a while before it» [16]. However, our observations show that before and during the release of the consonants /q/ and /k/, the degree of glottal opening is very similar. After the release the glottis began closing gradually in /k/ and more rapidly in /q/.

We have not seen any important differences between the glottal gestures during /s/ and /S/, except that in one repetition it seems that the glottis was slightly more closed in /S/ than in /s/.

Our observations of MA provide no direct support for the hypothesis advanced by Martinet (1953) cited by Cohen [4] that emphatic consonants were glottalized in Proto-Semitic, although they do not exclude the possibility that an earlier glottalization was lost in Arabic, or perhaps dialectally.

4. CONCLUSIONS

Our study shows no active involvement of the base of the tongue or epiglottis during the production of /h/. An anterior-posterior compression of the aryepiglottic sphincter is observed only in /ħ œ/. We conclude that MA /h/ is not an aryepiglottal sound as was suggested by Hess [9], but rather a true laryngeal consonant. We have also observed that the place of articulation of the pharyngeal consonant is lower and narrower than that of the emphatic and uvular consonants. This result is in accord with Ghazeli's [7] observations, but at odds with those of Laufer & Baer [12] who argued that all the emphatic, uvulars, and a pharyngeal consonants of Palestinien Arabic have a pharyngeal constriction located at the same place in the pharynx. We found no relevant acoustical or articulatory property shared by all MA guttural consonants.

We did not find any clear indication of glottalisation (total closing of the glottis) during the closure or release of /T/ or /q/, but the glottal opening of /T/ is narrower than that of /t/ just before and during its release.

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