EMA STUDY OF THE CORONAL EMPHATIC AND NON-EMPHATIC PLOSIVE CONSONANTS OF MOROCCAN ARABIC

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ABSTRACT

Our EMA data show that the longer VOT duration of the coronal non-emphatic /t/ compared to its emphatic cognate /T/ is due to laminal contact during /t/ vs. apical contact during /T/, and to jaw position, which reaches its target at the release of /t/, and before it during /T/. Although /T D/ are apical, their jaw position is as high as during laminal /t/. We attribute this unexpected /T D/ jaw posture to the biomechanic constraints induced by the secondary articulation of emphasis.

Keywords: EMA, emphasis, coronal, laminal, apical, jaw, VOT, endoscopy.

1. INTRODUCTION

Moroccan Arabic (MA) possesses the coronals /T D S/, called "emphatic consonants", and their non-emphatic cognates /t d s/ (for convenience we will note emphatics with upper-case letters). Emphasis is a secondary articulation (i.e. pharyngealization [8], or uvularization [10]), produced by retracting the tongue (Fig. 4). It spreads to the adjacent vowel to raise its F1 and lower its F2**.** The VOT is longer during /t/ and shorter during /T/ (Tab. 1). MA /t T/ also have laryngeal gesture patterns similar to the aspirated vs. non-aspirated opposition [14]**.** However, at the auditory level, /t/ is more like an affricate (long burst phase) than an aspirated (long aspiration phase) consonant. In whispered speech, where the laryngeal gesture differences are almost neutralized, the burst phase remains longer during /t/ than /T/ [14]. These observations suggest that supralaryngeal adjustments are also involved in this VOT difference. Here, we try to identify the nature of these supralaryngeal adjustments and their interactions with emphasis. We also consider whether pharyngealization (or emphasis) can also involve differences in a completely different articulatory area, i.e. apicality, laminality.

Secondary articulations are generally considered to be vocalic gestures [2, 12]. Authors associate vowels with jaw opening and consonants with jaw closing gestures [7, 9]. These two hypotheses predict that emphasis will induce a jaw lowering, which may explain part of the difference in VOT between /t T/. This prediction is also expected if we consider that guttural consonants (mainly pharyngeals) are produced by more extensive jaw lowering which permits the root of the tongue to be retracted more easily [4, 6].

The spatio-temporal parameters of the tongue and jaw movements during the production of MA coronal plosives will be analyzed. Since emphasis is added only to coronals (plosives & fricatives), this study will be limited to plosives /t d T D/.

2. METHOD AND MATERIAL

One Moroccan Arabic native speaker S1 (male, 38 years) participated in an EMA experiment (AG500, Carstens Medizinelektronik). Tongue, jaw, and lip movements were recorded with the following sensors: close to the tongue tip TTIP, the blade TMID and the back of the tongue TDOR, below the lower incisors JAW, and on the external extremities of the lips ULIP, LLIP. Only the horizontal and vertical positions of TTIP, TMID and JAW, at the onset, midpoint (of the occlusion phase), oral release, and offset of /C/ (i.e. onset of voicing) will be analyzed here (Fig.3).

S1 pronounced a list of words and a few pseudo-words, 7 times. Each list contains all MA consonants in initial, medial and final position. This study is limited to /t d T D/ produced in /ma_1ta_2bʃ, ma_1da_2bʃ, ma_1Ta_2bʃ, ma_1Da_2mʃ/, where the movement of the anterior part of the tongue is clearly defined. /a_2/ is accented, and "galha ___ hnaya" the carrier phrase. Figure 4 are summary data recorded separately with a nasendoscope to support our EMA findings. The EMA and acoustic analyses have been carried out using Matlab and statistics (ANOVA & t-test) using Statview.

3. RESULTS

3.1. Acoustic measures (Table 1)

Three one-factor ANOVA tests show that the total duration (TLD: [F(3, 24) = 42.187 p<0.001]), closure duration (CLOD: [F(3, 24) = 19.464, p<0.001],) and burst duration (BURD: [F(3, 24) = 136.659 p<0.001]) of /t d T D/ vary with /C/. PLSD Fisher tests show that the TLD of /d D/ is significantly shorter than /t T/ (p<0.001), BURD of /t/ is longer compared to /d T D/ (p<0.001), and identical during /d T D/ (/T/ vs. /D/, p = 0.36).

3.2. Articulatory measures (Figure 1, 2 & 3)

At /C/ onset, JAWy is in a high position which is quasi-identical during /t d T D/. Then, it moves upwards and forwards to reach its JAWx and JAWy targets, at the midpoint of /d D T/, and at the release of /t/. Then, JAW moves downwards and backwards. At the midpoint of /C/, JAWy is statistically identical during /t T D/ (/t/ vs. /T/: t (6) = 0.663, p = 0.532), but significantly lower during /d/ (/d/ vs. /t/: t (6) = 4.537, p<0.01; /d/ vs. /D/: t (6) = 3.768, p<0.01). JAWy is significantly higher at the release of /t/ than at its midpoint (t (6) = 6.735, p<0.001), but statistically identical to JAWy at the midpoint of /T D/ (/t/ vs. /T/: (t (6) = 2.267, p<0.064; /t/ vs. /d/: t (6) = 1.874, p = 0.11).

At the onset of /C/, TTIP is in a high and back position during /t/, slightly lower and more forward during /d/, and lower and slightly more forward during /T D/. Then, TTIP moves upwards to reach its highest position at the midpoint of /t/, before moving downwards and backwards. During /d T D/, TTIP moves upwards and forwards towards its midpoint; then moves downwards and forwards during /d/, only downwards during /T/ and downwards and backwards during /D/; after the release, TTIP moves downwards and backwards. At the middle of /C/, TTIPy is very high during /t/, intermediate during /d/ (/t/ vs. /d/: t (6) = 15.916, p<0.001) and lower during /T D/ (/d/ vs. /D/: t (6) = 13.506, p<0.001); /T/ vs. /D/: t (6) = 2.035, p<0,088). This same gradation is observed for TTIPy at the release of /C/ (/t/ vs. /d/: t (6) = 88.827, p<0.001; /d/ vs. /D/: t (6) = 20.699, p<0.001); /T/ vs. /D/: t (6) = 2.035, p = 0.088). TTIPy at the release of /C/ is significantly lower than its value at the midpoint (p<0.01).

At the onset of /C/, TMID is higher during /t/, intermediate during /d/ and lower during /T D/; TMIDx is identical during /t T D/ and slightly advanced during /d/. Then, TMID moves upwards and forwards to its target positions at the middle of /t/ which remains nearly the same at its release, before moving downwards and backwards. During /d/, TMID moves downwards and forwards; then downwards to reach, at the release, a slightly lower position that remains nearly the same at its offset. During /T D/, TMID moves forwards during /T/ but forwards and downwards during /D/ to reach a more advanced position at their midpoint. Then TMID moves backwards and downwards. At the midpoint of /C/, TMIDy is very high during /t/, intermediate during /d/ (/t/ vs. /d/: t (6) = 114.249, p<0.001) and very low during /T D/ (/d/ vs. /D/: t (6) = 20.699, p<0.001). This same gradation for TMIDy is observed at the release of /C/ (/t/ vs. /d/: t (6) = 14.426, p<0.001; /d/ vs. /D/: t (6) = 19.709, p<0.001; with /T/ vs. /D/: t (6) = 4.221, p<0.01). Compared to its value at the midpoint of /C/, TMIDy at the release is significantly lower during /d T D/ (p<0.001), but statistically identical during /t/ (t (6) = 0.774, p = 0.468).

4. DISCUSSION

At the midpoint of /C/, TTIPy is in its target position, with the highest value during /t/ compared to /d T D/; TMIDy during /t/ is also higher than during /d T D/. At the release of /C/, TMIDy is nearly at the same high position as at the middle of /t/, but moves more downwards during /d T D/. These observations clearly show that /t/ is very strongly laminal and /T D/ strongly apical, whereas /d/ is simply neutral.

JAW attains its highest position at the middle of /d T D/, and at the release of /t/ where the jaw has the highest vertical position. At the release of /t/, TTIP and TMID are also very high and very close to their target, reached at the middle of this consonant. A very similar movement of the jaw has been observed [11] for /t/ in German, for which they propose an explanation bound to the burst: "a late jaw target for the voiceless stop is produced in order to achieve a salient burst." Here it may also support affrication, since the jaw is known to be high for strident fricatives like /s/ [11].

The jaw and the tongue (TTIP and TMID), at the midpoint and at the release, are lower during /d/ than /t/. Similar results are also provided by previous studies [11, 5]. This difference can be attributed to the supralaryngeal adjustment observed during /t/ to achieve a salient burst. Since the burst of /d/ must remain very short and very weak, the tongue and jaw are freer to accommodate their positions to the adjacent vowel /a/ where they must be very low [13]. This difference between /t d/ seems also to be a strategy used by our speaker to increase the volume of the supralaryngeal cavity to maintain voicing as long as possible during the closure phase of /d/.

The target position for JAWy is statistically identical during /t D T/, and statistically lower during /d/ compared to /T D/. These two observations seem to constitute an argument against the hypothesis according to which the secondary articulation, that is a vocalic gesture, should induce jaw lowering. In fact, another difference was proposed between a consonantal and a vocalic gesture: "Consonantal gestures are those that produce an extreme obstruction in the mid-sagittal plane. Vocalic gestures are those that do not produce an extreme obstruction" [12]. This characterization doesn't predict a particular position for the jaw, but predicts that both the jaw and tongue participate to achieve a large constriction for the secondary articulation.

During /T D/, TTIP and TMID are in the lowest vertical positions. This posture seems to be necessary to retract the root of the tongue for the secondary articulation (Fig. 4). The more important rise of the jaw during /T D/, which reaches a target nearly identical to that of /t/, would, therefore, compensate for the lower position of TTIP.

Dart [3] observed that in French the laminal consonants have a higher jaw position compared to the apical consonants. According to Dart, this jaw lowering during apicals allows TTIP to curl up more easily. However, our emphatic consonants, which are strongly apical, have a jaw position which is as high as during /t/ even though the latter is strongly laminal. This observation shows that the high jaw target position during /T D/ may be due to their lower TTIP position. The jaw is controlled, therefore, in a subtle manner to compensate for the downward movements of the tongue induced by the secondary articulation.

5. CONCLUSION

Our data clearly show that the longer duration of the burst during non-emphatic /t/, compared to its emphatic cognate /T/, is related to the laminal contact during /t/ vs. apical contact during /T/.

The jaw is in its highest vertical position at the release of /t/, and before it during /d T D/. The jaw participates, therefore, in achieving the differences between /t T/ in relation to the spectral properties of their burst. The jaw can be adjusted in a very subtle manner: its target is aligned with the release of /t/, its position is very high during the emphatics even though they are apical, probably to compensate for the lowering of the tongue due to the retraction of its root to produce the emphasis.

6. AKNOWLEDGEMENT

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Figure 1. Mean values (7 tokens, in m) of vertical (y-axis) and horizontal (x-axis) positions of tongue tip (TTIP) and tongue blade (TMID) at the onset, midpoint, oral release (in gray), and offset of /t d T D/ pronounced in /-aCa-/ by our speaker.

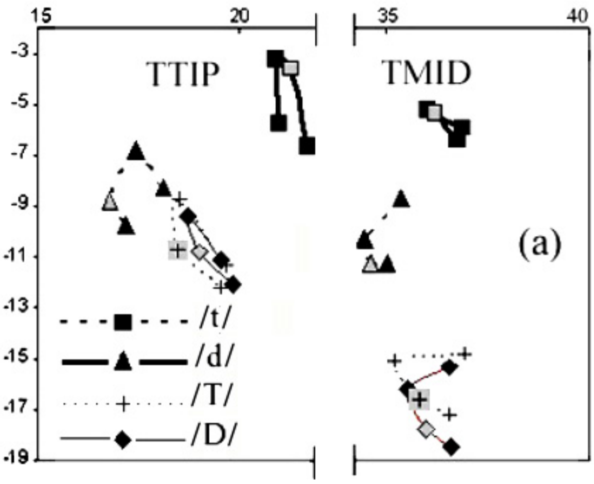

Figure 2. Mean values (7 tokens, in mm) of vertical (y-axis) and horizontal (x-axis) jaw positions at the onset, midpoint, oral release (in gray) and offset of /t d T D/ pronounced in /aCa/ by our speaker. Note different scaling of x and y axes.

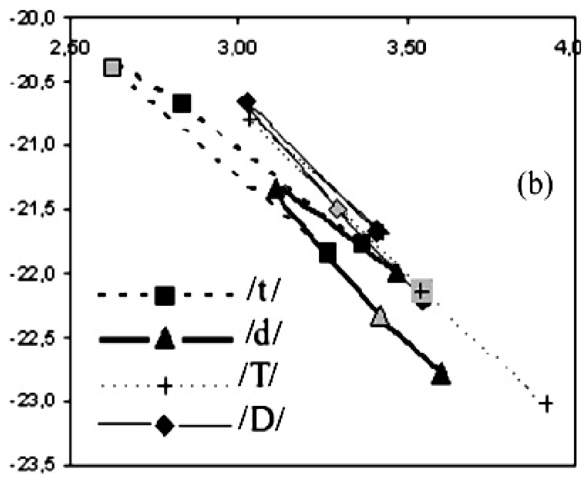

Figure 3: Vertical positions (in mm) of tongue tip (TTIPy), tongue blade (TMIDy) and jaw (JAWy) at the onset (1), midpoint (2), oral release (3) and offset of /t T/ in /matabʃ/ and /maTabʃ/. Zero on the y axis = mean value of signal over all data, x axis scaling is ms.

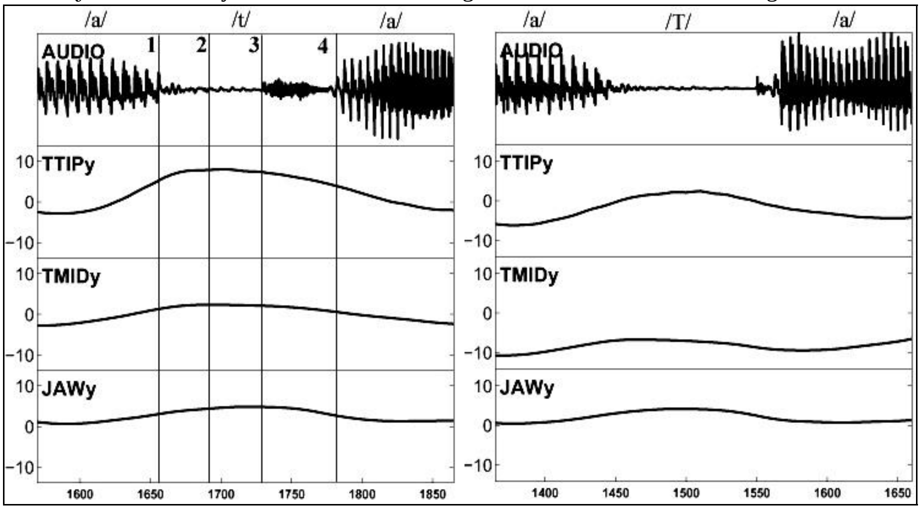

Figure 4: Endoscopic pictures of pharyngeal cavity at the middle of /t d T D/ in /-aCa-/ for the same speaker (S1).

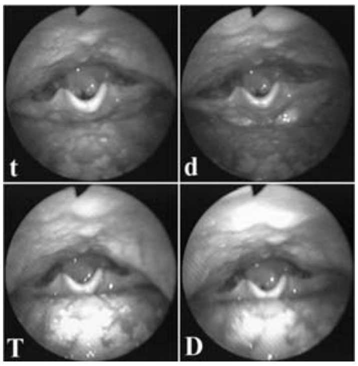

Table 1. Mean values of tongue tip (TTIPy), tongue blade (TMIDy) and jaw (JAWy) vertical positions at the midpoint and the oral release of /t d T D/ in /aCa/, and of total (TLD), closure (CLOD) and burst (BURD) durations. Each value = 7 tokens x 1 speaker.

	TTIPy (mm)		TMIDy (mm)		JAWy (mm)		CLOD (ms)	BURD (ms)	TLD (ms)
	Midpoint	Release	Midpoint	Release	Midpoint	Release	Closure duration	Burst duration	Total duration
/t/	-3.17	-3.57	-5.22	-5.31	-20.67	-20.39	74	48	122
	0.21	0.25	0.56	0.69	0.65	0.65	6	5	4
/d/	-6.78	-8.80	-10.29	-11.24	-21.33	-22.33	80	10	90
	0.52	0.28	0.72	0.68	0.61	0.64	8	3	7
/T/	-8.71	-10.76	-15.04	-16.60	-20.79	-22.14	98	14	112
	1.05	1.01	0.60	0.55	0.56	0.61	4	5	7
/D/	-9.37	-10.78	-16.21	-17.82	-20.66	-21.49	82	12	94
	0.39	0.45	0.26	0.31	0.55	0.38	6	3	7

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