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JAW PHASINGS AND VELOCITY PROFILES IN ARABIC

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ABSTRACT

The role of the jaw in rhythming quantity contrasts (VCC *vs.* VVC) in Arabic was examined by monitoring vertical displacements, at two rates, for two Tunisians and two Kuweitis. Results show that at conversational rate, contrasts depend on differences in absolute timing along only one time domain: the cycle between two jaw lowering onsets. At fast rate, relative timing values no longer carry quantity contrasts for two speakers (one in each dialect) within this cycle, whereas the contrast is still present in the cycle between two jaw lowering peak velocities for all speakers. For velocity profiles the contrast is at best visible in the jaw closing gesture. VCCs are all asymmetrical at normal rate and the symmetric shape, characteristic of the VVC control is generally adopted at fast rate; except for the VCCs of the two speakers who resisted rate degradation in both cycles.

Keywords: Jaw phasings, velocity profiles, Arabic, quantity contrasts.

1. INTRODUCTION

This paper focuses on the search for correlates of linguistic quantity contrasts in the time domain of a carrier rhythmic articulator, the jaw (for a similar approach, see recently [1]). Hence the issue is to find reliable structural differences in movement patterns instead of invariant properties (for more details, see [2]).

2. METHODS AND PROCEDURES

Items were chosen in order to display different heights in the recruitment of the jaw: [zɛzza] or [dʒɛzza] "he has sheared (the sheep)" *vs.* [zɛɛza] or [dʒɛɛza] "he has rewarded", respectively in Tunisian and Kuweiti Arabic, randomly repeated by 4 adult speakers (2 in each dialect), at 2 speaking rates (conversational and fast). The carrier phrase was "he has not—Lamin (name)". Jaw vertical position and velocity signals were monitored, using a mandibular kinesiograph (Myotronics K5AR) and recorded on FM tape. The data were digitized at 160 Hz for the jaw and 8 kHz for the audio signal.

The following events (corresponding to velocity zero-crossings and peaks) were detected manually on an editor in order to determine two cycles for the study of jaw phasings: jaw lowering onset (called "Vocalic" Cycle Onset or VCO), jaw lowering maximum velocity (Maximum "Vocalic" Velocity, MVV), jaw raising onset ("Consonantal" Cycle Onset, CCO), and jaw raising maximum velocity (Maximum "Consonantal" Velocity, MCV).

Two-way analyses of variance (ANOVAs) – with factors, Quantity (VCC *vs.* VVC) and Rate (conversational *vs.* fast) – were performed on cycle and phase measurements for data from each speaker individually. When interactions were found, Tukey hsd tests were run. Only significant results at or above 0.01 level are reported here.

3. JAW CYCLES AND PHASINGS

Fig. 1 displays phasing patterns in the two cycles. In the so-called "Vocalic" Cycle (VCO-VCO), the jaw opening phase (VCO-CCO) is expressed as a percentage of this cycle. Likewise for the jaw "open" phase (MVV-MCV) in the so-called Maximum "Vocalic" Velocity cycle (MVV-MVV).

3.1. Duration of jaw cycles

Effect of *Quantity* is consistent for the VCO-VCO cycle. The latter was substantially longer for VVC structures than for VCC ones. Tunisian speaker 1 (henceforth Sp. 1): $F(1,44) = 37.37$, $p < 0.0001$; Tunisian speaker 2: $F(1,36) = 300.15$, $p < 0.0001$; Kuweiti speaker 3: $F(1,36) = 179.50$, $p < 0.0001$; Kuweiti speaker 4: $F(1,36) = 165.91$, $p < 0.0001$. For MVV-MVV, no speaker reached $p < 0.01$, except Sp. 2: $F(1,36) = 27.48$, $p < 0.0001$. This means that, apart from this speaker, there was generally no difference in the MVV-MVV cycle and this was mainly due to a trend towards isochrony (cf. *infra*).

Rate effects were consistent for both cycles: this means that compression was actually performed by all four speakers. For VCO-VCO, Sp. 1: $F(1,44) = 167.61$, $p < 0.0001$; Sp. 2: $F(1,36) = 28.89$, $p < 0.0001$; Sp. 3: $F(1,36) = 310.82$, $p < 0.0001$; Sp. 4: $F(1,36) = 1211.08$, $p < 0.0001$. For MVV-MVV, Sp. 1: $F(1,44) = 126.09$, $p < 0.0001$; Sp. 2: $F(1,36) = 27.73$, $p < 0.0001$; Sp. 3: $F(1,36) = 228.43$, $p < 0.0001$; Sp. 4: $F(1,36) = 442.69$, $p < 0.0001$.

Quantity-by-Rate interaction was significant only for Sp. 4 in the MVV-MVV cycle: $F(1,36) = 21.17$, $p < 0.0001$. This speaker had no significant quantity difference at conversational rate, but reached significance at fast rate ($p < 0.01$).

In summary, the overall absence of interaction (except for Sp. 4) corresponds to two different types of behavior within each cycle: 1) the quantity contrast which is generally present at conversational rate for the initiation cycle VCO-VCO holds steadily at fast rate (this is shown by the presence of both quantity and rate effects); 2) the trend to isochrony for the peak velocity cycle MVV-MVV, is globally the same at conversational and fast rate (this is shown by the presence of rate effect *only*).

3.2. Jaw up-and-down phasings

For all speakers, in the two cycles, there was a significant effect of *Quantity* for jaw opening and "open" phases: their movements took up proportionally more time in both cycles for long vowels than for short ones. For %[VCO-CCO/VCO-VCO], Sp. 1: $F(1,44) = 61.81$, $p < 0.0001$; Sp. 2: $F(1,36) = 192.61$, $p < 0.0001$; Sp. 3: $F(1,36) = 98.91$, $p < 0.0001$; Sp. 4: $F(1,36) = 41$, $p < 0.0001$. For %[MVV-MCV/MVV-MVV], Sp. 1: $F(1,44) = 156.45$, $p < 0.0001$; Sp. 2: $F(1,36) = 342.36$, $p < 0.0001$; Sp. 3: $F(1,36) = 436.48$, $p < 0.0001$; Sp. 4: $F(1,36) = 98.16$, $p < 0.0001$.

As regards *Rate*, some speakers did not reach $p < 0.01$ significance: Sp. 2 and Sp. 4 in the VCO-VCO cycle; and Sp. 1 and Sp. 2 in the MVV-MVV cycle.

Except for Sp. 2, who kept his quantity contrast stable across rate changes, significant *Quantity-by-Rate* interactions were found. For %[VCO-CCO/VCO-VCO], Sp. 1: $F(1,44) = 17.07$, $p < 0.0002$; Sp. 3: $F(1,36) = 89.9$, $p < 0.0001$; Sp. 4: $F(1,36) = 26.53$, $p < 0.0001$. For %[MVV-MCV/MVV-MVV], Sp. 1: $F(1,44) = 53.70$, $p < 0.0001$; Sp. 3: $F(1,36) = 19.02$, $p < 0.0001$; Sp. 4: $F(1,36) = 22.08$, $p < 0.0001$. Thus, for three out of the four speakers, significant reduction of the phasing contrast occured at fast rate in both cycles. At this rate, relative timing values no longer carry the quantity contrast for two speakers (one of each dialect: Sp. 1 and Sp. 4) within the VCO-VCO cycle, whereas the contrast is still present throughout the MVV-MVV cycle, with significant differences (at $p < 0.01$; even for Sp. 1, see 1b in Fig.1, with a small 4% difference, but with only 1% SD overlap).

The MVV-MVV cycle is thus the best time domain, both for contrast preservation and realization of the isochronic linguistic structure. Note that in a preceding study with the same items, no isochrony and no phasing difference at fast rate were found for another Tunisian (see [3], Fig. 1b and [4]; Fig. 4a-b); but the same trends were observed for another Kuweiti ([4], Fig. 3a-b).

4. JAW VELOCITY PROFILES

Fig. 2 displays velocity profiles normalized in time for the closing gesture CCO-VCO (Acceleration phase CCO-MCV is expressed as a percentage of this closing duration). In fact, differences in skewness of the profiles correlated at best with the VCC vs. VVC contrast within this gesture.

Effects of *Quantity* are significant for %[CCO-MCV/CCO-VCO]. For Sp. 1: $F(1,24) = 6.77$, $p < 0.0156$; Sp. 2: $F(1,24) = 34.61$, $p < 0.0001$; Sp. 3: $F(1,24) = 71.15$, $p < 0.0001$; Sp. 4: $F(1,24) = 15.52$, $p < 0.0006$. This means that the proportion of acceleration in the jaw closing gesture is smaller for VCC structures than for VVC ones.

No subject showed significant overall effect of *Rate* for this acceleration phase. But, two of them displayed *Quantity-by-Rate* interactions: Sp. 1: $F(1,24) = 17.12$, $p < 0.004$; Sp. 4: $F(1,24) = 10.51$, $p < 0.0035$. For these two, significant differences in %acceleration phase at normal rate were no longer present at fast rate.

In summary, at normal rate, VCC velocity profiles for all speakers were skewed to the left, whereas VVC were quite symmetrical (cf. Fig. 2). This symmetric shape was generally adopted at fast rate, except for speakers 2 and 3, who were precisely those who maintained their contrasts at this rate in the VCO-VCO cycle (cf. *supra*). Note that this behavior was dialect independent.

5. CONCLUSION

The peak velocity cycle of the jaw (MVV-MVV) was the best time domain for quantity contrast resistance to rate in relative timing values (up-and-down phasings). Moreover this cycle paralleled, at best, linguistic isochronic structures of the Arabic contrasts (VCC vs. VVC) under examination.

Regarding velocity profiles, contrasts were better revealed in the closing gesture. VCC profiles were skewed to the left, showing a clear plateau trend on the right due to the long consonantal [zz] realizations which follow the short vowels. But the symmetry observed for slow like fast *closing* gestures for VVC is contrary to preceding findings by [5: 688] for speech ([5: 690 sqq.] reviews similar results by Nelson *et al.*, 1984 and Kelso *et al.*, 1985) and mastication. A recent study by [6] recalls however that the tendency to produce, at fast rate, bell shaped profiles is a general one, whereas at slow rates profiles are more bumpy. The fact that speakers who lose their contrasts at fast rate adopt symmetric profiles, corresponds to this economy trend. However, in the light of such studies, both the symmetry of VVC profiles, in the closing gestures following long vowels, at normal rate, and their smoothness, must be attributed to a specific control.

6. REFERENCES

[1]: Munhall, K.; Fowler, C.; Hawkins, S. & Saltzman, E.: "Compensatory shortening" in monosyllables of spoken English. J. of Phonetics, Vol.20, pp. 225-239, 1992.
[2]: Jomaa M.: Organisation temporelle acoustique et articulatoire de la quantité en arabe tunisien. Doctoral Thesis, Grenoble III, 1991.
[3]: Delattre, C.; Jomaa, M.; Worley, C. & Abry, C.: The phasing of the jaw in consonant and vowel lengthening. Eurospeech, Vol.2, pp. 416-419, 1989.
[4]: Delattre, C.; Jomaa, M.; Al-Dossari, A; Worley, C. & Sock, R.: Comparaisons articulatori-acoustiques des structures temporelles en arabe et en français. 18èmes J.E.P., pp. 113-117, 1990.
[5]: Ostry, D.J. & Flanagan, J.R.: Human jaw movement in mastication and speech. Archs Oral Biol., Vol.34, pp. 685-693, 1989.
[6]: Adams, S.G.; Weismer, G. & Kent, R.D.: Speaking rate and speech movement velocity profiles. J.S.H.R., Vol. 36, pp. 41-54, 1993.

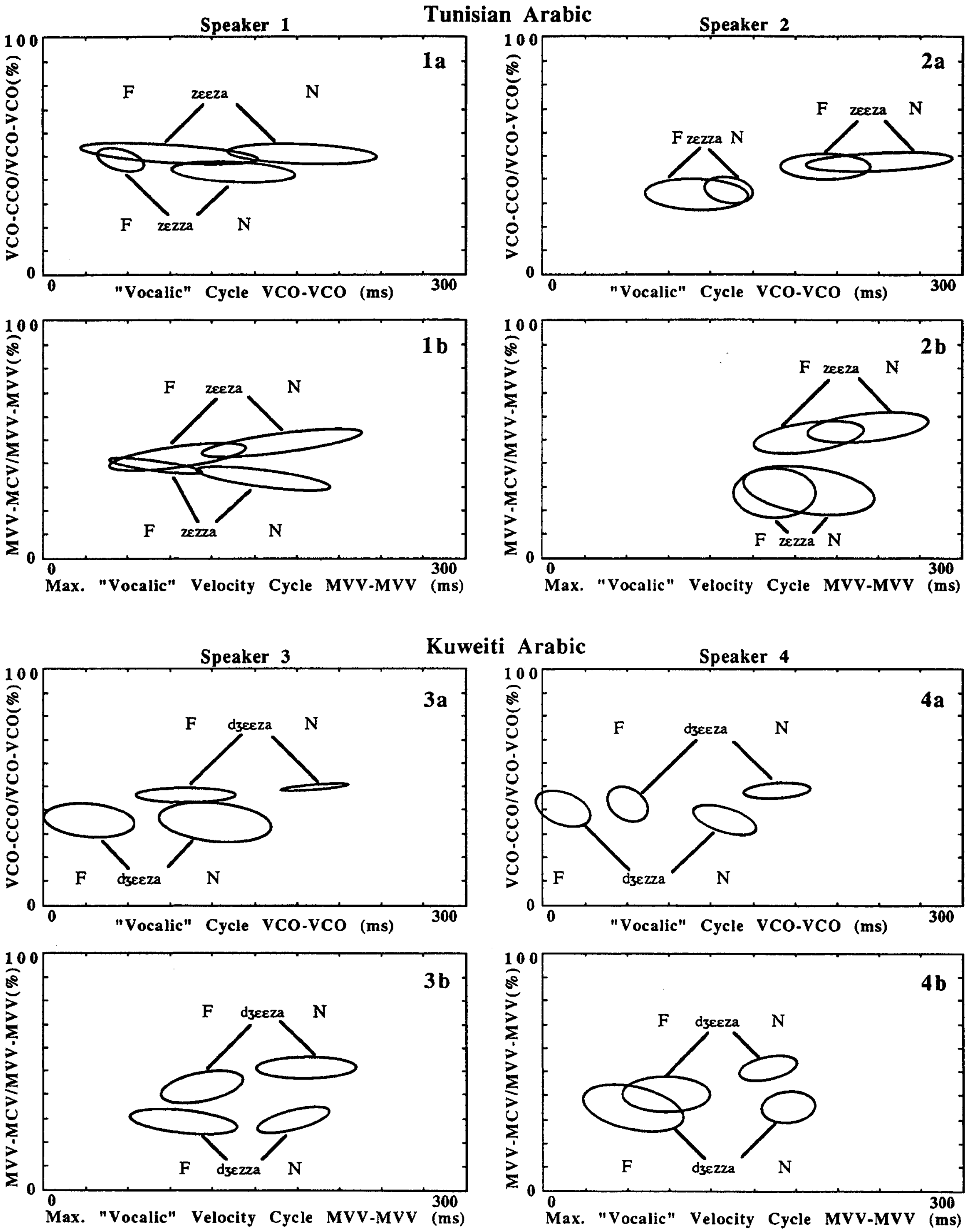

Fig. 1: Phasings (90% dispersion ellipses) in the jaw cycles at two rates N (normal or conversational) and F (fast).

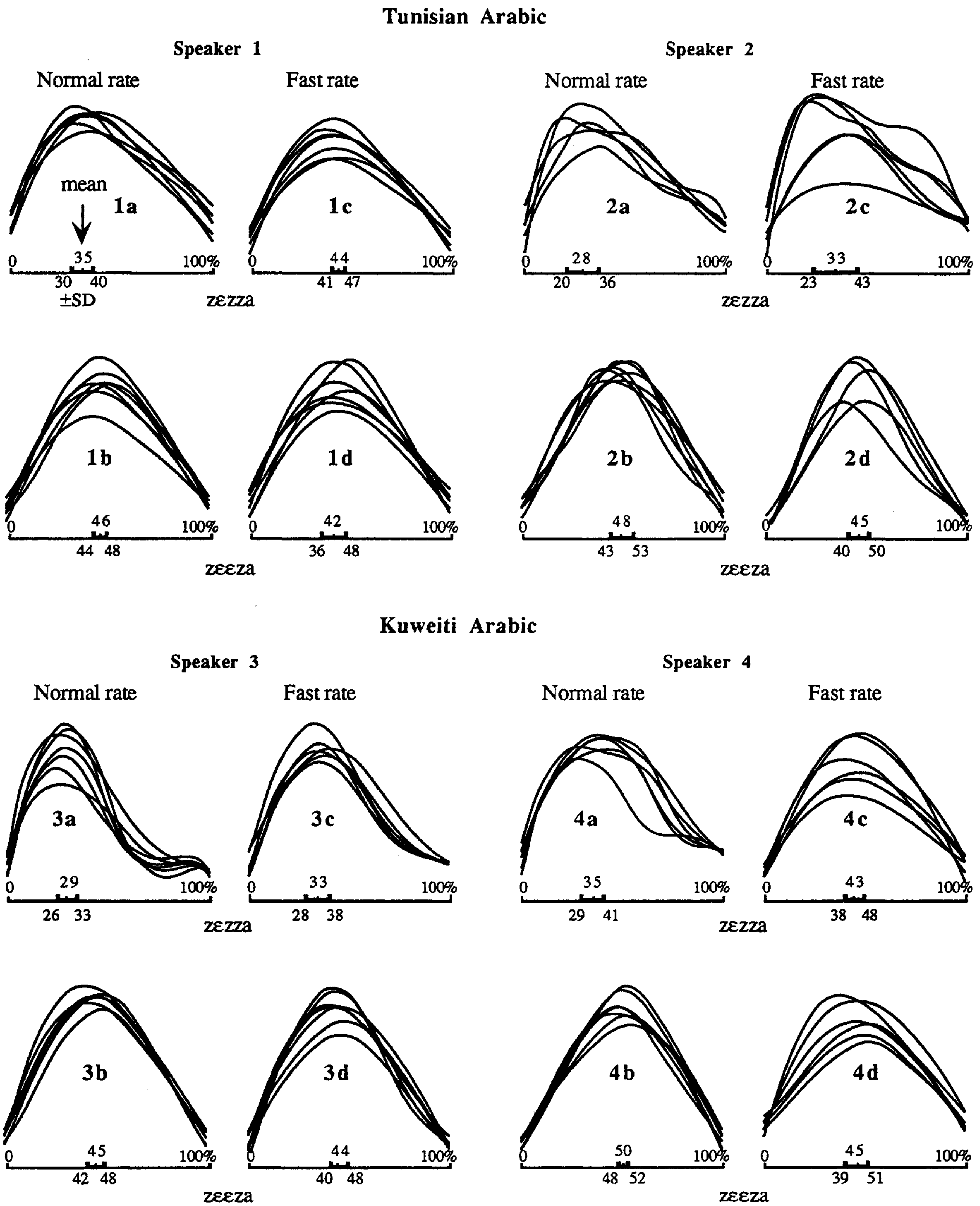

Fig. 2: Velocity profiles of the raising gestures (CCO-VCO) normalized in time.
(N.B.: amplitude scales are normalized in rounded values; initial and final values are taken from samples closest to zero+ velocity).