C-Center and Syllabification in Moroccan Arabic

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1. Working Hypothesis

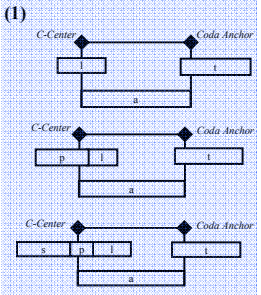
- **There is a temporal basis to hierarchical prosodic structure**

2. Previous Work: C-Center

Languages described as having complex onsets (Georgian: Vogt 1971; English: Kahn 1976) show a pattern of timing between onset consonants and the following vowel whereby the vowel is timed globally to the center of the consonant cluster, or "c-center", as calculated by the mean of consonant midpoints (Browman and Goldstein 1988).

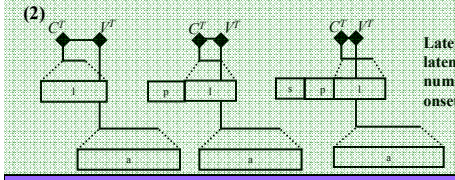
Several measurable consequences of c-center timing may form **the basis for a phonetic diagnostic of syllable onset-hood**. Here we combine two such measures, (1) temporal stability and (2) latency, to investigate the syllabic constituency of initial clusters in Moroccan Arabic (Oujda Dialect).

(1)



Stability: Measures of the interval from C-center to Coda will be more stable across ((C)C)C than measures from left edge to coda and from right edge to coda.

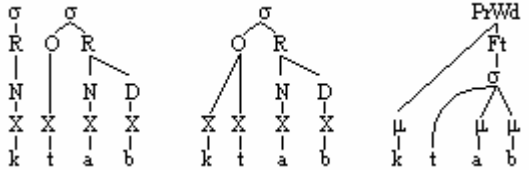
(2)



Latency: C^{Target} to V^{Target} latency will decrease as the number of consonants in onset position increases.

2. Syllables in Moroccan

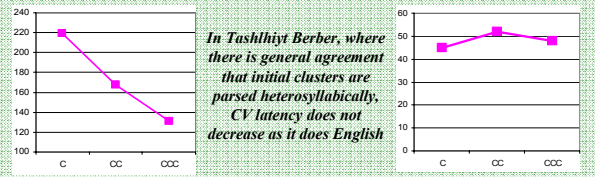
Proposals for Moroccan Arabic syllable structure disagree in their treatment of word-initial consonant clusters:



(Dell and Elmedlaoui 2002:252) (Benkirane: 1998:346) (Heath 1987: 266, 271-272) (Kiparsky 2003:159-60, 165-66)

$C^{Target}V^{Target}$ Latency by # of initial consonants

English (Goldstein 2006) **Berber (Goldstein, Chitoran, Selkirk 2007)**

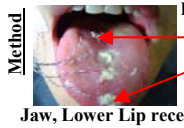


In Tashlhiyt Berber, where there is general agreement that initial clusters are parsed heterosyllabically, CV latency does not decrease as it does English

3. Experimental Procedure

3-D Electromagnetic Articulography (EMMA)

(Hoole et al. 2003)



Lingual receivers:

Tongue Body(TB)

Tongue Tip(TT)

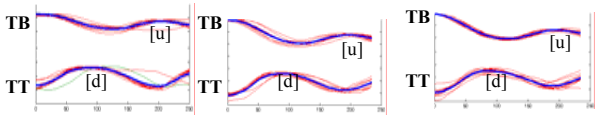
Jaw, Lower Lip receivers not shown

Corpus (N = 96)

3~4 repetitions each of 5 different C/CC pairs
(e.g. tab 'to repent' ~ ktab 'book')

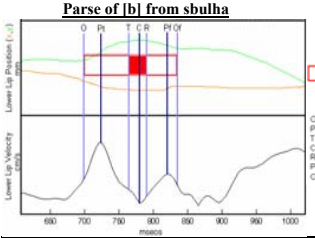
10 repetitions each of 2 different C/CC/CCC triplets
(e.g. bulha 'her urine'~ sbulha 'her ear' ~ ksbulha 'they owned for her')

Positional signal (y dimension) for 10 tokens (red) with group mean (blue)

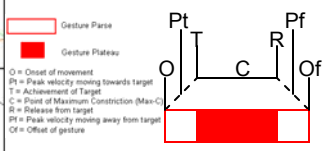


du from dulha (N=10) **du from kdulha (N = 10)** **du from bkdulha (N = 10)**

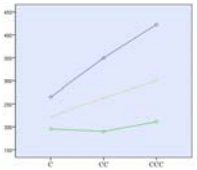
Parse of [b] from sbulha



Gesture Parse based on % of peak velocity



4. Stability Results



Repeated Measures ANOVA

***Dependent Variable*:** intervals from consonant cluster to anchor measured from the left edge, right edge and c-center.

Independent Variables: CONSONANT {C,CC,CCC}, EDGE {Left, Right, C-Center} and WORD {((k)s)bulha, ((b)k)dulha}

Key result: Significant interaction of EDGE and CONSONANT, indicating that the effect of adding a consonant is not uniform across 3 edges.

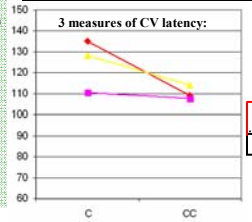
Post Hoc ANOVAs for each edge indicate that the significant interaction is attributable to *right edge to anchor* measurement.

Left Edge to Anchor
C-Center to Anchor
Right Edge to Anchor

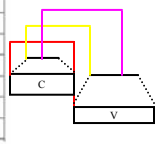
As consonants are added, the *left edge to anchor* measure and the *c-center to anchor* measure increase significantly, but there is no significant effect of consonant on the *right edge to anchor measure*. This is reflected in the coefficient of variance for each of the measures.

Left Edge to Coda			C-Center to Coda			Right Edge to Coda		
MEAN	SD	RSD	MEAN	SD	RSD	MEAN	SD	RSD
452	182	29%	260	22	12%	237	18	8%

5. Latency Results



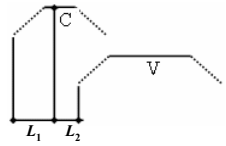
In addition to C^{Target} to V^{Target} latency used in past studies, latency measures based on C^{Onset} to V^{Onset} and $C^{Max\text{-}C}$ to $V^{Max\text{-}C}$ were also calculated.



$C^{Max\text{-}C}$ to $V^{Max\text{-}C}$
C^{Target} to V^{Target}
C^{Onset} to V^{Onset}

All three latency measures trended in the direction of the C-center effect, but **only C^{Onset} to V^{Onset} was significant**

6. Decomposition of the $C^{Onset}V^{Onset}$ latency decrease



C^{Onset} to V^{Onset} latency decrease can be decomposed into two components: L_1 and L_2, which are affected by independent factors and together compound to produce a significant effect.

6.1 L_1 decrease

Adding a consonant pushes the target CV sequence away from the prosodic word boundary:

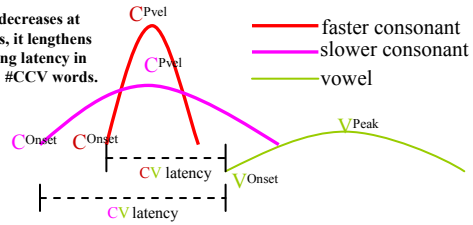
$_{PrWd}$[CVCCV] → $_{PrWd}$[CCVCCV]

Prosodic boundaries are known to influence the peak velocity of consonants (Fougeron and Keating 1997; Byrd *et al.* 2005)

Across our corpus, there is a significant negative correlation between peak velocity and intervals measured from Onset (a) or Pt (b), but not from Target (c,d):

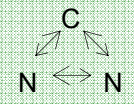
Interval	pearson's *r* (*p* value)
a) O to Pt	$r = -.206$ ($p = .044$)
b) Pt to T	$r = -.406$ ($p < .001$)
c) T to C	$r = -.123$ ($p = .231$)
d) T to R	$r = -.159$ ($p = .122$)

As peak velocity decreases at PrWd boundaries, it lengthens $C^{Onset}V^{Onset}$ making latency in #CV longer than #CCV words.



6.2 L_2 decrease

One possible explanation for the leftward shift is the presence of a Nucleus-to-Nucleus timing relation between C_1 and V in C_1C_2V (as in the syllable parse in 2a), which resembles the V-to-V timing relation generally assumed in VCV sequences (e.g Smith 1991).



Peak velocity increase is significant for coronals but not labials; however, labials also contribute C^{Onset} to V^{Onset} latency decrease. Thus, the prosodic word effect can account for some but not all of the decrease in C^{Onset} to V^{Onset} latency.

7. Conclusions

(1) The c-center does not exhibit the same privileged status with respect to temporal stability in Moroccan Arabic as it does in English.

(2) Likewise, there is no significant decrease in C^{Target} to V^{Target} latency, as there is in English. There is, however, a significant decrease in C^{Onset} to V^{Onset} latency from #CV to #CCV conditions. This can be accounted for by the cumulative effect of the prosodic word boundary and leftward shift of the vowel.

Both of these results support a local CV timing relation and are consistent with a bi-syllabic parse of initial clusters. More generally the results provide support for the idea that prosodic structure is embodied in characteristic patterns of gestural coordination.

In sum, if independent influences on timing are properly factored out, it is possible to recover consistent signatures of syllable structure from the timing of articulatory movements. Therefore, our results validate a rigorous methodology for instrumental investigation of syllable structure.

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