



Prosodic hierarchy and articulatory control: evaluating the pi-gesture hypothesis in Italian EMA data

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Prosodic hierarchy

- Speakers package the speech stream into smaller constituents (« prosodic phrasing ») which are hierarchically organized

The letters from Malaga | as far as I know, are in the drawer

- The number and type of prosodic constituents vary across languages

Major ↑

Minor ↓

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graph TD
    IP --- AP1[AP]
    IP --- AP2[AP]
    AP1 --- s1[s]
    AP1 --- s2[s]
    AP2 --- s3[s]
    AP2 --- s4[s]
  
```



Intonation phrase

Intermediate phrase

Accentual Phrase

Syllable



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Scope of preboundary lengthening

- In the vicinity of prosodic boundaries, segments exhibit acoustic final lengthening (e.g. Oller, 1973; Klatt, 1976; Wightman *et al.*, 1992) and *initial lengthening* (Oller, 1973).
- Wightman et al. [1992] showed that several degrees of acoustic final lengthening can be identified, but finally only 3 or 4 are retained in current ToBI-style prosodic transcription systems.
- Temporal scope of acoustic right-boundary might not be limited to the last syllable or segment, but its effect goes back to the rime of the stressed syllable (Turk and Shattuck-Hufnagel, 2007), at least in American English.
- In Italian, Petrone (2008) showed that while accented syllable duration is strongly affected by prosodic constituency, inconsistent effects are found for the duration of the unstressed syllables immediately adjacent to the boundary.



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Articulatory consequences of boundary-induced lengthening

- Articulatory movements get larger, longer and further apart at phrase edges (Edwards et al., 1991; Beckman and Edwards, 1992; Fougeron and Keating, 1997; Byrd and Saltzman, 2003).
- The effect is incremental for larger/stronger boundaries (phrase finally: e.g., Byrd & Saltzman 1998, Byrd 2000, Cho 2005, Tabain 2003b, Tabain & Perrier 2005, and phrase initially: e.g., Byrd & Saltzman 1998, Cho & Keating 2001, Fougeron 2001, Cho 2005, Keating et al. 2004, Tabain 2003b).
- Gestural adjustments at phrase-edges are yet to be understood for Italian, though much is known in the acoustic/prosodic domain (D'Imperio 2000, 2002; D'Imperio et al., 2005; Petrone, 2008, *inter alia*).

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Models of articulatory lengthening

- Articulatory movements at prosodic boundaries have often been interpreted as **pure temporal phenomena**
 - controlled by **stiffness modulations** (Edwards et al. 1991)
 - or **external clocks** (pi-gesture approach by Byrd and Saltzman, 2003) slowing down or speeding up the movement
- **Local phenomenon:** Stretching and shrinking of articulatory gestures next to the boundary
- Effects are **larger adjacent** to the boundary
- Similar effects on the left (pre-boundary) and right (post-boundary) side (Byrd et al. 2006) -> but results may be confounded by prominence

The π -gesture framework

- Prosodic events (such as phrase boundaries) have a temporal interval of activation, similar to constriction gestures (Byrd and Saltzman, 2003). This predicts that:
 - ❖ **strength of activation of π -gesture will be correlated with slowing down of constriction movements**
 - ❖ **stronger prosodic boundaries will be associated to stronger π -gesture activation**
 - ❖ **boundary effects should be local (tied at the boundary, Riggs and Byrd 2007).**

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The π -gesture framework

FIG. 1 A schema of the π -gesture model representing the overlap of a π -gesture at a phrase juncture with several closing movement gestures. Shading indicates strength of the π -gesture effect as the π -gesture's activation increases to maximum (darkest shading). The constriction gestures are representative of any consonant or vowel. In our experiment, the constrictions potentially represent the consonants N D D N.

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Byrd et al. 2006.

PREBOUNDARY EFFECTS ← → POSTBOUNDARY EFFECTS

FIG. 4. (Color online) Consonant closing movement and opening movement duration results. The top bar for each speaker's pair is control and the bottom bar is test. (The bold line at center is merely a graphical convenience to separate results in the two conditions.)

...a new DOdo (only IP boundary)

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Boundary vs accentual effects on gestures

- Byrd et al. (2006) found **longer preboundary C closing and opening movement and longer time-to-peak velocities** even when C was not immediately adjacent to the boundary because of an intervening final vowel (e.g. "dodo]_{IP}")
- **In Italian**, closing/opening movements are larger and less stiff for stressed/accented than unstressed syllables (Avesani et al. 2007).
 1. **What about preboundary effects?**
 2. **Is there an effect of boundary type (from major to minor)? Is there an effect of vicinity to stress?**
 3. **Does the effect go back to the stressed syllable, independent of vicinity to the boundary?**

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Articulatory parameters

- Major prosodic boundary
- Minor prosodic boundary

Movement velocity ↓

Duration of a gesture ↑

Movement amplitude ↑

i.e. the higher the boundary in the Prosodic Hierarchy, the slower the velocity, the longer the segment & the larger the movement amplitude

-> larger amplitude is a byproduct of longer duration - having more time to move

Note: Similar changes (except velocity) have also been described for unstressed -> stressed syllables

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Acoustic parameters

- Pre-boundary lengthening: ?

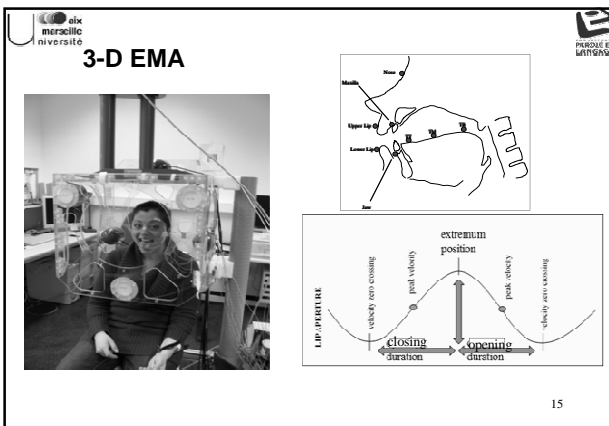
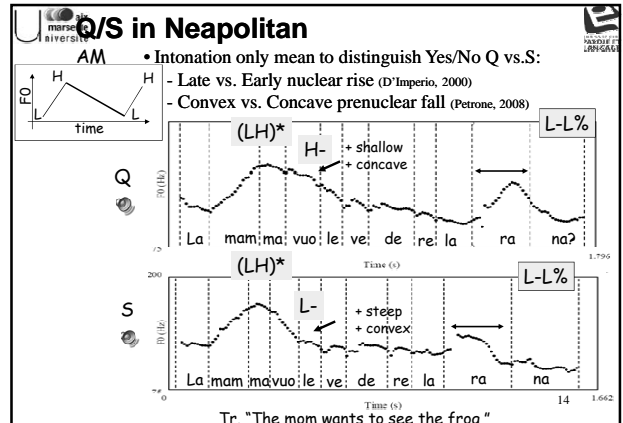
- Temporal scope back to the stressed syllable rhyme in English (Turk & Shattuck-Hufnagel, 2007)
- Articulatory and acoustic effects increasing from lower to higher constituents

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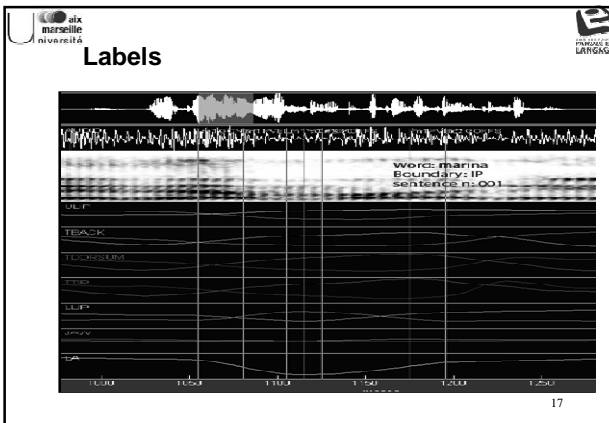
Corpus

Boundary type	Sentences
Major Intonational phrase (IP)	<i>Le lettere da Malaga e da Panama, per quanto ne so, stanno nel cassetto</i> "The letters from Malaga and from Panama, as far as I know, are in the drawer"
Intermediate phrase (ip)	<i>Le lettere da Malaga e da Panama stanno nel cassetto</i>
Accentual phrase (AP)	<i>Le lettere da Panama e da Malaga stanno nel cassetto</i>
Minor Syllable	<i>Le lettere da Marina e da Gastone stanno nel cassetto</i> "The letters from X and from X are in the drawer"

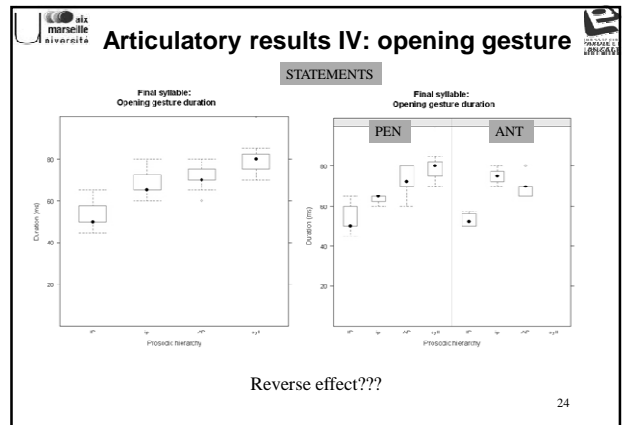
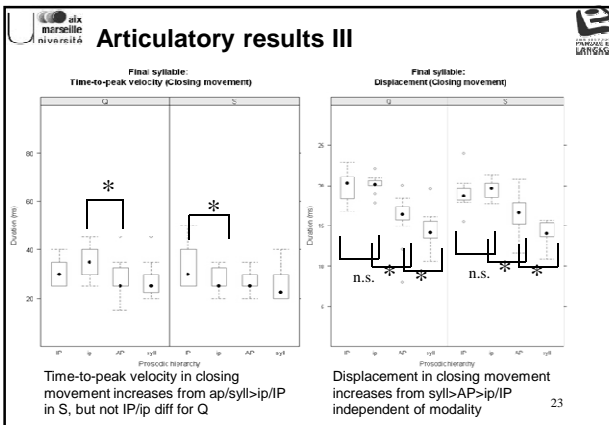
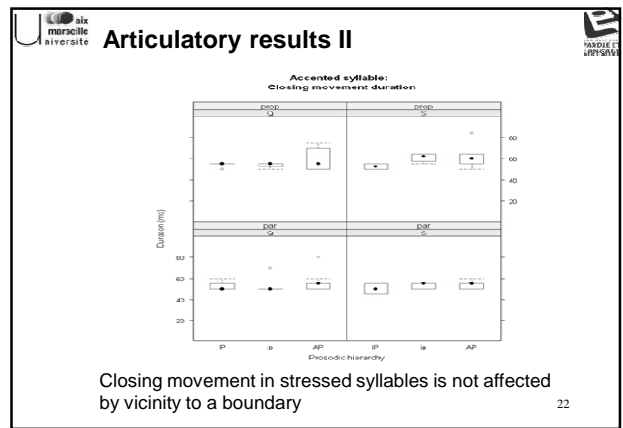
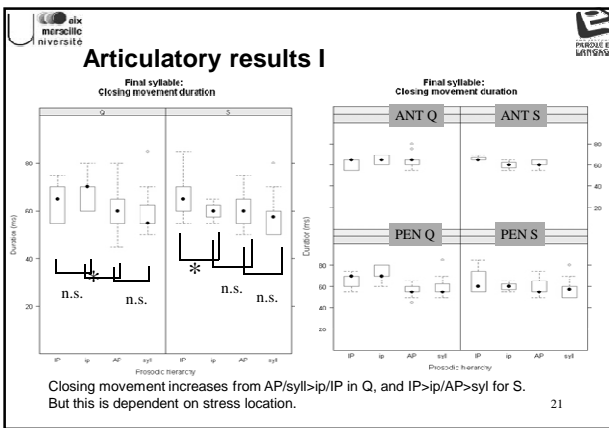
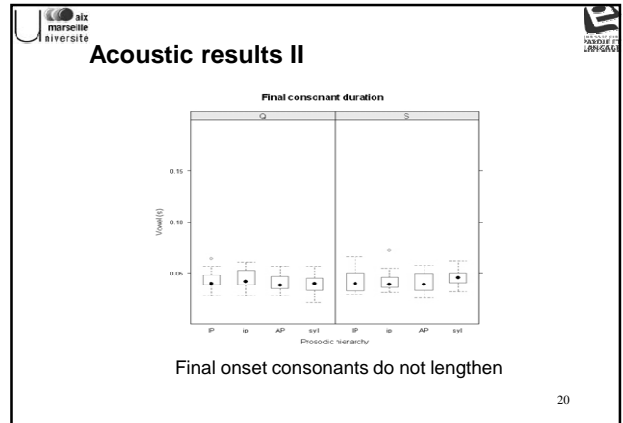
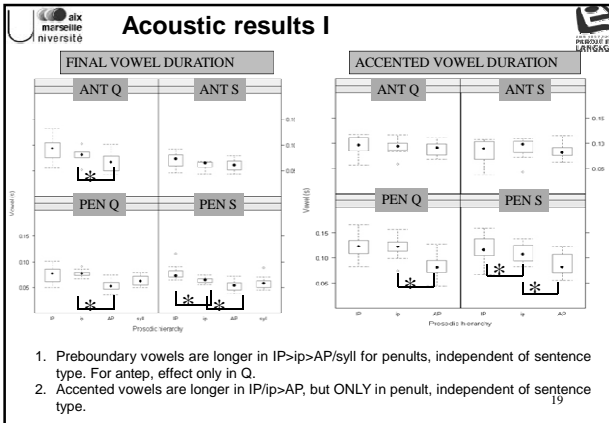
Word-final s.		Stressed s.		4 boundary types X 2 stress X 2 Italian speakers
Penult.	Antpenult.	Penult.	Antpenult.	
ABRA ^s ma	PA ^s nama	Ta ^s MA ^s ra	MA ^s rica	

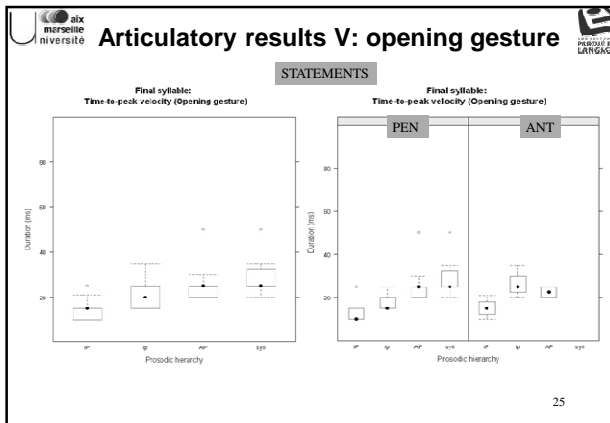


- Method**
- **Kinematic data:** AG500 EMA, analysis of 2 coils, UL (upper lip) and LL (lower lip) for calculating Lip Aperture (Euclidean Distance); visual inspection conducted through *Mview* (M. Tiede).
 - **Acoustic analysis:** preboundary consonant and vowel duration; accented vowel duration
 - **Subjects:** 2 Neapolitan Italian speakers
 - **Statistics:** Linear Mixed Models with additive factors ($p < .05$). Fixed: Prosodic Hierarchy (IP/ip/AP/syll), Sentence Type (Q/S), Stress (par/prop); Random: Words.
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- Hypotheses**
- Incremental effect of prosodic phrasing:**
IP > ip > AP > syll
 - Acoustic vocalic/consonant pre-boundary lengthening will cumulatively increase with prosodic boundary strength
 - Labial constriction movement for preboundary C will have longer duration, greater amplitudes and slower velocity when preceding a stronger boundary
 - Effects of prosodic phrasing on articulatory and acoustic variation are local and thus independent of pitch accent/stress location (penult vs antepenult)**
 - Similar prosodic phrasing effects in both questions and statements**
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- Summary I**
- The acoustic results show a clear preboundary lengthening for the word final vowel from the lowest levels (AP/syll) to the highest prosodic levels (ip and IP), but no difference between smallest levels (AP and syll).
 - Onset consonants, on the other hand, do not show a comparable lengthening effect.
 - Lengthening is strongest in the final syllable, though an incremental effect is also found on the stressed syllable (as for English, cf. Turk and Shattuck-Hufnagel, 2007), though this is true only when the stressed syllable is very close to the boundary, i.e. one syllable away (i.e. in penultimate but not in antepenultimate syllables).
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- Summary II**
- The kinematic temporal results show a lengthening pattern for the closing movement of the preboundary labial consonant, as well as for time-to-peak velocity and displacement of the same, despite not being immediately adjacent to the juncture (one segment away).
 - This was somehow dependent on vicinity to the stress
 - The effect does not extend to the closing movements of stressed syllable
 - Statistical analysis showed mixed evidence for 2 or 3 levels of phrasing, in both Q/S
- > Preboundary effects rather local in Italian, but unresolved discrepancy between acoustic and articulatory data
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- Conclusion**
- As predicted by the π -gesture hypothesis, closing labial movements of preboundary consonant show temporal prosodic effects despite not being immediately adjacent to the juncture (one segment away).
 - The temporal effects are incremental, being stronger for boundaries higher in the prosodic hierarchy, but evidence for dependency from modality and stress vicinity.
 - Similar evidence for velocity and spatial data.
 - The effect does not extend to the closing movements of stressed syllable.
 - Puzzling and inverse results for opening gesture!
 - Need to extend data analysis to other speakers and segmental types.
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