Consonant timing in Australian languages

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General Theme

- Segmental articulation and how it interacts with different levels of prosodic structure in a group of Australian Aboriginal languages

- Working assumption that “the phonetic realization of an individual speech segment depends ....on its position in the entire prosodic structure” (Keating 2006:169)

- Articulation of singleton and consonant clusters in word-medial (and word-final) position
Languages examined in this study

Two major groups
‘Pama-
nyungan’ or non-prefixing (S & centre) – Warlpiri, Arrernte
‘non-Pama-
Nyungan’ or prefixing (N) – Bininj Gun-wok, Iwaidja
2 typical (spatio-)temporal signatures of “higher level” prosodic structure

- Articulatory lengthening, strengthening of consonant at left edge – e.g. Accentual Phrase vs Intonational phrase (although language specific variation)

- Articulatory lengthening and also supra-glottal expansion or localized hyperarticulation of vowel in accentually prominent syllable
Temporal signatures of “lower level” prosodic structure

- Articulatory timing relations at syllable level that support CV versus VC syllable unit e.g. C-center theory (Goldstein, Pouplier, Marin, and colleagues)
- Degree of cross-linguistic variation – e.g. syllabic consonants in Slovakian (Pouplier and Benus 2011)
Australian languages?

- Articulatory lengthening but not strengthening of consonant at left edge of Intonational Phrases – e.g. Arrernte (Tabain 2009)
- Sonority expansion or localized hyperarticulation of CONSONANT that follows accentually prominent vowel – e.g. Warlpiri (Butcher and Harrington 2003)
Warlpiri - medial consonants are carriers of prosody: supraglottal expansion (ema data)

0 ms = onset of /ʊ/ in /kuju/

(Butcher & Harrington 2003)
VC syllable?

- Arrernte has been analysed as VC language (e.g. Breen and Pensalfini 1999)
- VC preference developing more generally for Australian languages?
- Part of tendency *not* to favour onsets or “left edges” in general
- Consonant loss, neutralization in word-initial contexts is typical in many CENTRAL Australian languages
Medial consonants... 

Place cues tightly controlled at CV and VC boundary

(Tabain, Breen & Butcher 2004)
Medial consonants in clusters...

- Allegedly **resistant to assimilation** to following consonant in a cluster (e.g. Butcher 2006)
  - Warlpiri /’canpa/ ‘sorcerer’  NOT: ['cæmbæ]
    **BUT:** ['c æmbæ]
  - /’jinka/ ‘laughter’  NOT: [’ jɪŋɡæ]  **BUT:** [’ jɪŋɡæ]

- Avoidance of synchronic anticipatory coarticulation, mirroring stability of coronal/peripheral sequences **historically** - “Tolerance of heterorganic sequences” (Evans 2006)
Residual "coronal" gesture (tongue tip)

dorsal gesture (back of the tongue)

A common example from English

"HAND-GRENade" - highly gradient productions /hæn grəneɪd/ → *[hæn grəneɪd]

From Barry (1991:15)
Syllable phonotactics: Electropalatographic studies of lingual-palatal contact in English consonant sequences show that syllable onsets less variable than syllable codas in inter-syllabic VC1#C2V contexts (although manner differences – C1)
Coarticulation resistance

- Need to preserve **paradigmatic** segmental contrasts an important output constraint in Australian languages

  - restrictions on **coarticulatory variation**, because place of articulation contrasts must be maintained in positions where normally coarticulation might occur, e.g. in clusters

- **Syntagmatic** constraint: C1 more important than C2 in clusters – **helps to cue Accentual prominence**

  - preferred syllable phonotactics – VC timing or no preference for CV or VC timing?
Predictions for Australian Languages

- In medial hetero-syllabic clusters $VC_1\#C_2V$
- $C_1$ will be longer than, or as long as $C_2$
- $C_1$ will be as stronger or less variable than $C_2$, or at least as strong if VC and CV contexts equally controlled
BUT…

- Different place of articulation interactions e.g. **retroflex+velar** clusters will behave differently from **alveolar+velar** clusters
  - different articulatory requirements of C1 or C2 - “resistant” consonants (e.g. DAC model)
- Expect a degree of **temporal overlap** of apical/dorsal gestures
- Different manner of articulation effects depending on C₁ (e.g. Bombien et al. 2010)
Electropalatagraphic corpus

5 speakers of 3 languages
- Iwaidja – male & female
- Warlpiri – female
- Arrernte – two females

Tokens in two carrier phrases to control focus
- i.e. utterance initial versus utterance final

Token – focal accent
# Consonant Inventories

## Warlpiri

<table>
<thead>
<tr>
<th>Consonants</th>
<th>peripheral</th>
<th>apical</th>
<th>laminal</th>
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<tr>
<td></td>
<td>labial</td>
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<td>alveolar</td>
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<td>stops</td>
<td>p</td>
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<td>η</td>
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<td>glides</td>
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## Vowels

<table>
<thead>
<tr>
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<th>front</th>
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<tbody>
<tr>
<td>high</td>
<td>ɪ</td>
<td>ʊ:</td>
</tr>
<tr>
<td>low</td>
<td>ə</td>
<td>ə:</td>
</tr>
</tbody>
</table>
Iwaidja - 3 rhotics and 4-5 laterals

<table>
<thead>
<tr>
<th></th>
<th>Peripheral</th>
<th>Coronal</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td></td>
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<td>b</td>
<td>k</td>
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<tr>
<td>Nasal</td>
<td>m</td>
<td>n</td>
</tr>
<tr>
<td>Approximant</td>
<td>w</td>
<td>w̃</td>
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<tr>
<td>Liquid</td>
<td>Tap</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stopped Lateral</td>
<td></td>
</tr>
</tbody>
</table>

(Birch, in prep)

70% sonorants – 30% obstruents
Materials

- series of /N#k/, /N#t/ /N#d/& /N#c/ &, /L#th/, /L#d/ /L#d/, /L#c/ /L #k/
- Most sequences in corpus are heterosyllabic and front+back clusters
- Not all contrasts are present in the three languages
- Iwaidja corpus has final /lk#/ (range of other final sonorant+stop clusters are also possible)
COG (7.5 - .5)
Higher value — front articulation
Lower value — back articulation
Overall distribution of contacts in palate

| alveolar | postalveolar | palatal | velar |

AI (0-1, higher values = more anterior)
DI (0-1, higher values = more contact in palatal, post-palatal regions)

inykiri

20 ms  
AI = .70

50 ms  
DI = .91
/nk/ cluster (\textit{kinki}, 3\textsuperscript{rd} repetition)
Acoustic duration – $N_1C_2$

**ns**

**ns**

**ns**

**ns**
Timing: Cluster ratio $N_1C_2$

“robust” nasal component in NC clusters, but $C_2$ can be as long, rarely longer
Timing: Cluster ratio

Laterals $L_1C_2$

Shortest...

Longest
Predictions

Predictions....
- $C_1$ will be as long or longer than $C_2$

Results...
- General effect – Nasals account for up to 70% of overall cluster duration, laterals 30-50%
- Great deal of variation – slower speakers, lower ratios (i.e. $C_2$ can be as long as $N_1$, longer than $L_1$)
- Singleton nasals can be shorter OR longer than nasals in clusters
Alveolar clusters $N_1^-$ Arrernte
Alveolar clusters $N_1$- Iwaidja
Retroflex clusters $N_1$- Iwaidja and Warlpiri
Lateral Clusters

Alveolar – no variation vs retroflex at C1 midpoint
Predictions

Predictions....

- Limited **spatial** variation of $C_1$ due to $C_2$

Results...

- Evidence of **spatial modification** in $N_1$ due to $C_2$, but not in /l/ clusters due to intrinsic articulatory characteristics of lateral
- alveolar + stop - COG of /n/ **lower** before palatal in Iwaidja and velar stops in all three languages
- retroflex + stop - COG is **higher** before /c/ vs /k/
C2 variability?

Palatal Contact Trajectories – AI & DI

Arrernte

Warlpiri

Iwaidja

English

$C_1$ more variable than $C_2$
Predictions

Predictions....
- More \textbf{spatial} variation of $C_2$ versus $C_1$

Results...

- $C_2$ is \textbf{more} variable than $C_1$ if we examine palate trajectories for entire cluster – $C_1$ looks to be more tightly controlled in apical+dorsal clusters

- Articulatory timing differences?
Timing: gestural overlap

Warlpiri

AI trajectories show that time course of “coronal gesture” changes abruptly approximately halfway through the nasal segment (75 ms mark)

DI trajectory also shows movement suggesting late anticipation of following velar
Timing: gestural overlap

Arrernte & Iwaidja

Nasals
IWAIDJA - Nasal vs Lateral

/nk/

/lk/
Laterals – less overlapped compared to nasals
High level of variability
Predictions

Degree of coronal+dorsal temporal overlap

Results...

- Clear evidence of coproduction – temporal overlap
- Manner of articulation differences in articulatory timing, but highly variable
Articulatory timing relations?

- Different temporal coordination patterns in onsets vs. codas in a range of languages e.g. English (e.g. Byrd 1995; Marin and Pouplier 2010), German (Hermes et. al 2008), Arabic (Shaw et al. 2009)

- Different articulatory timing of VC$_1$#C$_2$V, VC$_1$# and VC$_1$C$_2$# in Iwaidja
IWAIDJA - /l/ Coda timing?

Graphs showing the timing of /l/ codas for different variations of Iwaidja.
Cluster articulation in this corpus largely confirms our prediction that onset of C1 is tightly controlled (for the most part!) in the case of non conflicting gestures – some spatial modification of C1 in anticipation of C2.

N1 is usually **stronger, less variable**, and **longer** than C2, although L1 **stronger (less variable)** but not always longer.
Articulatory timing?

- Longish acoustic (and articulatory) durations of initial sonorants - more time to realise $C_1$ gesture, reduce degree of spatial modification.
- Not just simple later re-phasing of dorsal gesture: longer overlap = longer duration of $C_1$.
- Manner differences – intrinsic articulatory requirements of laterals.
Prosodic strengthening?

- Some support for prosodic strength of C following perceived accented vowel
- Suspect patterns are more extreme in prosodically strong contexts anyway!
- Durational adjustments to preserve place cue - perceptual recoverability (after Chitoran and Goldstein)
- VC vs CV? Further investigation of articulatory timing “c-centers” in final clusters
- Opposite pattern to typical CV timing relationships?