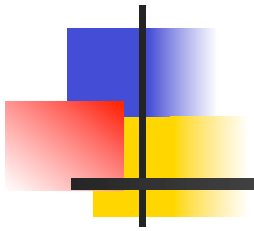

Consonant timing in Australian languages

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University of Melbourne

(collaborators: Andy Butcher, Debbie Loakes, Bruce Birch, Jonathan Harrington)

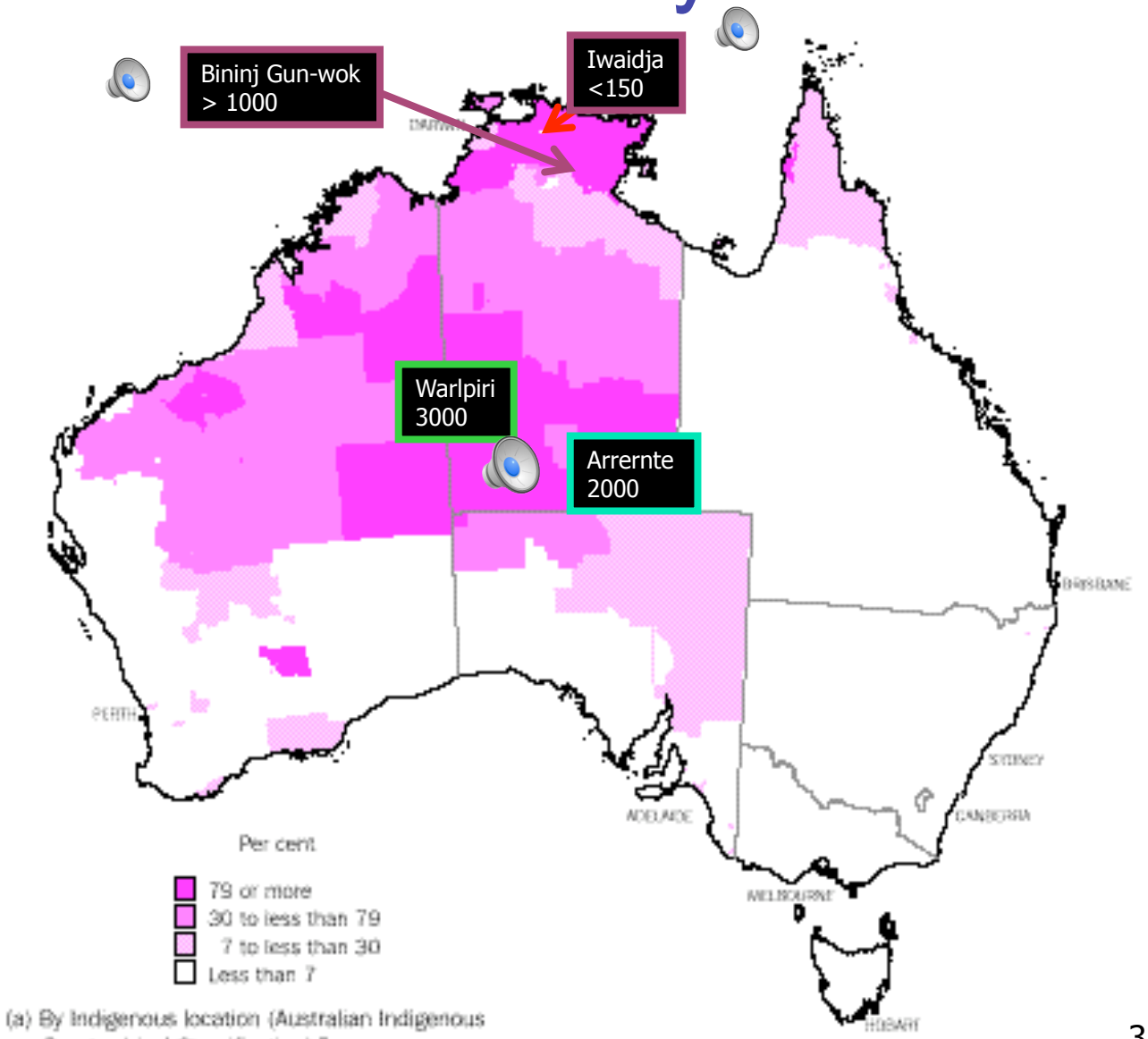
VIU Workshop - October 2011

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



(a) By Indigenous location (Australian Indigenous Geographical Classification).*

Source: Unpublished data, 1996 Census of Population and Housing.

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 expansion or localized hyperarticulation of vowel in accentually prominent syllable

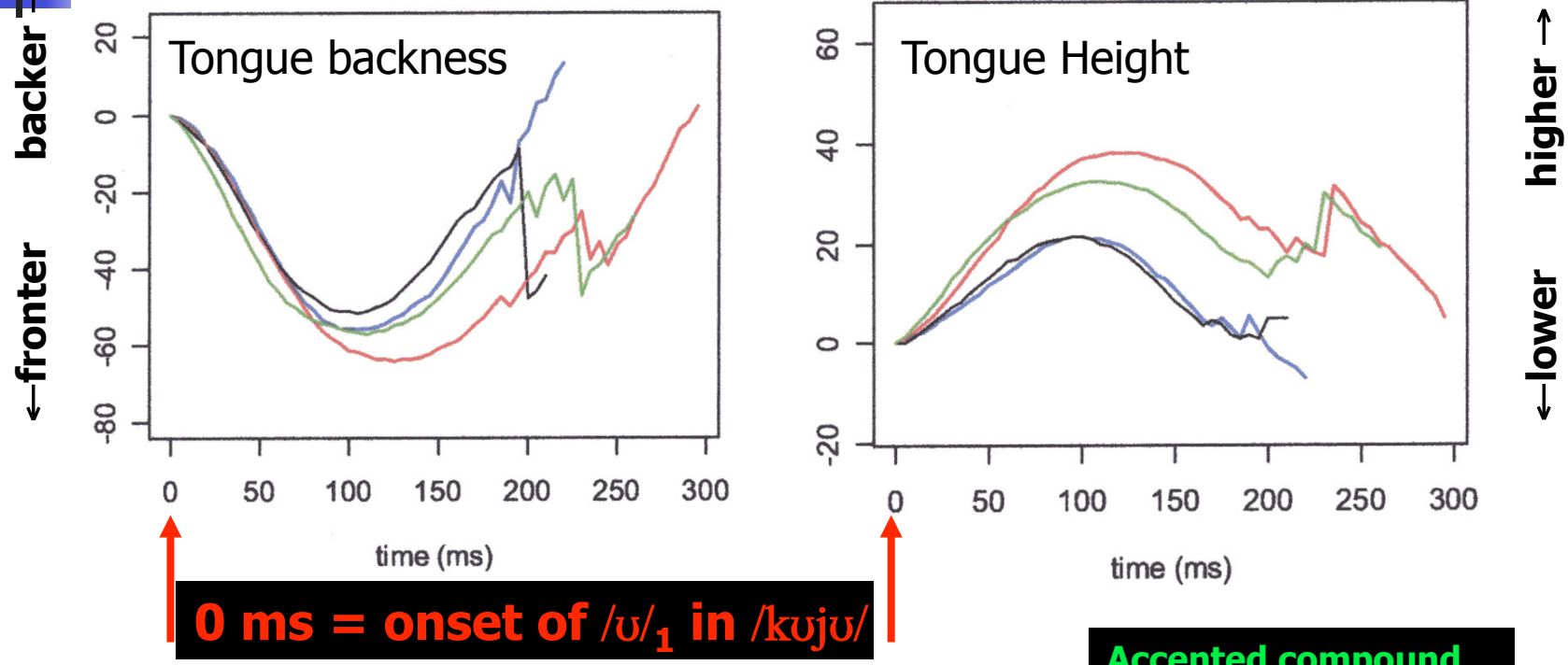
Temporal signatures of "lower level" prosodic structure

- 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)

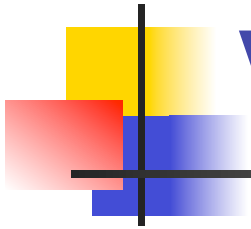
Warlpiri - medial consonants are carriers of prosody: supraglottal expansion (ema data)



(*Butcher & Harrington 2003)*

Accented compound
Accented N + V

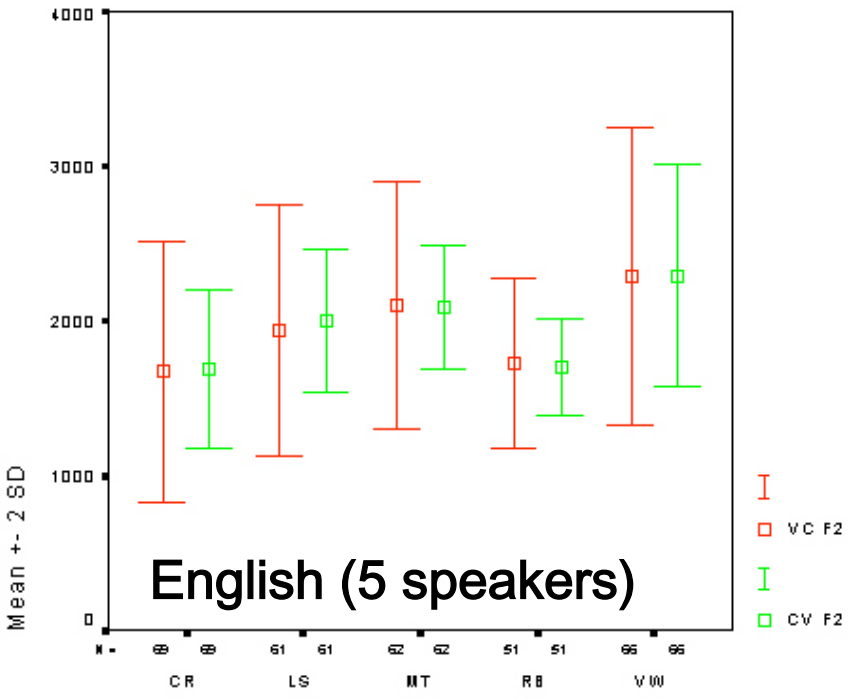
Unaccented N + V

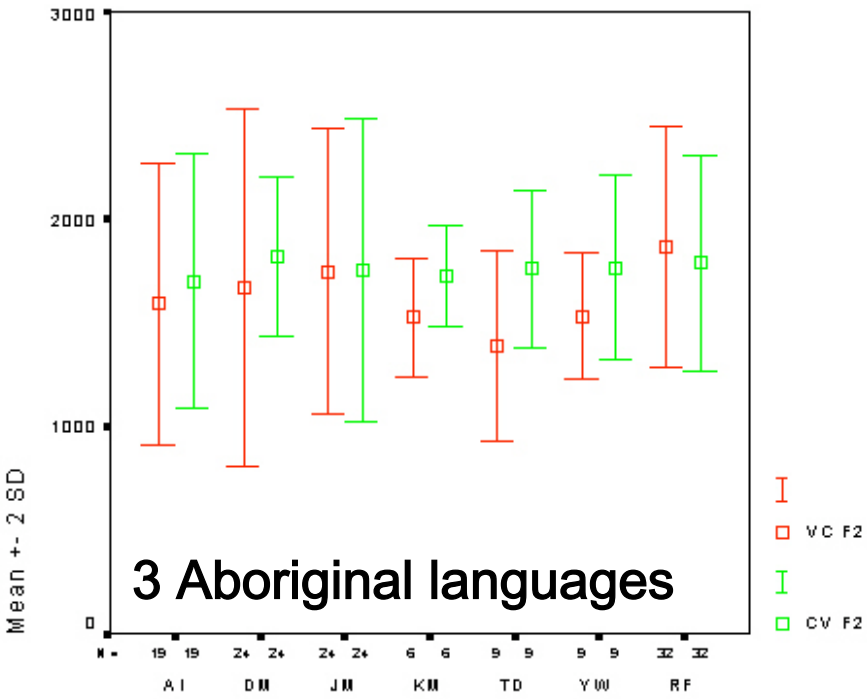


VC syllable?

- 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...





at CV boundary
at VC boundary

(Tabain, Breen & Butcher 2004)

Place cues tightly controlled at CV and VC boundary

Medial consonants in clusters…

- Allegedly **resistant to assimilation** to following consonant in a cluster (e.g. Butcher 2006)

Warlpiri /ˈcaɳpa/ '*sorcerer*' NOT: [ˈcɐmbɐ]
BUT: [ˈcɐɳbɐ]

/ˈjinka/ '*laughter*' NOT: [ˈjɪŋgɐ] **BUT:** [ˈjɪngɐ]

- Avoidance of synchronic anticipatory coarticulation, mirroring stability of coronal/peripheral sequences **historically** - "Tolerance of heterorganic sequences" (Evans 2006)

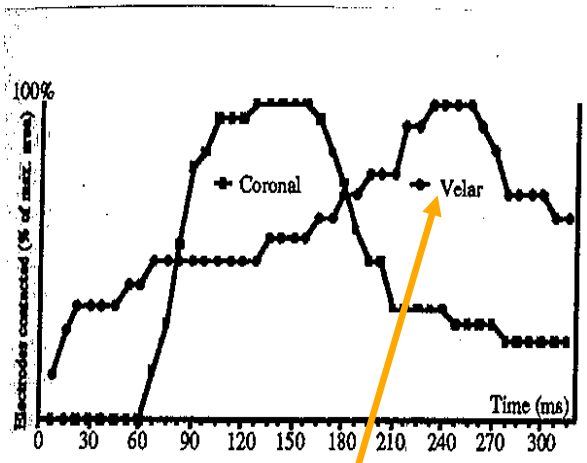


Figure 3: Gestural Trajectories for [n g] in 'hand grenade' (slow utterance)

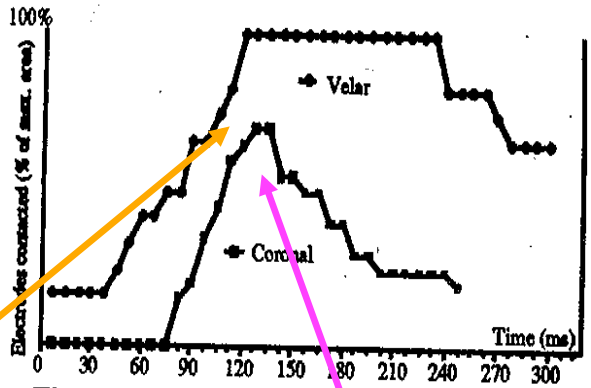


Figure 4: Gestural Trajectories for [n g] in 'hand grenade' (fast utterance)

A common example from English

dorsal gesture (back of the tongue)

Residual "coronal" gesture (tongue tip)

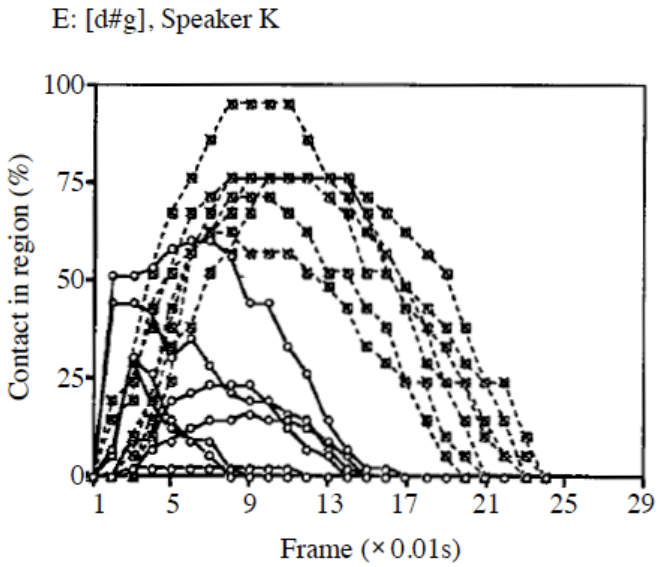
From Barry (1991:15)

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

Coproduction: Lingual palatal contact

- **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**

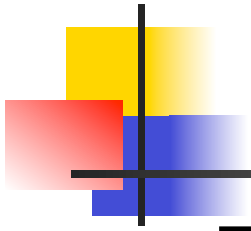
  - **preferred syllable phonotactics –** VC timing or no preference for CV or VC timing?

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 C_1(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

Consonants

	peripheral		**apical**		**laminal**
	labial	***velar***	***alveolar***	***postalv***	***alveopalatal***
stops	p	k	t	ʈ	c
nasals	m	ŋ	n	ɳ	ɲ
laterals			l	ɭ	ʎ
rhotics			r	ɽ	
glides	w			ɻ	j

Vowels

	front		back	
high	ɪ	ɪː	ʊ	ʊː
low	ɐ	ɐː		

Iwaidja - 3 rhotics and 4-5 laterals

		Peripheral		Coronal		
				Apical		Alveo-pal
		Labial	Velar	Alveol	Retro	
Stop		b	k	t	ʈ	c
Nasal		m	ŋ	n	ɳ	ɲ
Approximant		w	ɰ		ɻ	j
Liquid	Tap			r	ɽ	
	Lateral			l	ɭ	
Stopped Lateral				l^d	$ɭ^ɖ$	

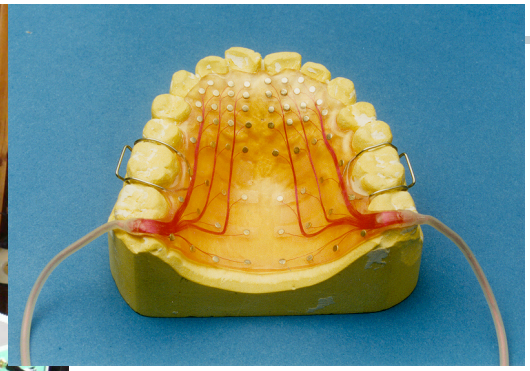
(Birch, in prep)

70% sonorants – 30% obstruents

Materials

- series of /N#k/, /N#t/ /N#ɖ/& /N#c/ &, /L#th/, /L#d/ /L#ɖ/, /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

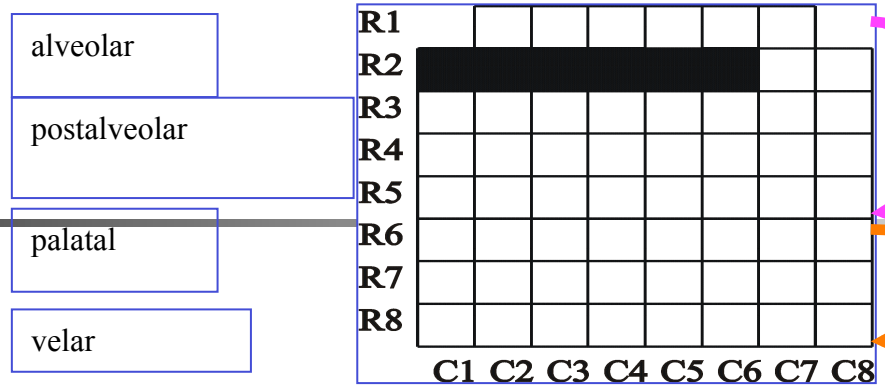
Electropalatography - Reading Electropalatograph v. 3



COG (7.5 - .5)
Higher value – front articulation

Lower value – back articulation

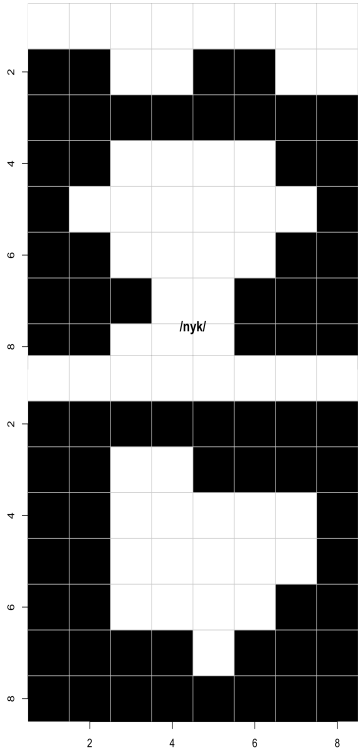
Overall distribution of contacts in palate



AI (0-1, higher values=more anterior)

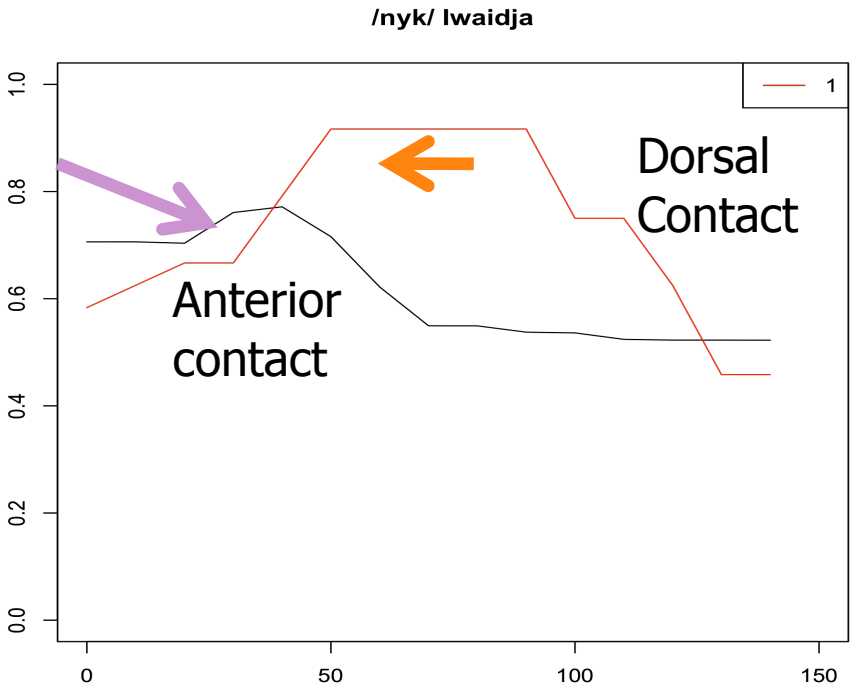
DI (0-1, higher values= more contact in palatal, post-palatal regions)

inykirri /nyk/

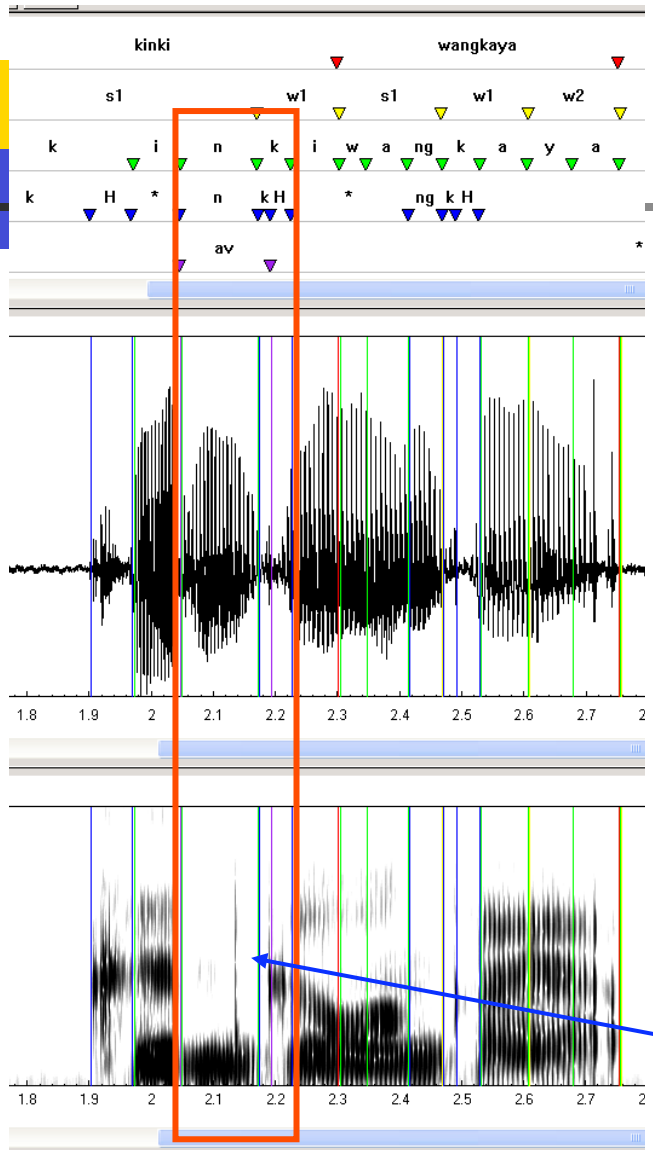


20 ms
AI = .70

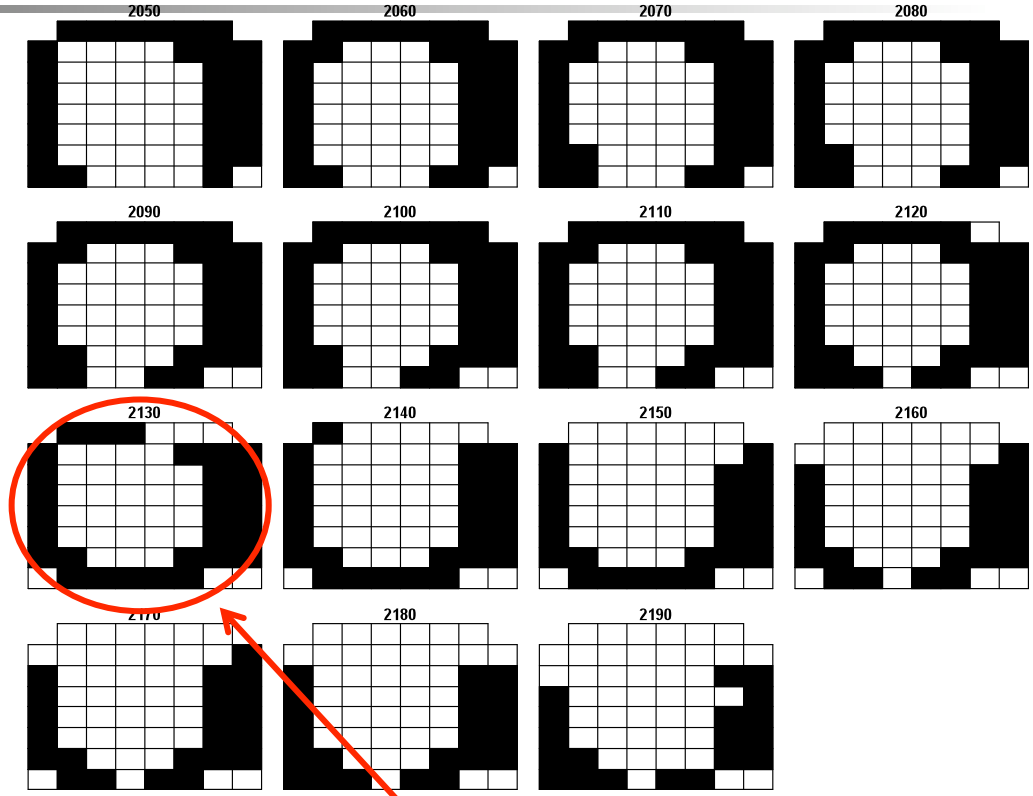
50 ms
DI = .91



/nk/ cluster (*kinki*, 3rd repetition)

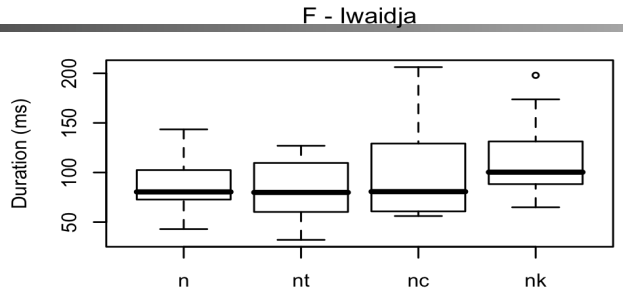


Warlpiri

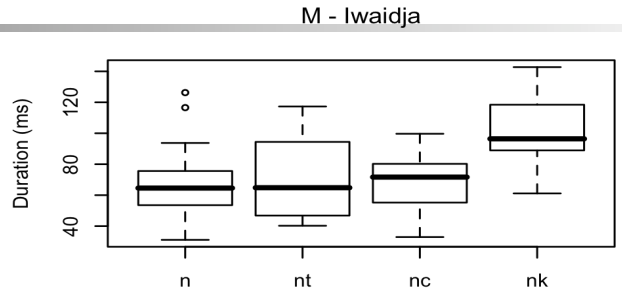


Acoustic closure /k/

Acoustic duration – $\mathbf{N_1}C_2$



ns



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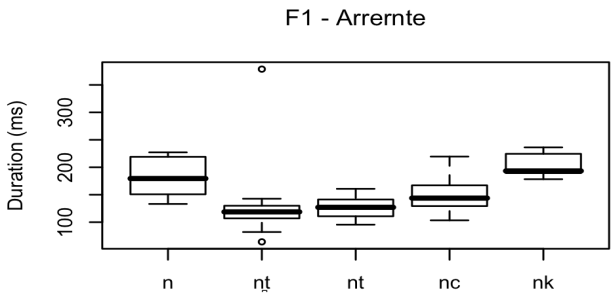

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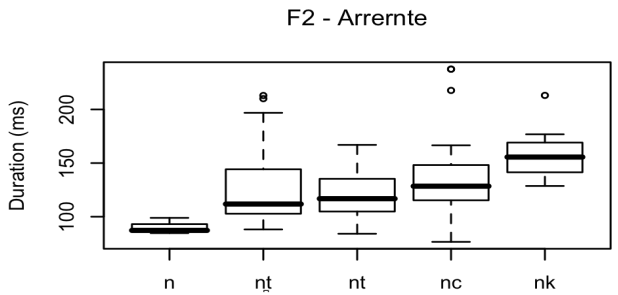
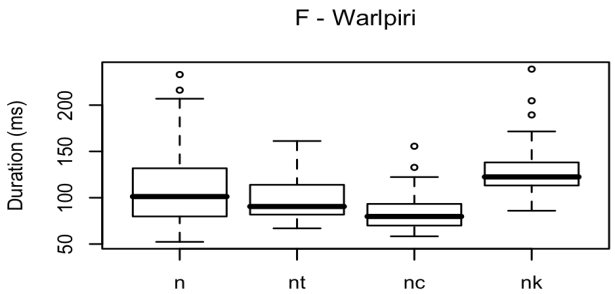


ns



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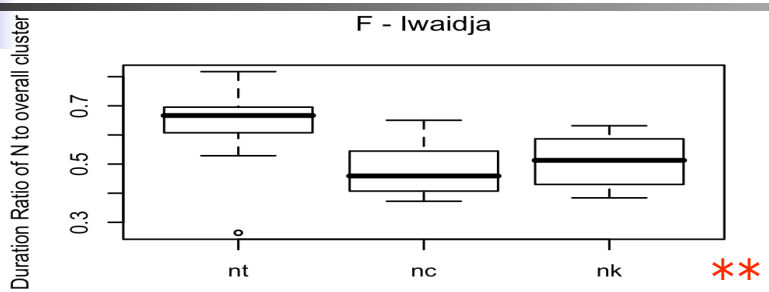
Timing: Cluster ratio N_1C_2



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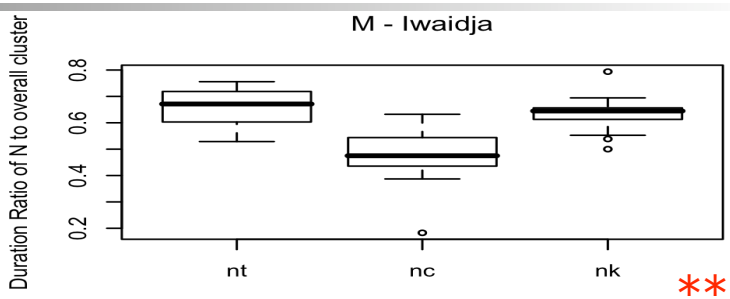

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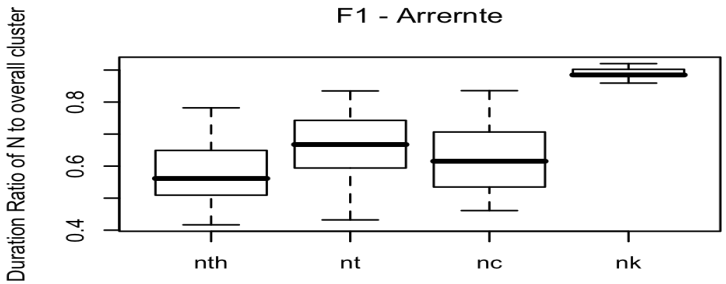

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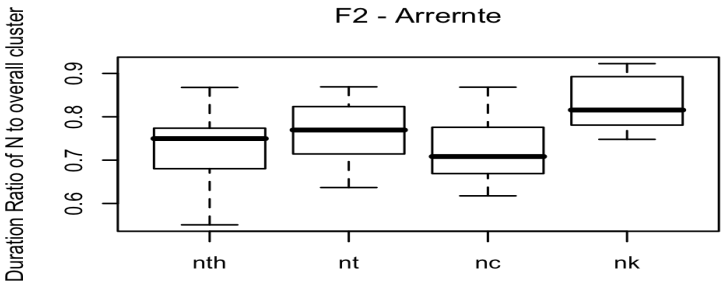

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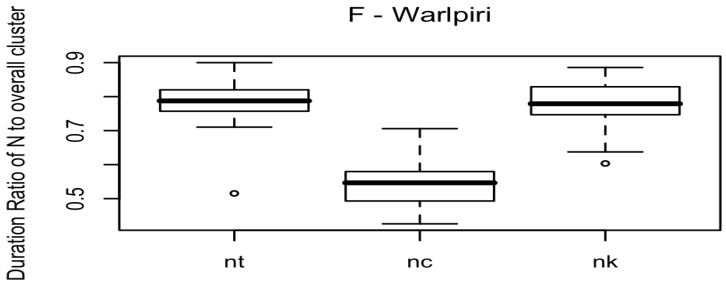

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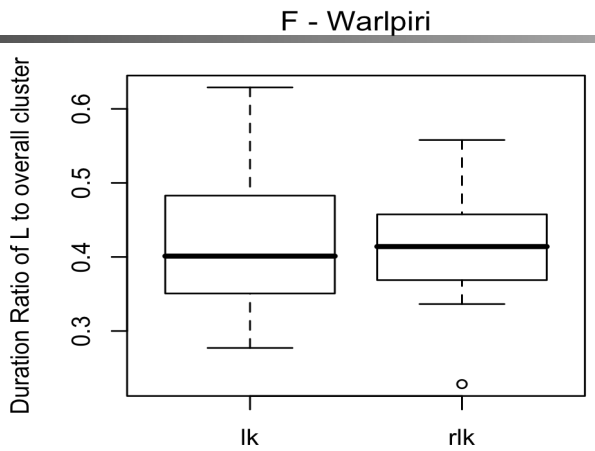
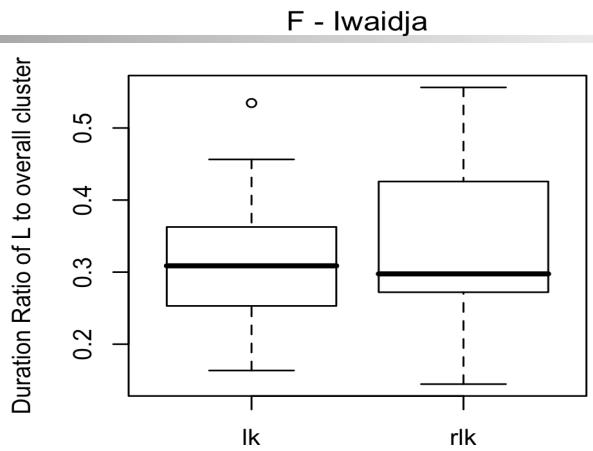
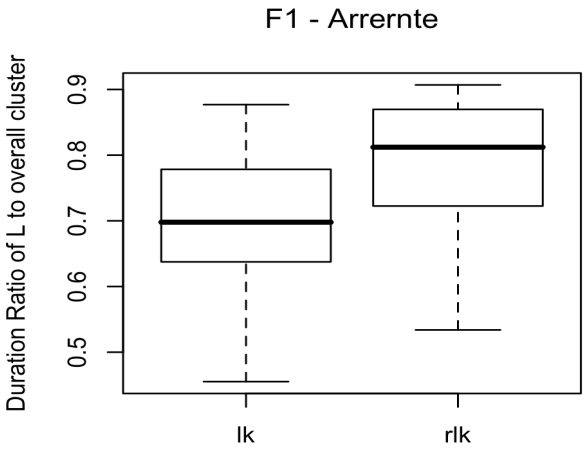
"robust" nasal component in NC clusters, but C2 can be as long, rarely longer

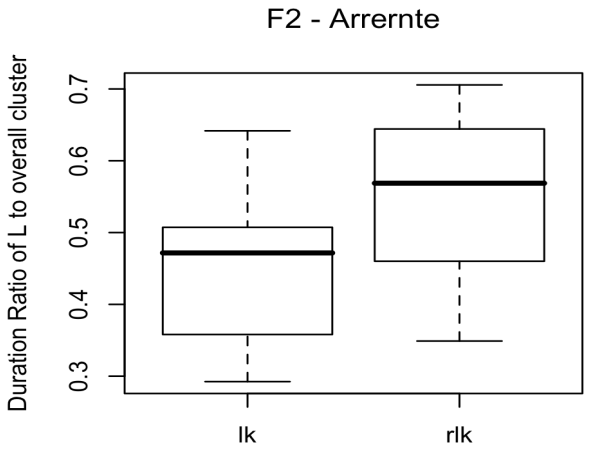
Timing: Cluster ratio Laterals L_1C_2

Shortest…









Longest

Predictions

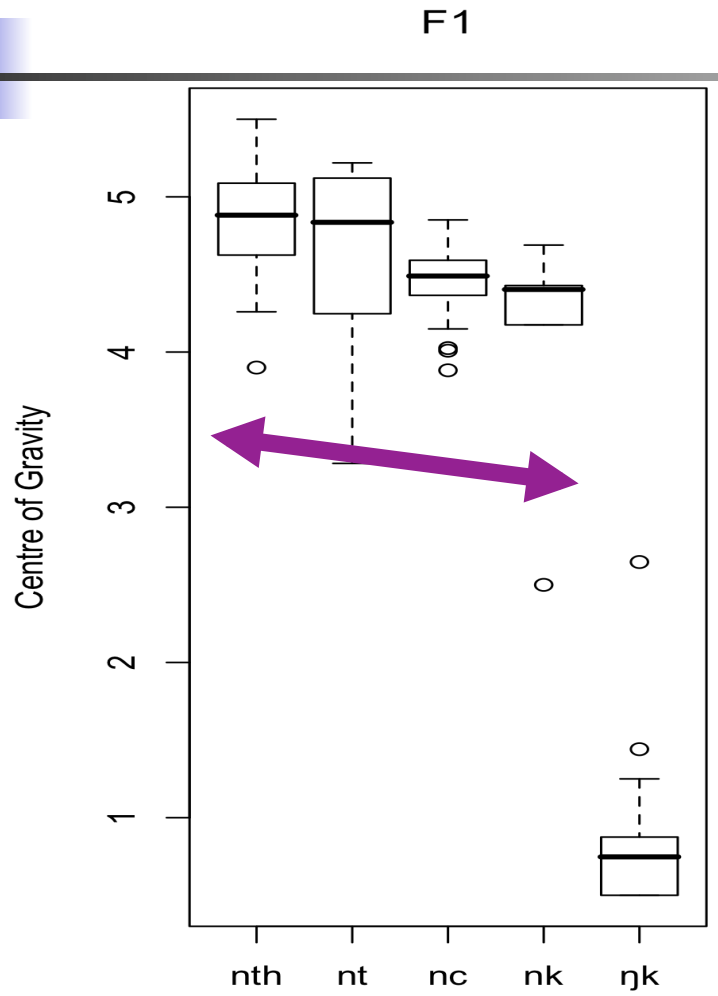
Predictions….

- 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



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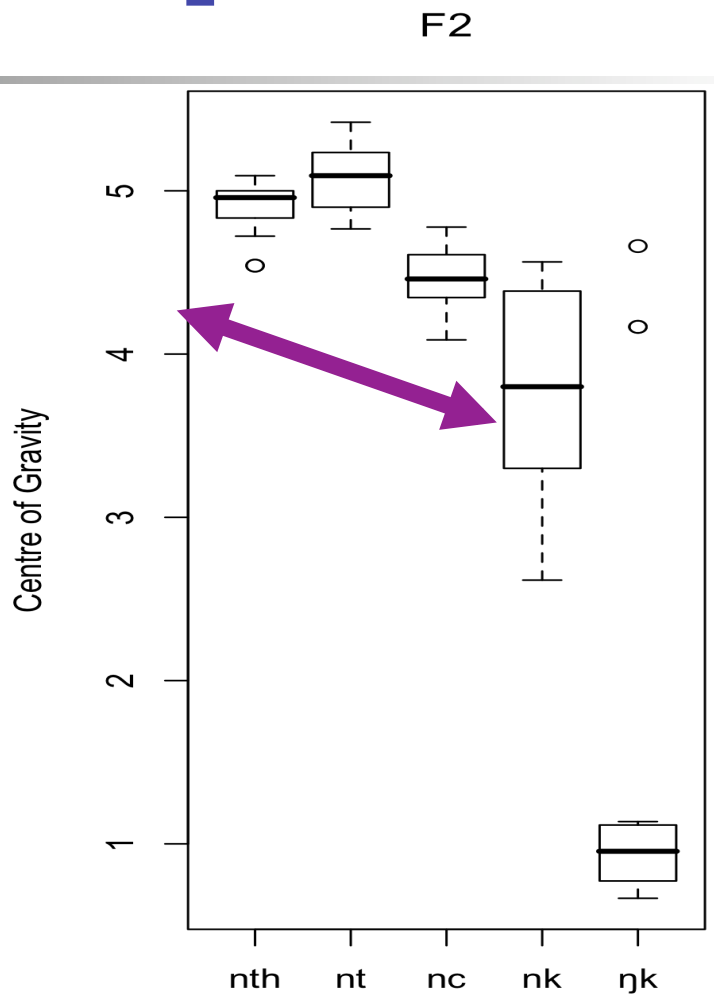

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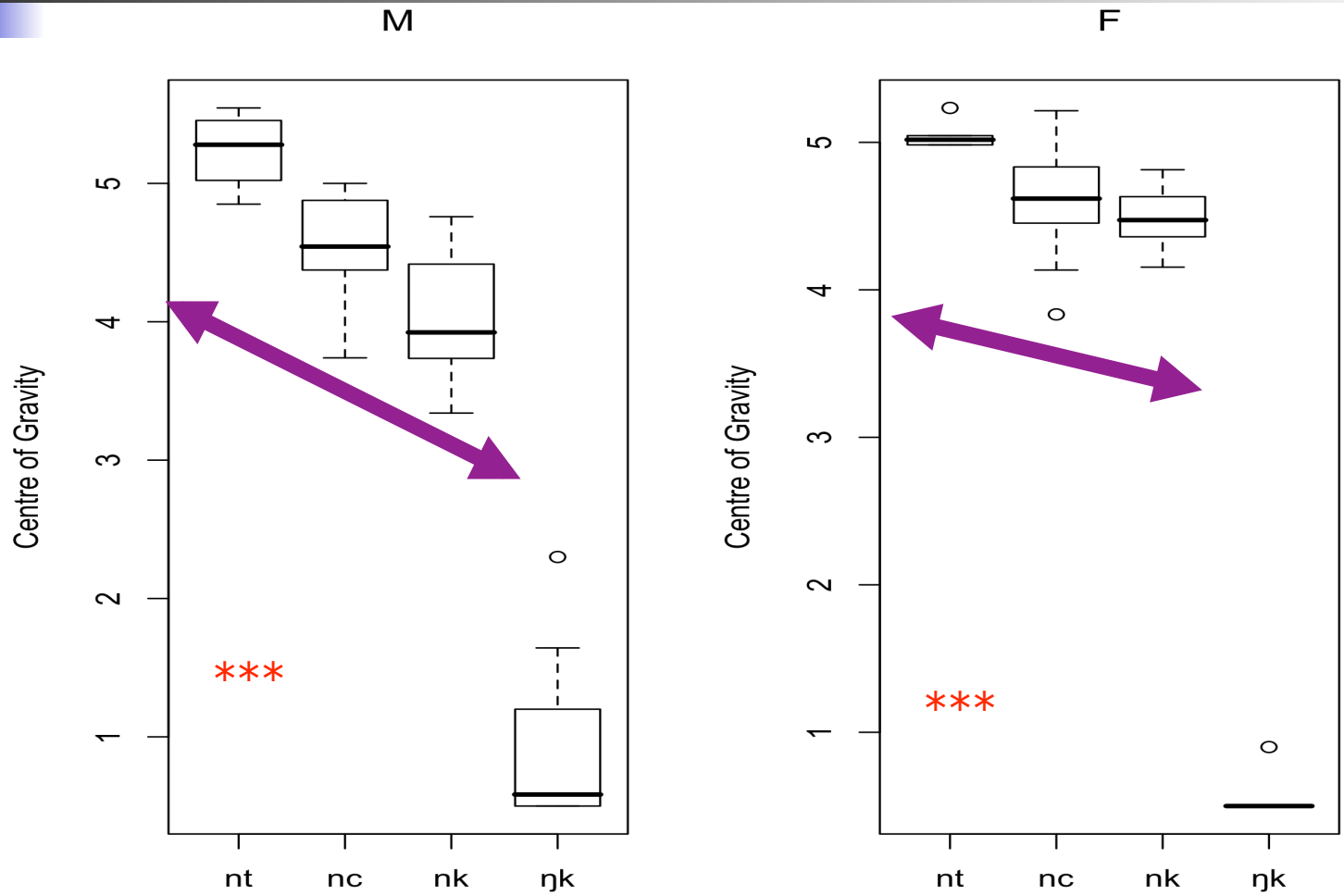
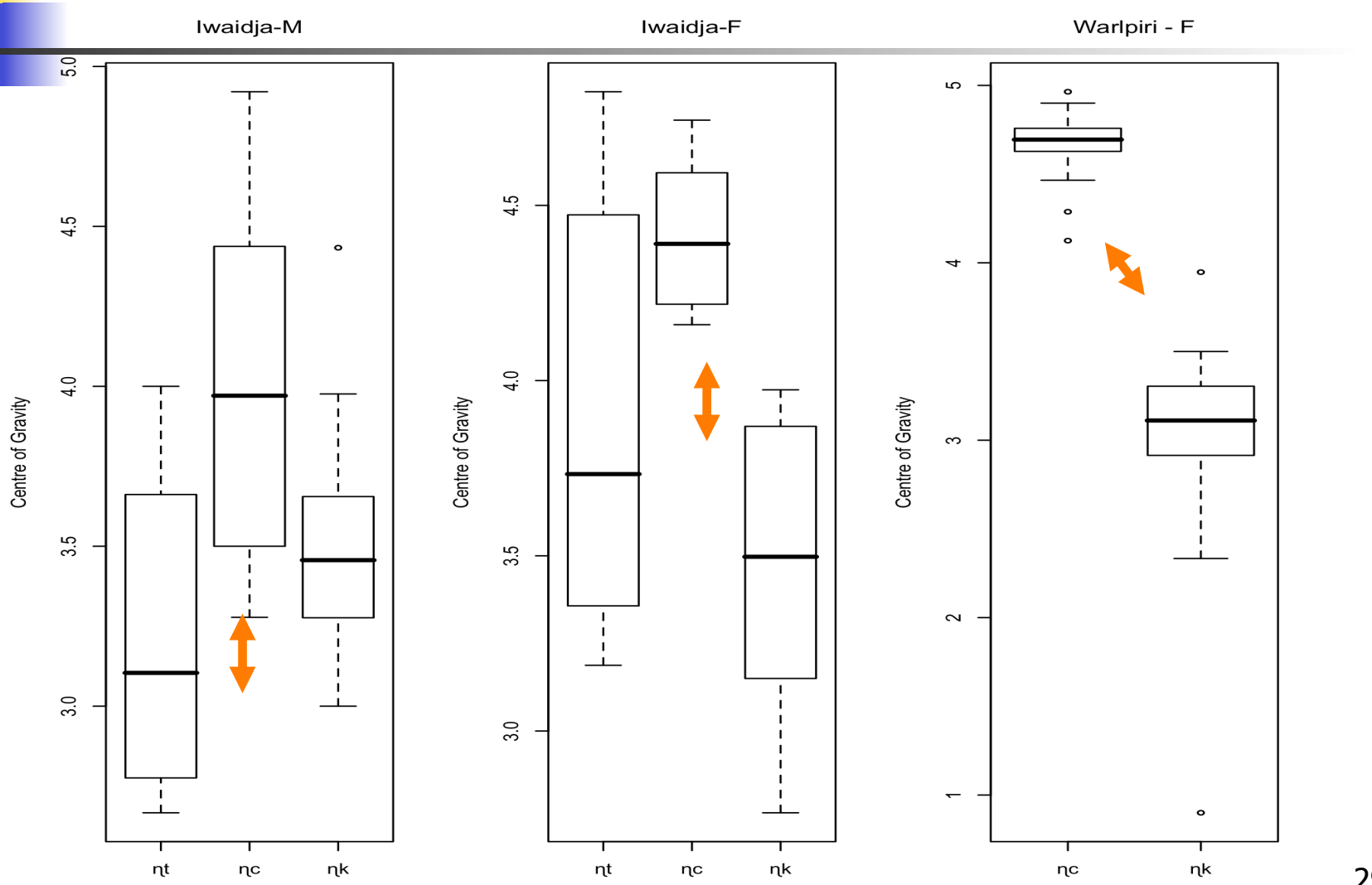
Alveolar clusters N_1- Iwaidja

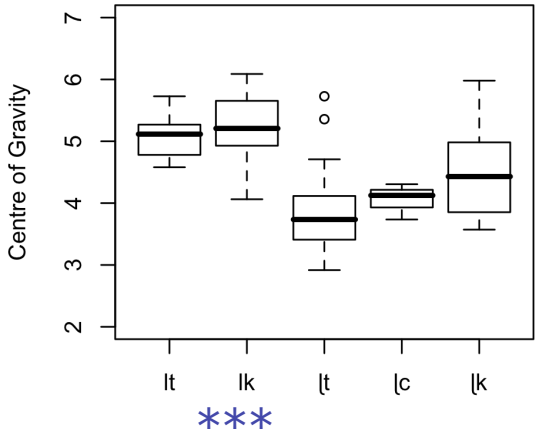


Retroflex clusters N_1- Iwaidja and Warlpiri



Lateral Clusters

Iwaidja - F



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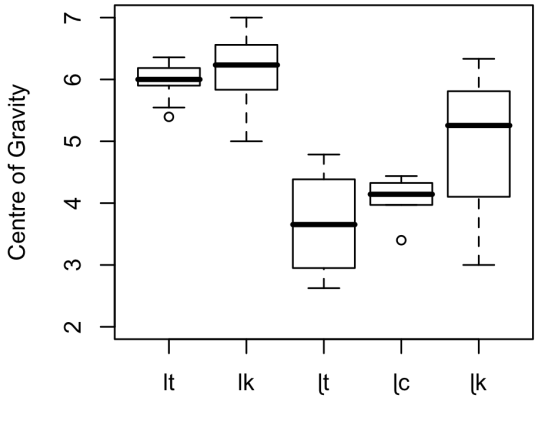
Iwaidja - M



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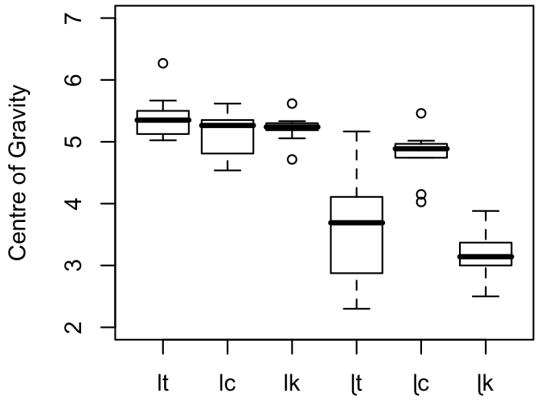
Warlpiri- F



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Alveolar – no variation vs retroflex at C1 midpoint

Predictions

Predictions….

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

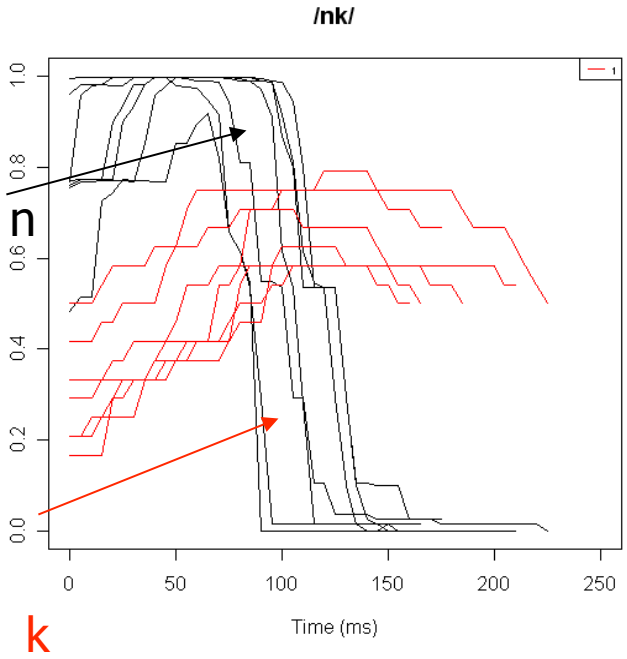
Results…

- 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/

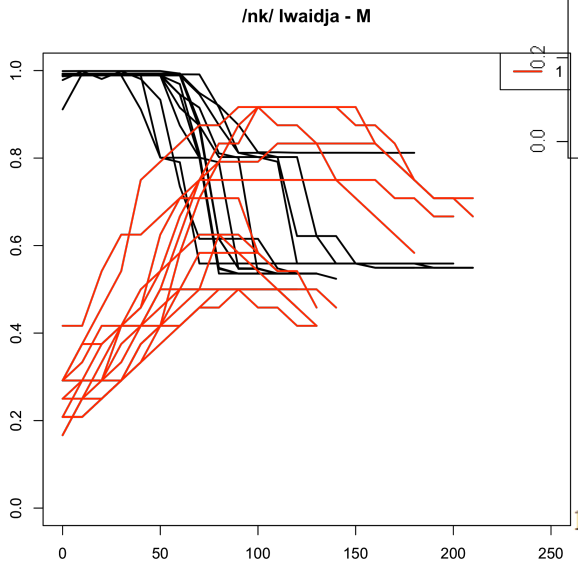
C2 variability?

Palatal Contact Trajectories – AI & DI

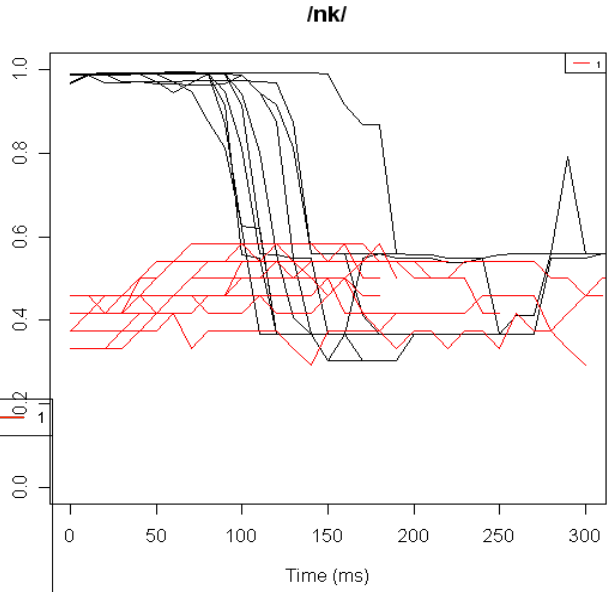
Warlpiri



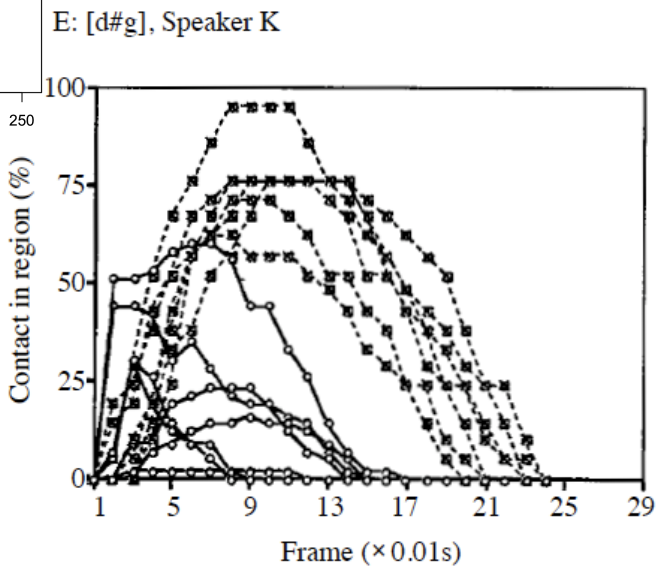
Arrernte



Iwaidja



English
C_1 more variable than C_2



Predictions

Predictions….

- More **spatial** variation of C_2 versus C_1

Results…

- C_2 is **more** variable than C_1 if we examine palate trajectories for entire cluster – C1 looks to be more tightly controlled in apical+dorsal clusters

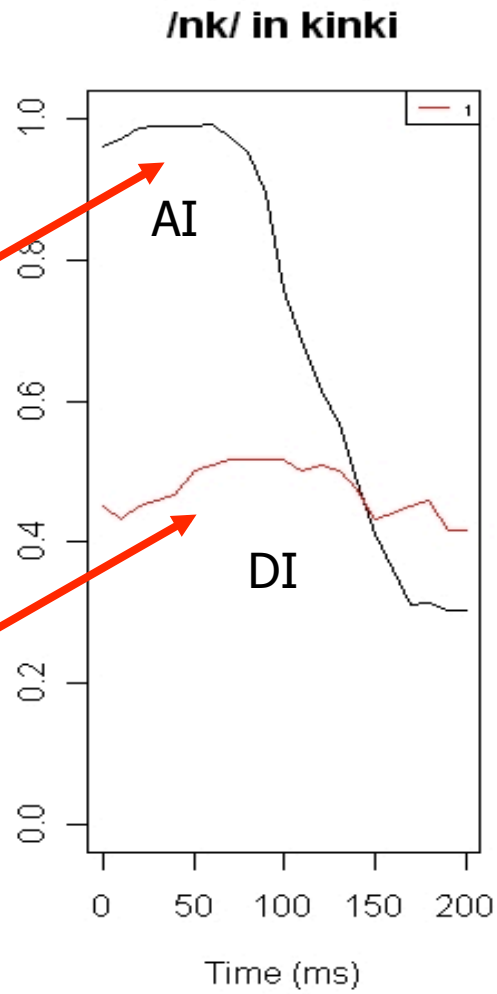
- Articulatory timing differences?

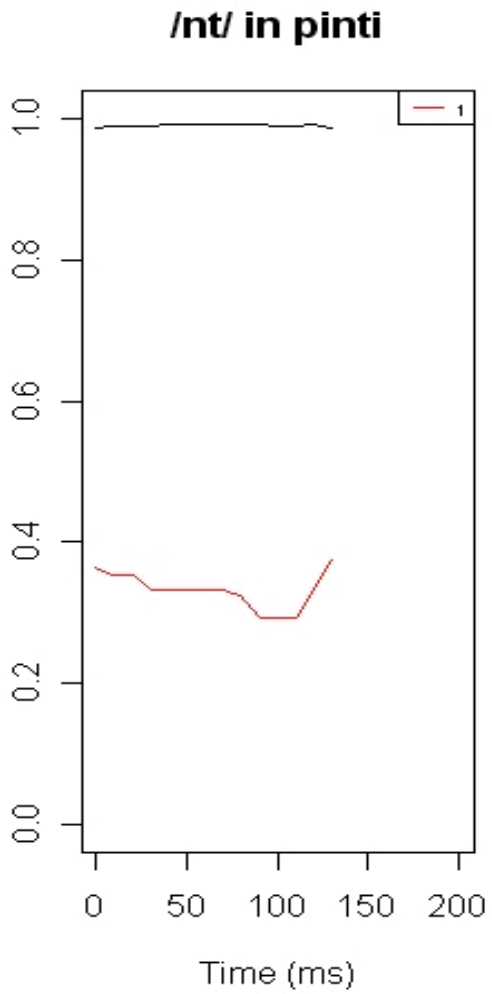
Timing: gestural overlap

Warlpiri

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

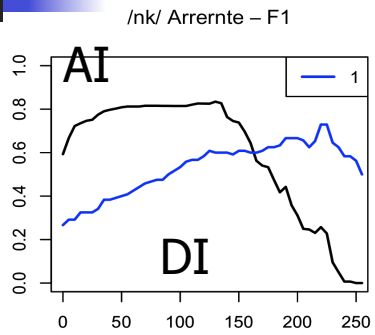
DI trajectory also shows movement suggesting late anticipation of following velar

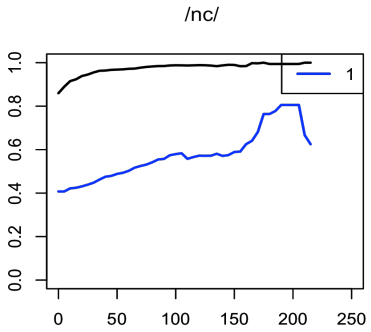


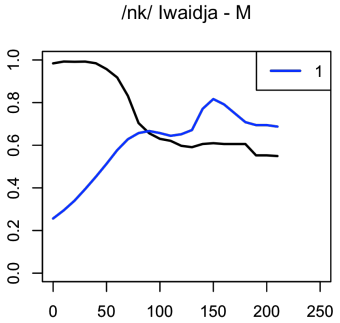


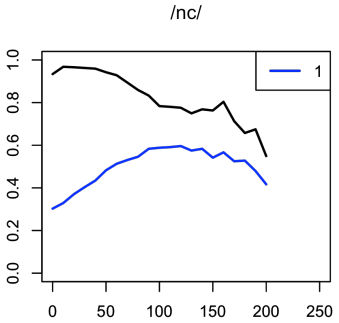
Timing: gestural overlap

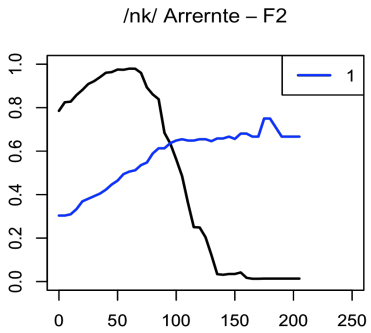
Arrernte & Iwaidja

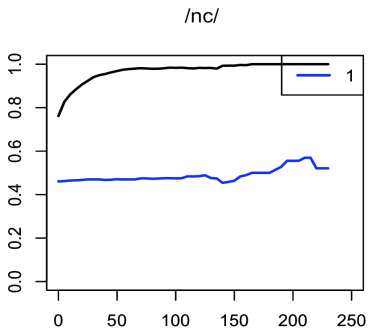


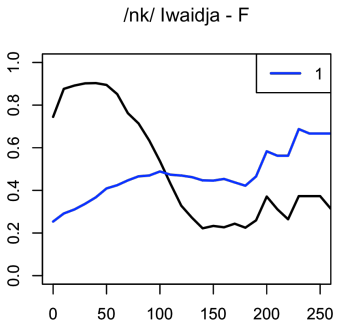


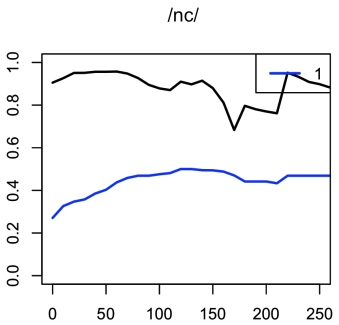






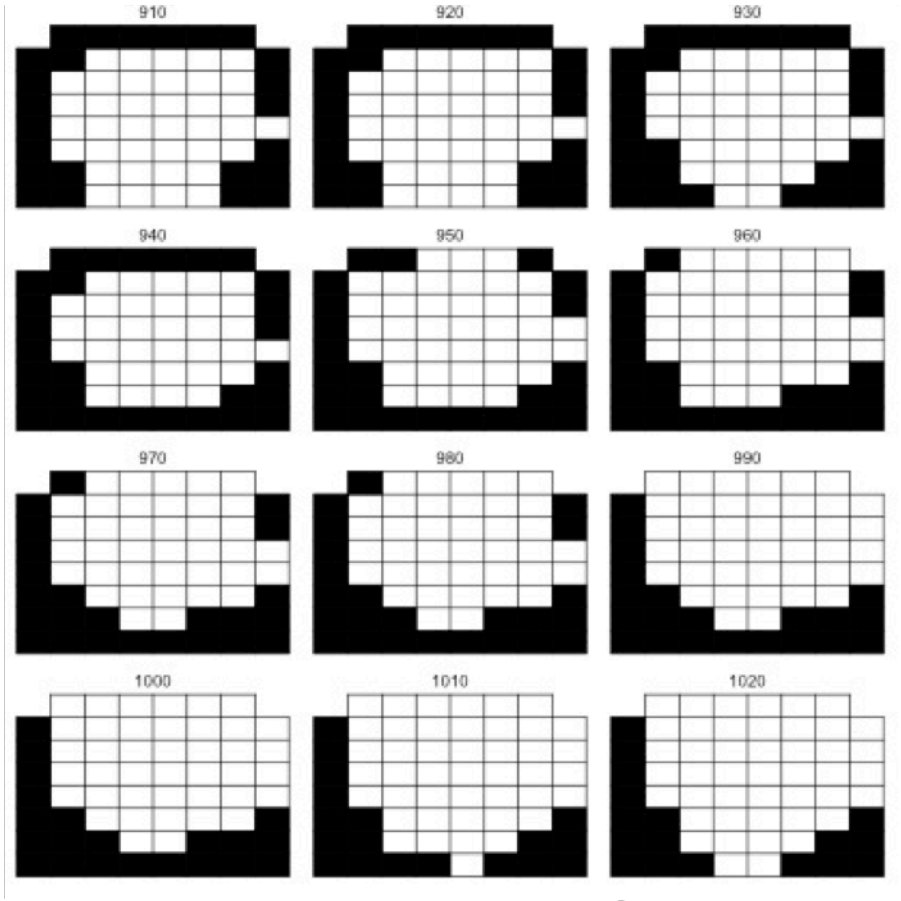






Nasals

IWAIDJA - Nasal vs Lateral



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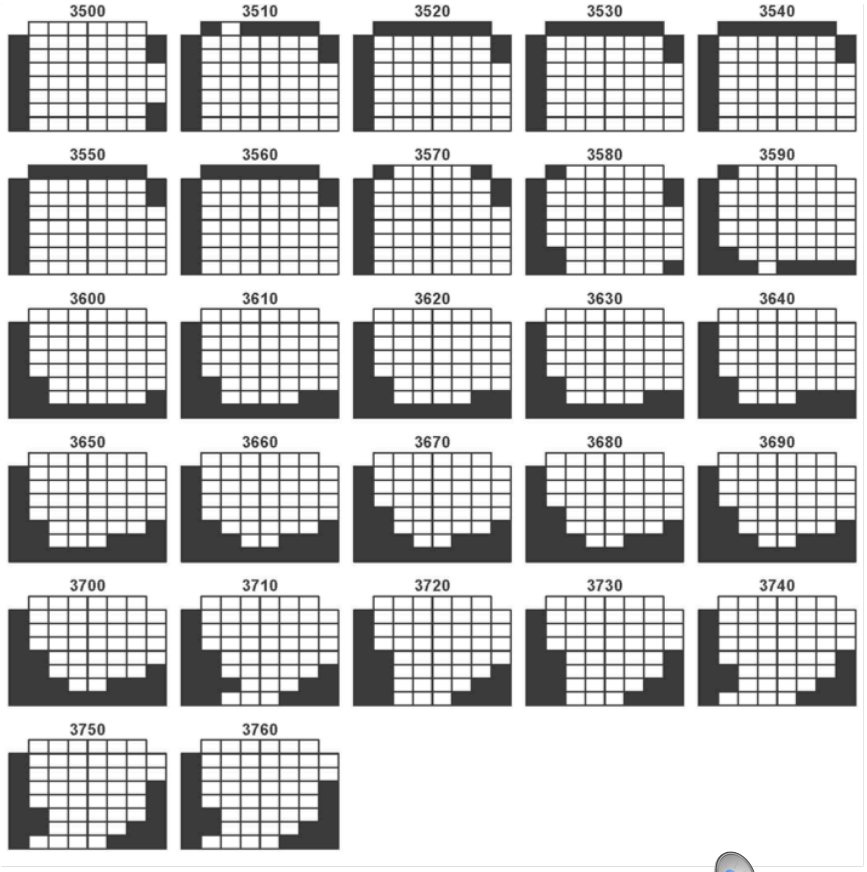
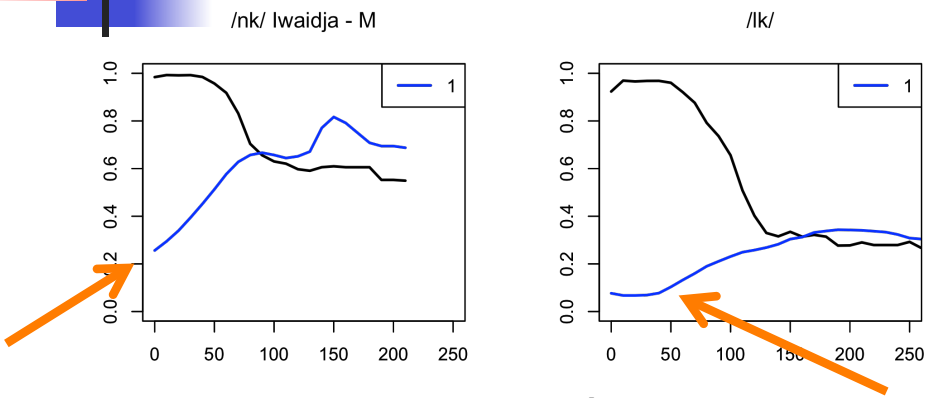


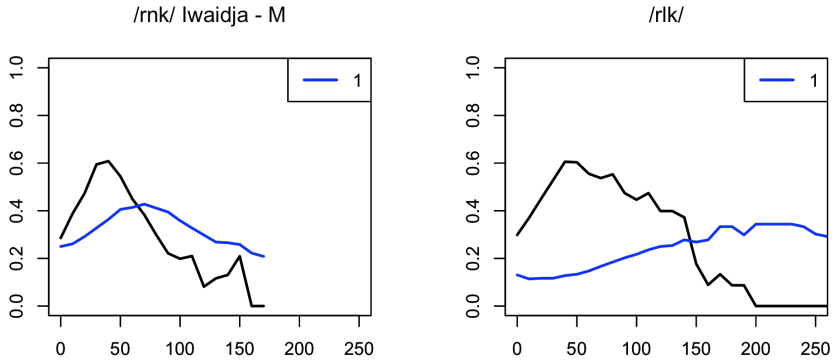
/lk/

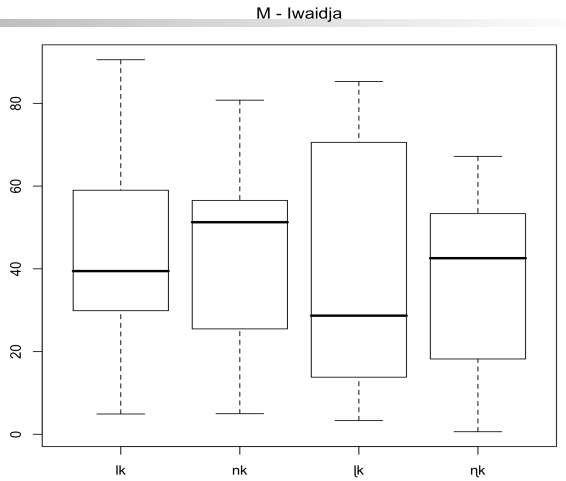
IWAIDJA - Temporal overlap

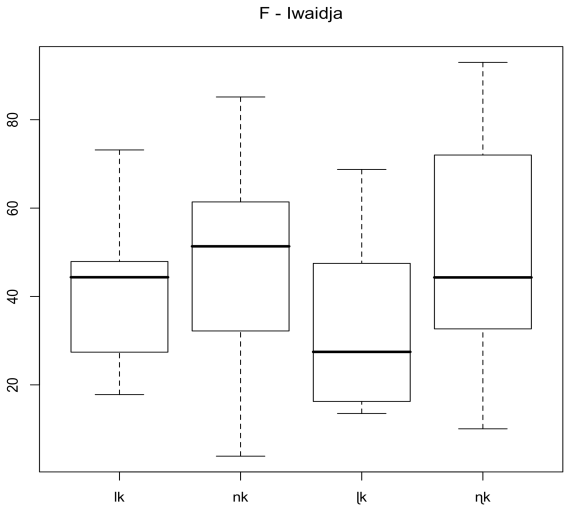


Earlier....

Later....







Laterals – less overlapped compared to nasals
High level of variability

Predictions

Predictions….

- Degree of coronal+dorsal temporal overlap

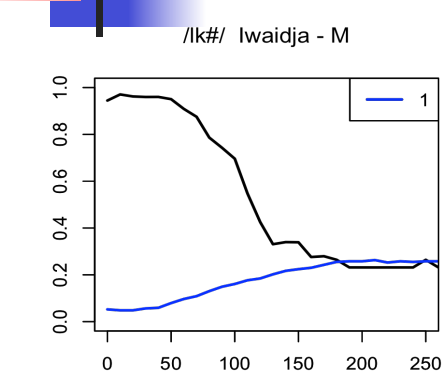
Results…

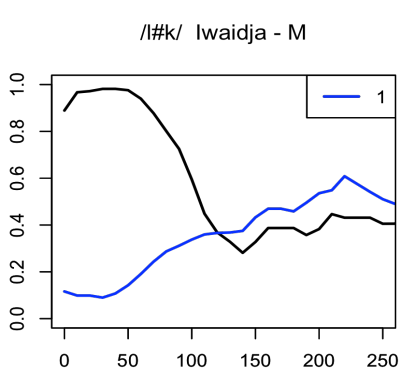
- Clear evidence of coproduction – temporal overlap
- Manner of articulation differences in articulatory timing, but highly variable

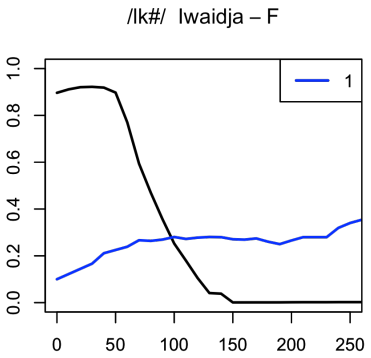
Articulatory timing relations?

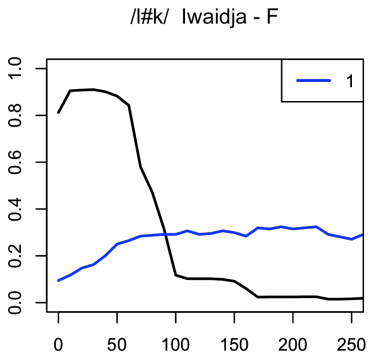
- Different temporal coordination patterns in onsets vs. codas in a range of languages e.g. English (e.g. Byrd 1995; Marin and Pouplier 2010), German (Hermes et. al 2008), Arabic (Shaw et al. 2009)
- Different articulatory timing of $VC_{1\#}C_2V$, $VC_{1\#}$ and $VC_1C_{2\#}$ in Iwaidja

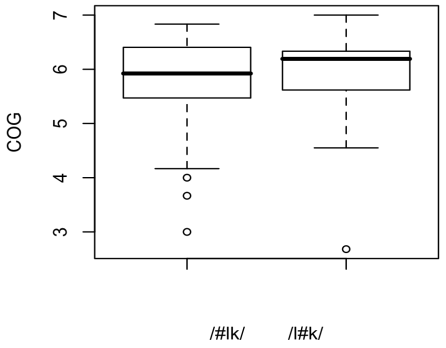
IWAIDJA - /l/ Coda timing?

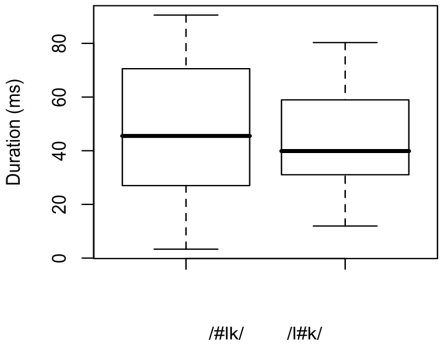


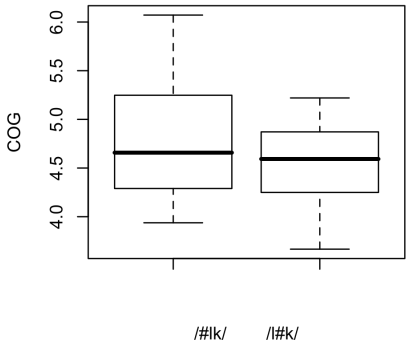


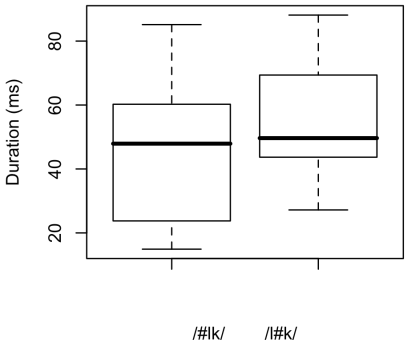




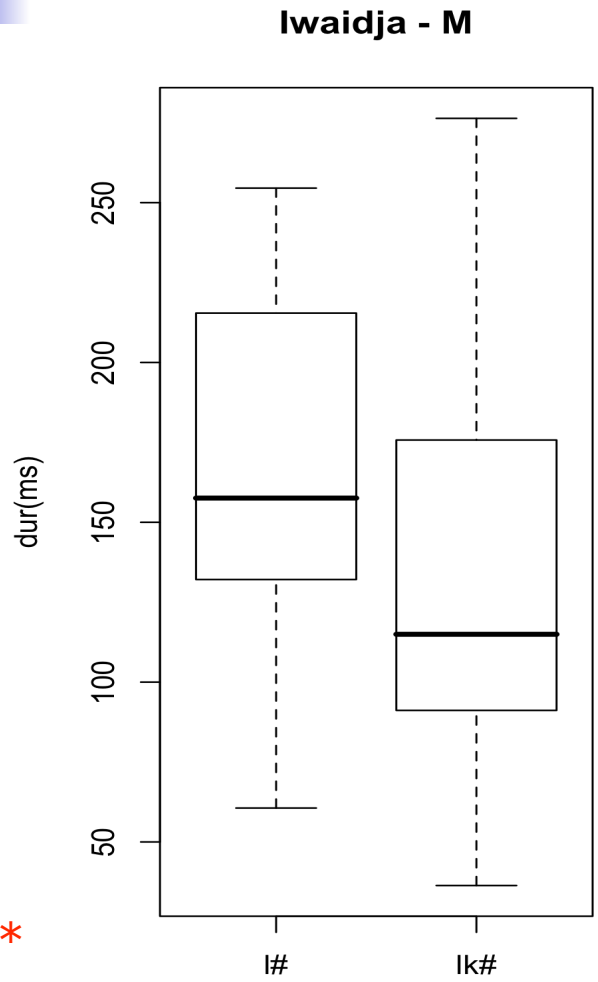








Iwaidja – vowel duration



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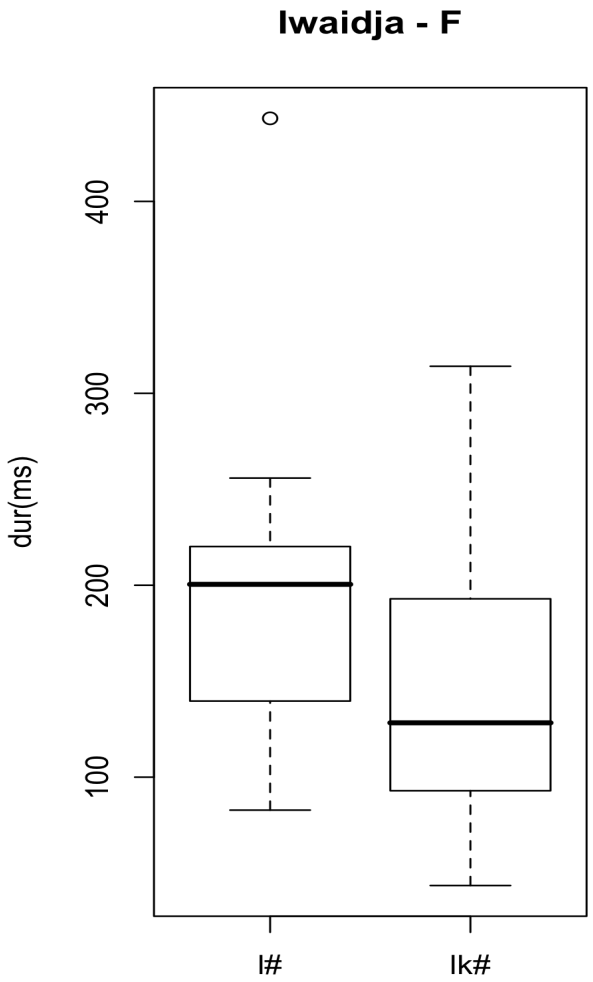

ns

Summary

- 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?