Towards a Gestural Characterization of Liquids:

Evidence from Spanish and Russian

Michael Proctor

Thursday 08-Jul-10

LabPhon 12

University of New Mexico

Phonetically Diverse Segments, Similar Behaviors

Slavic: Complex onsets, complex codas

Romance: Restricted onsets, prefer open syllable

RUSSIAN:	#CCCC-		SPANISH:	#CC-	
/fspl-/	*всплыть*	‘come to light’	/pɾ-/	*prado*	‘field’
/fsplʲ-/	*всплеске*	‘splash’	/pl-/	*placa*	‘sheet’
/fspɾ-/	*вспрыснуть*	‘to spray’	/bɾ-/	*brava*	‘fierce’
/vzbɾ-/	*взброс*	‘upthrust’	/bl-/	*blanca*	‘white’
/vzdɾ-/	*вздрогнуть*	‘to shudder’	/tɾ-/	*trampa*	‘trick’
/vzdɾʲ-/	*вздремнуть*	‘to snooze’	/dɾ-/	*drama*	‘drama’
/fstɾʲ-/	*встреча*	‘meeting’	/kɾ-/	*crasa*	‘crass’
/fskɾ-/	*вскрыть*	‘to open’	/kl-/	*clara*	‘egg white’
/fskɾʲ-/	*вскритнуть*	‘to cry out’	/gɾ-/	*gramo*	‘gram’
/vzglʲ-/	*взгляд*	‘glance’	/gl-/	*glasea*	‘he glazes’
/vzgɾʲ-/	*взгрустнуься*	‘to feel sad’	/fɾ-/	*franca*	‘sincere’
			/fl-/	*flaca*	‘skinny’

Segmental diversity: ɾ - ɾʲ - ɾ̪ - ɾ - ʀ - ʁ - ɬ - l - lʲ - l̪ - lˠ

Shared Phonological Behavior

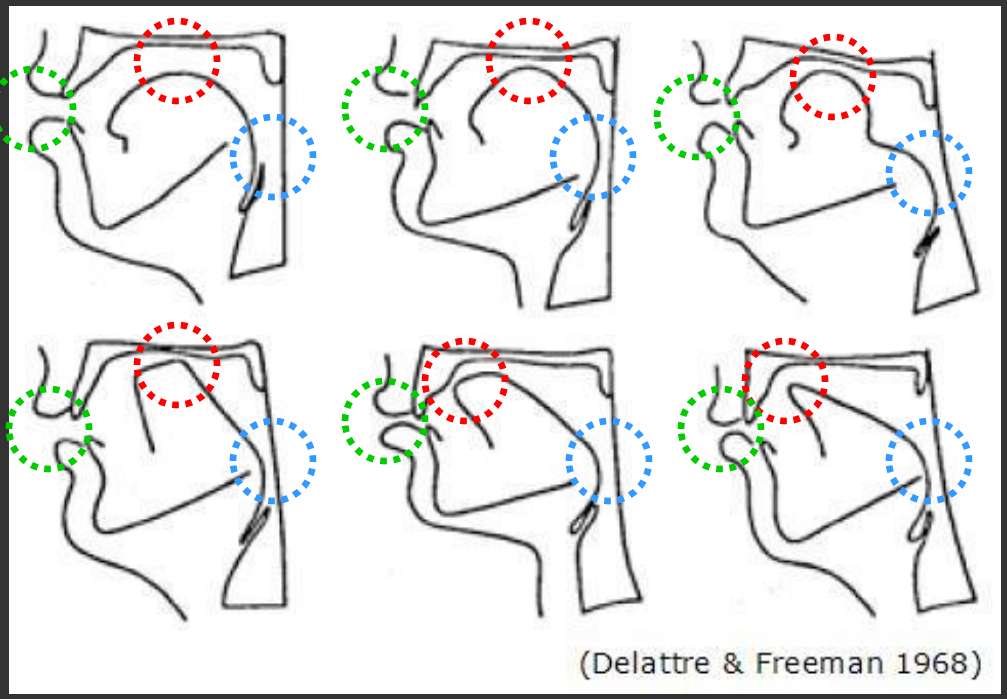
- Liquid consonants (Romance, Slavic, cross-linguistically):
  - facilitate clusters
  - show affinity for nucleus
  - vocalize
  - neutralize
  - metathesize (diachronically, synchronically)
  - are acquired late (L1, L2)

- Fundamental Question:
  - *why does such a diverse set of segments pattern together within and across phonologies*

Articulatory Characterization of Rhotics

Delattre & Freeman (1968):

- two broad /ɹ/ configs
  - bunched
  - retroflexed
- two essential constrictions
  - coronal
  - pharyngeal



Zawadzki & Kahn (1980):

- /ɹ/ coronal-pharyngeal
- assymetrical in syllable
- similar allophony to /l/

Gick, Iskarous, Whalen & Goldstein (2003):

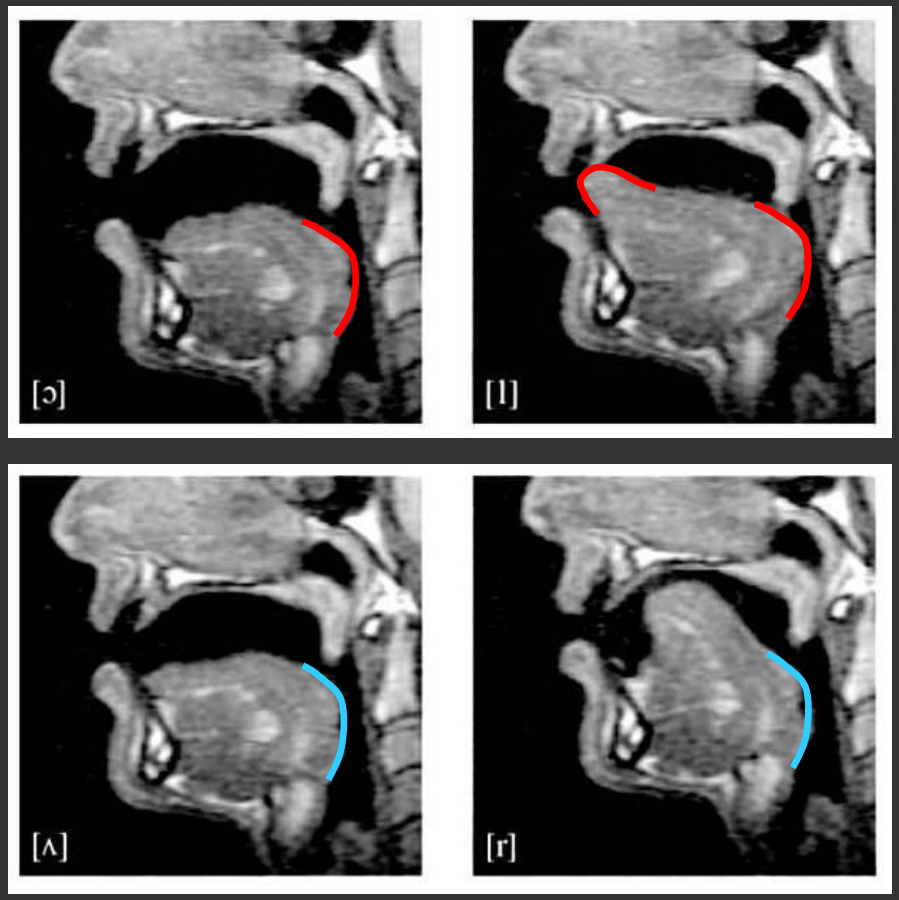
- AmE /ɹ/ produced with labial, coronal & tongue-root gestures
- acoustic stability stems from articulatory stability
- freedom of degree of constriction > freedom of place of constriction

Articulatory Characterization of Laterals

Giles & Moll (1975):
- same dorsum for all /l/s
- dorsal contours ~ vowels

Hardcastle & Barry (1980):
- /l/ = coronal + dorsal
- dorsal component vocalic

Sproat & Fujimura (1993):
- consonantal apical gesture
- vocalic dorsal gesture
- inherently asynchronous
- dark/light allophony follows



Gick, Kang & Whalen (2003):
- single post-oral gesture shared between /l/-/ɔ/, and between /ɹ/-/ʌ/
- consistent with accounts of intrusive liquids

Phonetic Characterization of Liquids

Evidence that liquids characterised articulatorily:

- {l} & {r} both consist of coronal + dorsal gestures
- {l} & {r} both employ consonant-like + vowel-like components
- {l} & {r} both assymetrical w.r.t. syllable: vocalic gesture closer to nucleus

Typologically-inadequate data:

- bulk of studies American English
- 18% of languages ≥ 2 rhotics, 31% ≥ 2 laterals (Maddieson 1984)
- majority of 2-liquid systems unlike English (/ɹ/ 7%, /r/ 41%)

Phonetically-inadequate data:

- largely acoustic
- static, not dynamic (Fant 1960, Straka 1963, Jones 1969)
- isolated contexts

Experimental Investigation of Liquid Production

- Goals:
  - examine liquid production in *wider variety of languages*
  - languages contrasting *multiple rhotics, laterals*
  - characterize *articulatorily, dynamically*

- Hypothesis:
  - *liquid production involves more global tongue shaping than obstruents* (Goldstein 1989)

- phonetic characterization of liquids
- articulatory characterization of Spanish liquids
- articulatory characterization of Russian liquids

Spanish Liquids

- /r/-/ɾ/:

  coro [ˈkoro] ‘choir’

  corro [ˈkoro] ‘circle’

- /l/: always clear [l]

  no dark allophony *[ɬ]

  dorsal gesture?

	LAB	LD	DEN	ALV	PA	PAL	VEL	
Stop	p		t̪				k	
	b		d̪				g	
Nasal	m		n̪			ɲ		
Affricate					tʃ			
Fricative		f		s̪			x	
Rhotic				r				
				ɾ				
Lateral			l̪					
Vowel						i		u
						e		o
							a	

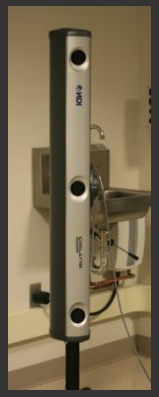
(Hualde 2005)

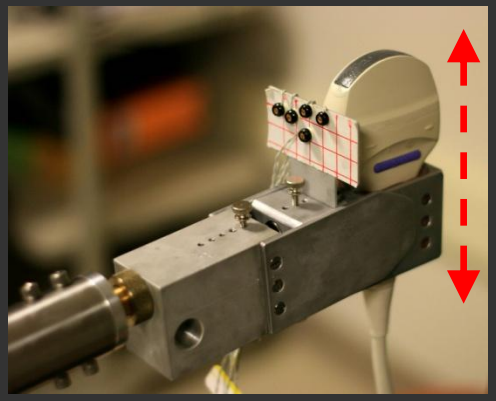
Experimental Investigation of Liquid Production

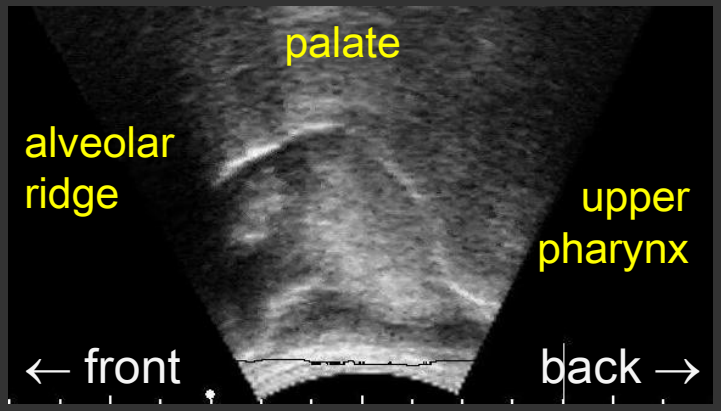
- Methodology
  - elicit each liquid in variety of phonological contexts
  - compare articulation with coronal obstruents in same contexts
  - seek patterns of articulatory activity which characterise production
  - *gesture*: Browman & Goldstein (1995)

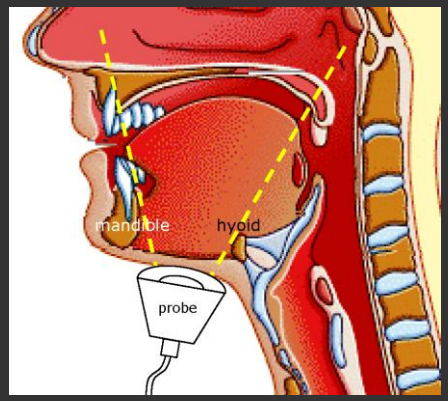
Method – Ultrasound

- **HOCUS:** Haskins Optically-Corrected Ultrasound System (Whalen et al. 2004)
  - ultrasound: 127 fps midsagittal lingual articulation
  - audio: 22 kHz synchronized acoustic recording
  - OptoTrak: 127 fps 3D location of anatomical markers









Method – Corpora

Symmetrical Intervocalic Environments:

front	low	back
[e _ e]	[a _ a]	[u _ u]

Stimuli:

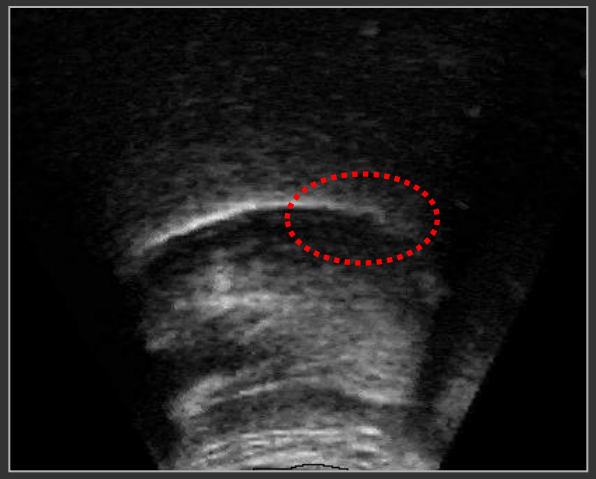
ele	*pala*	*pulula*
erre	*parra*	*acurruca*
ere	*para*	*gurú*
hede	*pada*	*vudú*

Method – Subjects

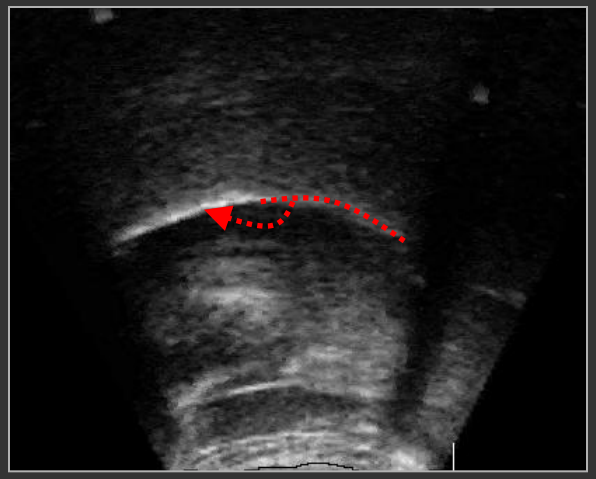
	Born	Age	Variety	Years in US
M1	Managua	25	Nicaraguan	15
W1	Guaynabo	21	Puerto Rican	3.5
W2	Quito	20	Ecuadoran	19
W3	Miami	20	Cuban	20
W4	S. Domingo	19	Dominican	15

Spanish Consonants – Intervocalic [a_a]

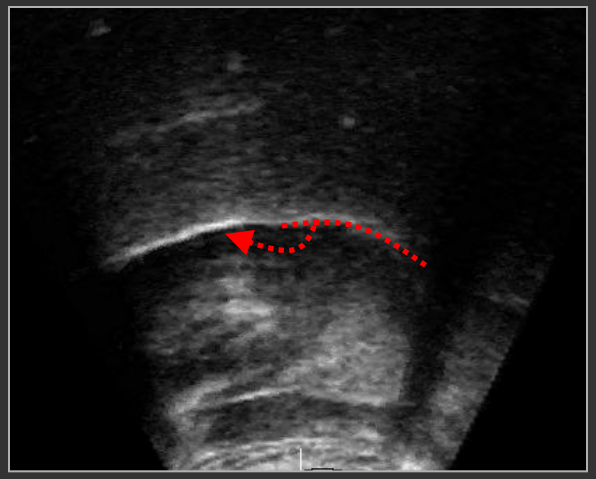
Stop: [aða] (W1)



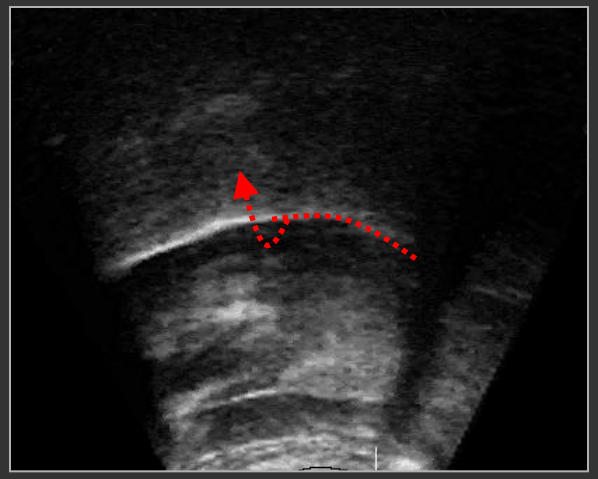
Lateral: [ala] (W1)



Tap: [aɾa] (W1)

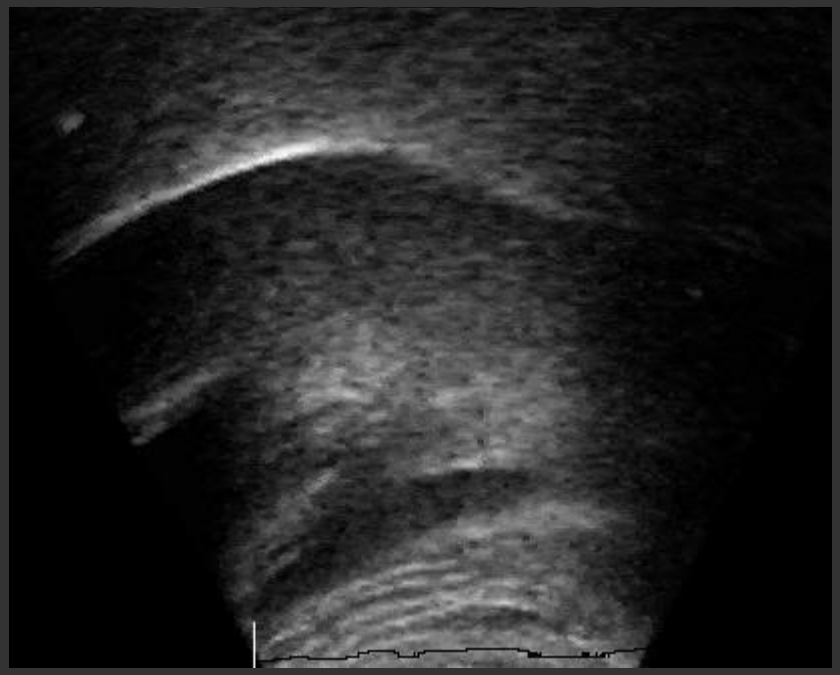


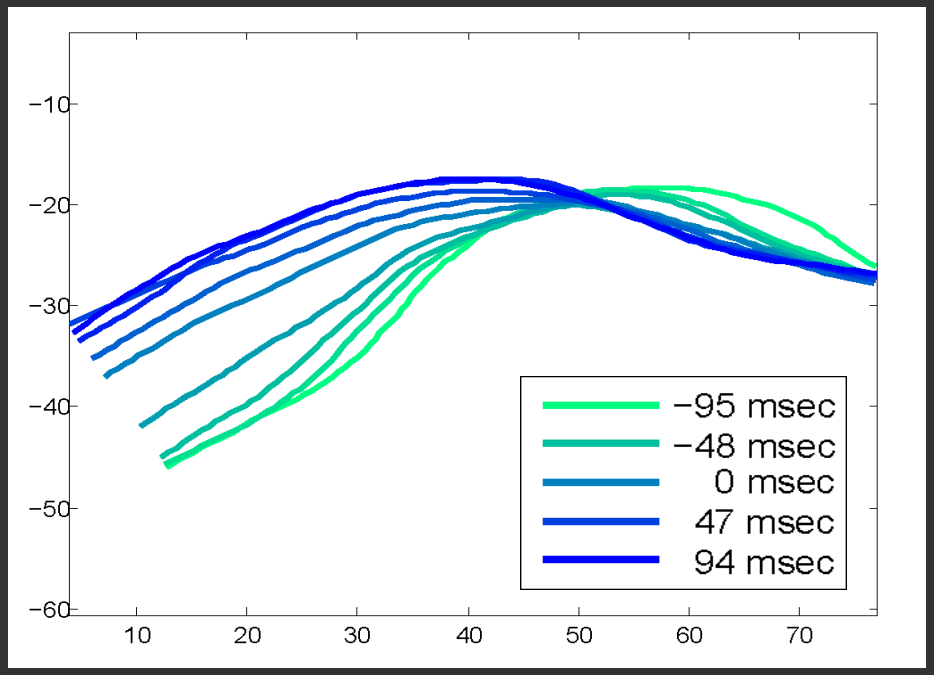
Trill: [ara] (W1)



Dynamic Comparison of Dorsal Articulation

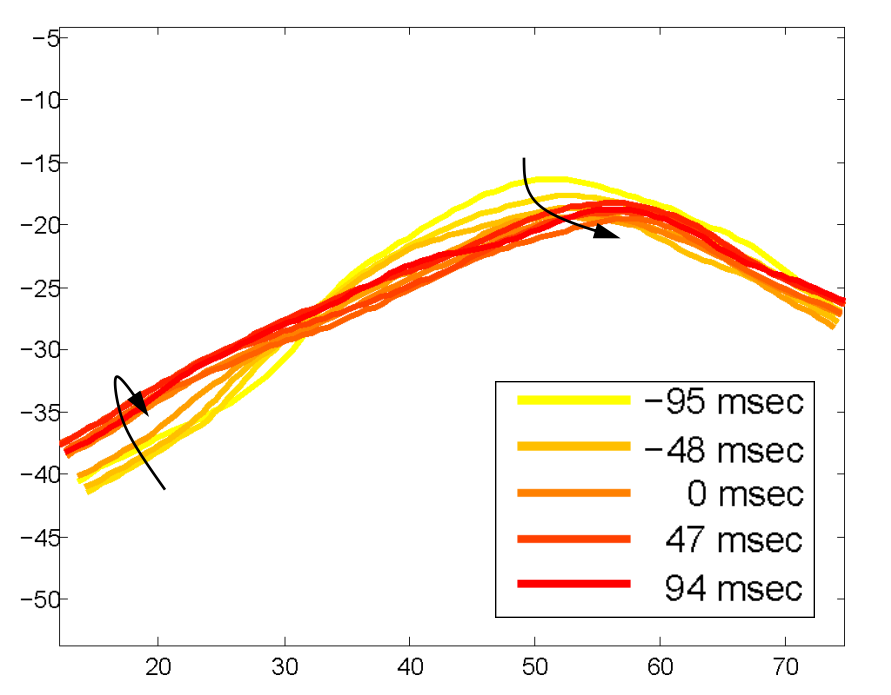
Liquid: [ara] (Subject M1)





Dynamic Comparison of Dorsal Articulation

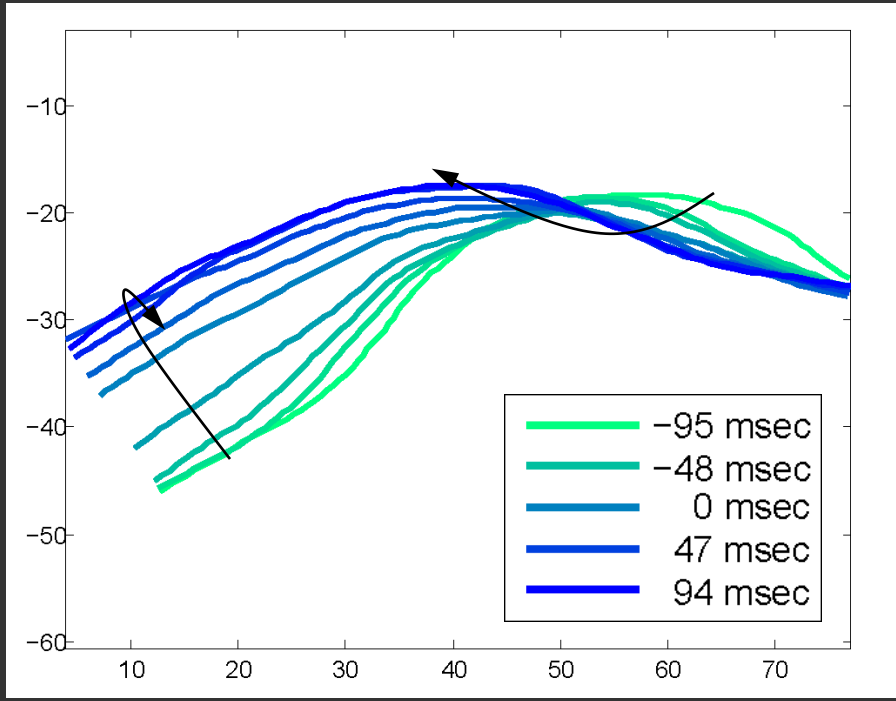
Obstruent: [aða] (Subject M1)



- little dorsal movement evident
- movement towards vocalic target

⇒ **dorsum controlled by vowel**

Liquid: [ara] (Subject M1)

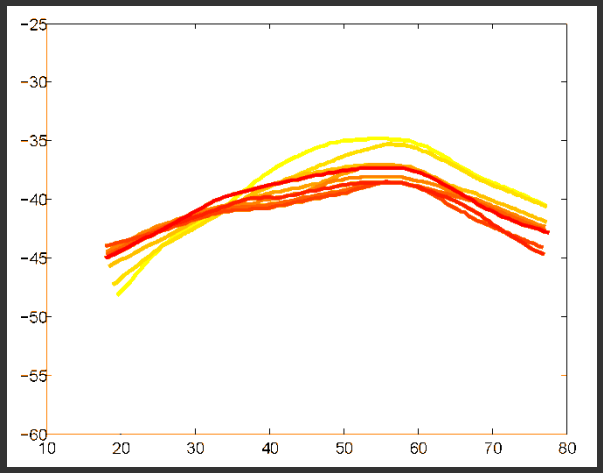


- greater lingual motion
- movement away from vocalic target

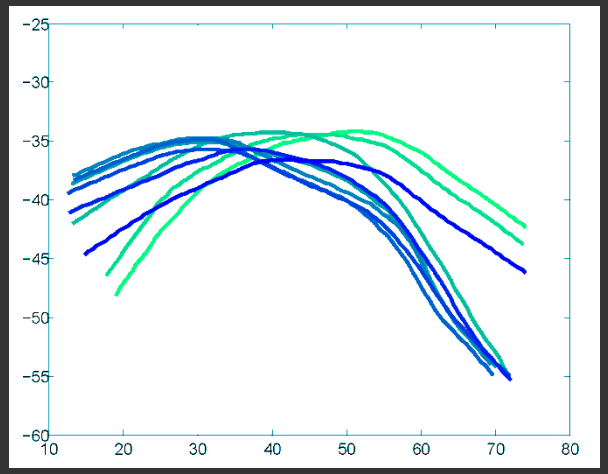
⇒ **dorsum controlled by liquid**

Dynamic Comparison of Dorsal Articulation: [a_a]

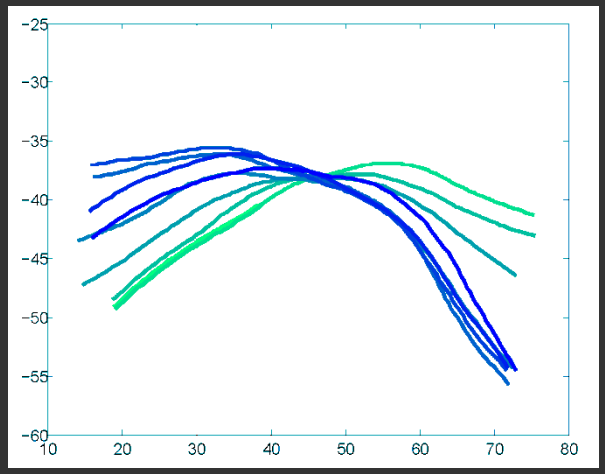
Stop: [aða] (W1)



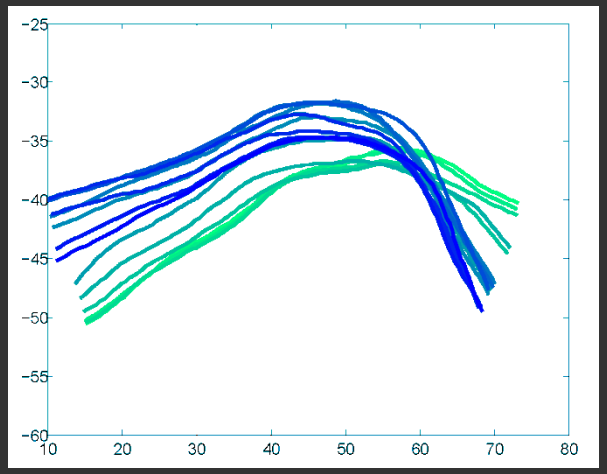
Lateral: [ala] (W1)



Tap: [ara] (W1)

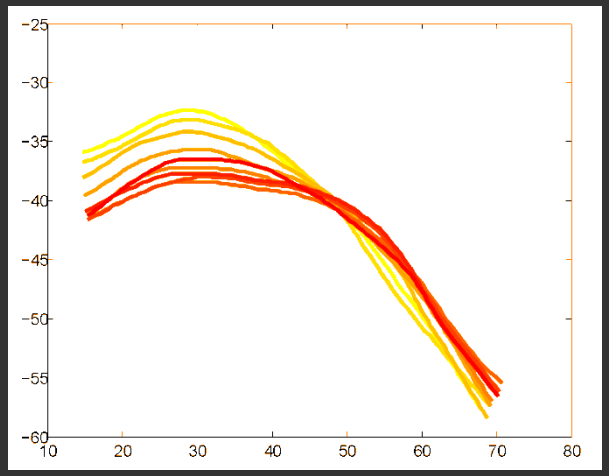


Trill: [ara] (W1)

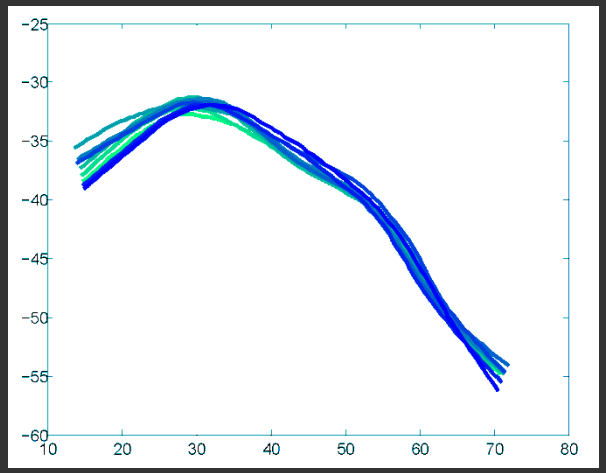


Dynamic Comparison of Dorsal Articulation: [e_e]

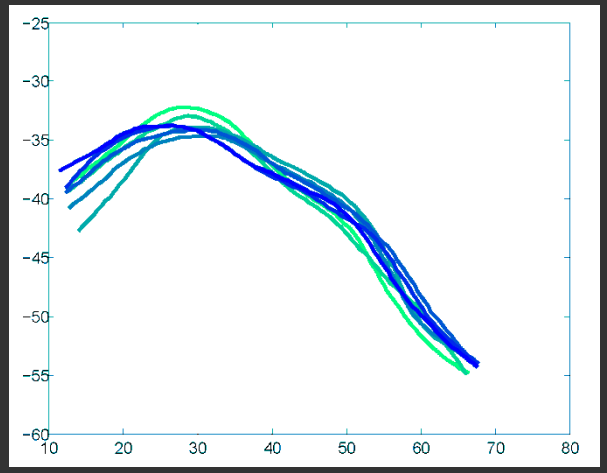
Stop: [eðe] (W1)



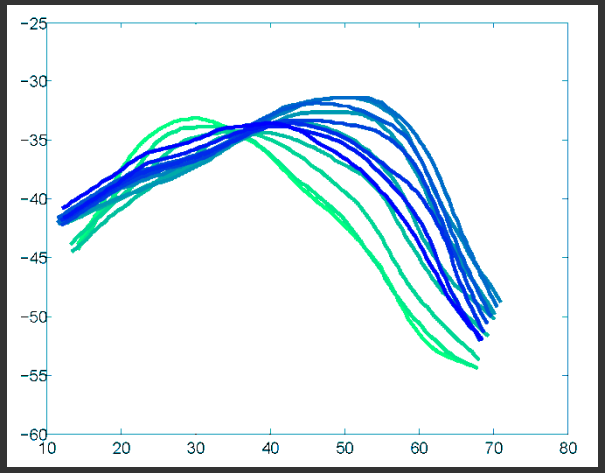
Lateral: [ele] (W1)



Tap: [ere] (W1)



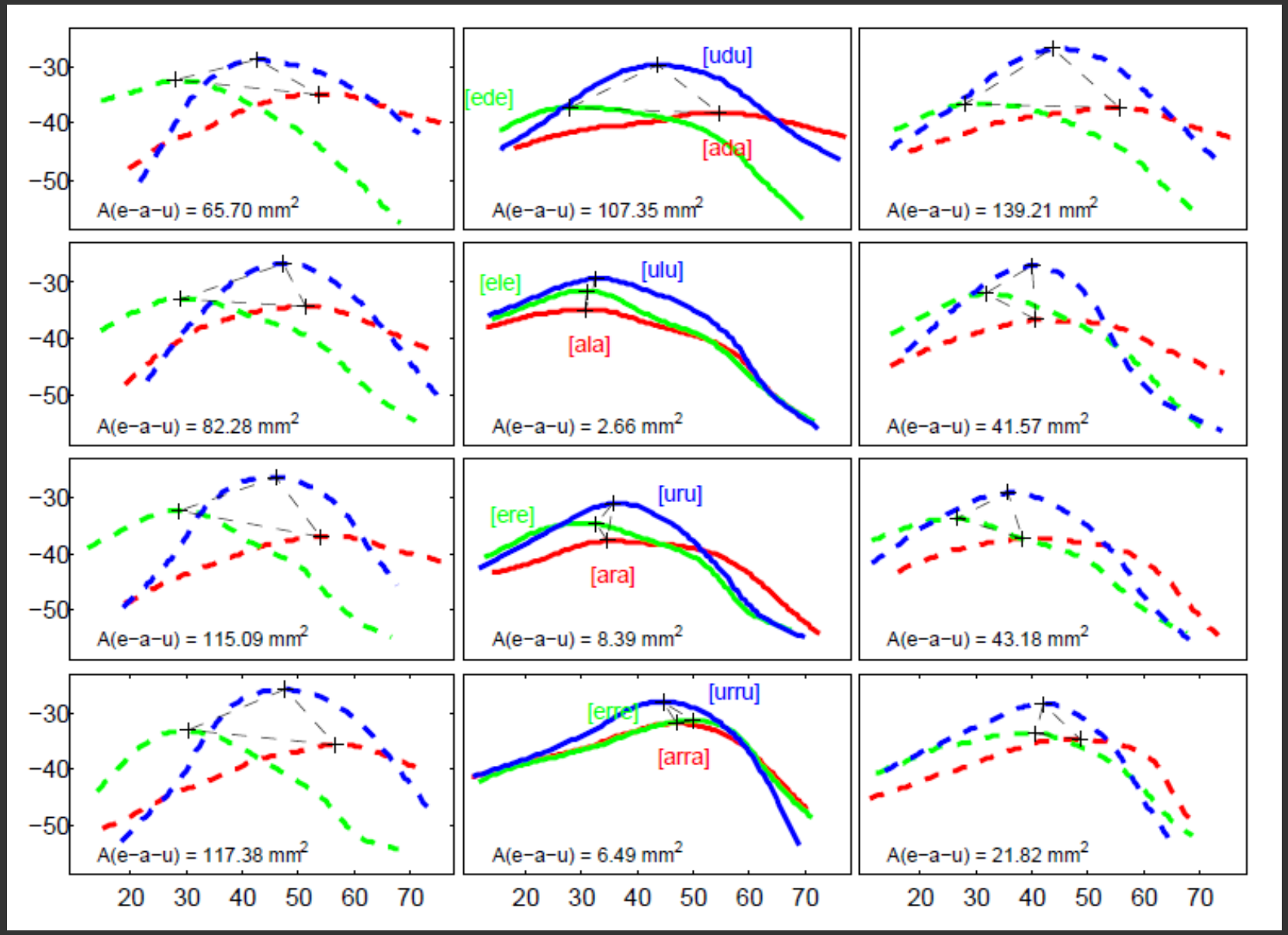
Trill: [ere] (W1)



Articulation of Spanish Liquids

- Recasens & Farnetani (1990): Dark [ɫ] more resistant to vowel coarticulation at the dorsum than clear [l].
  - English [ɫ], Russian [lˠ]: coronal+dorsal gesture
  - German, Italian, Spanish [l]: no dorsal gesture
- Recasens (2004):
  - "production of clear [l] … involves activation of the tongue-tip only."
  - Darkness in [l-ɫ] is a scalar phenomenon: Catalan varieties
- Dynamic lingual trajectories from ultrasound data suggest that Spanish clear [l] also involve dorsal gestural component
- How to characterize this target?

Comparison of Degree of Coarticulation: W1



Quantification of Degree of Coarticulation

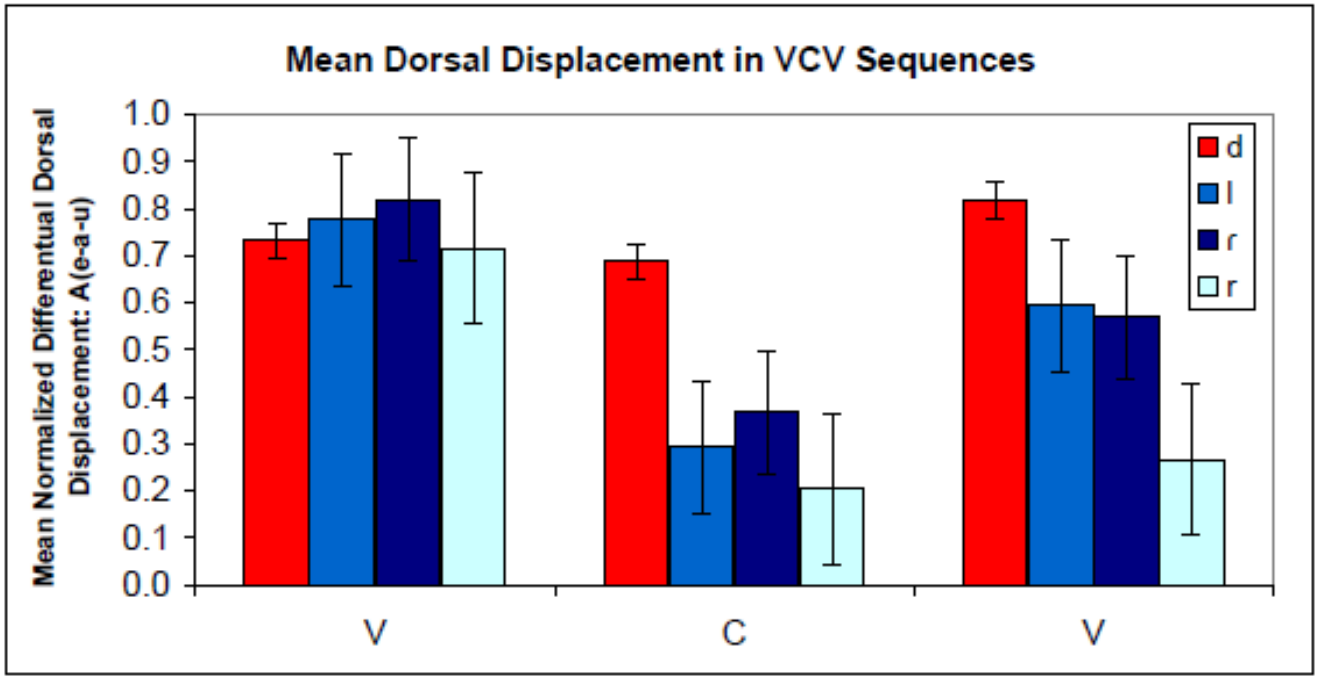


FIGURE 4.31: **Mean normalized differential dorsal displacement** for Spanish coronal consonants – all subjects.

TEST	V1-STOP = V1-LIQ	C-STOP = C-LIQ	V2-STOP = V2-LIQ
ANOVA	0 (p=0.5929)	1 (p = 0.0022)	1 (p = 0.0073)
Rank Sum	0 (p=0.3827)	1 (p = 0.0068)	1 (p = 0.0291)

Quantification of Dorsal Constriction Location

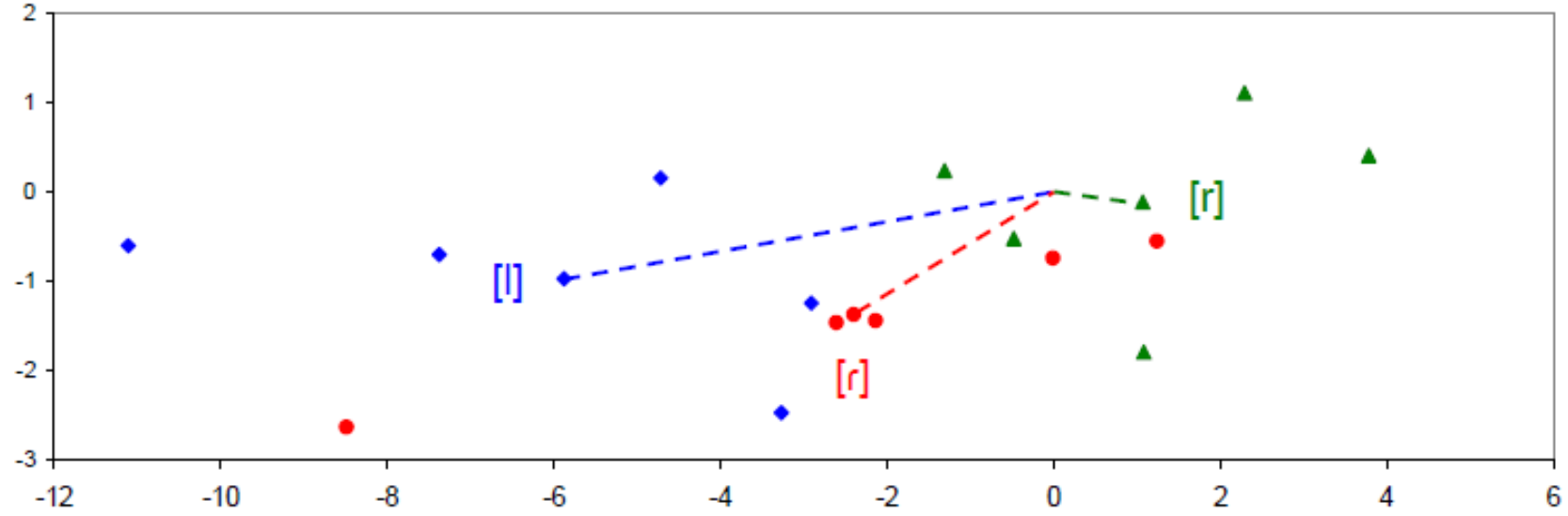
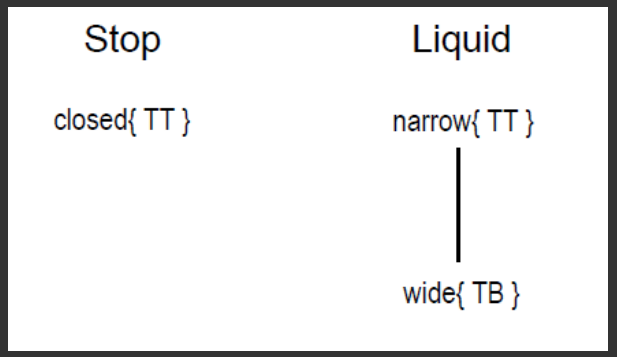


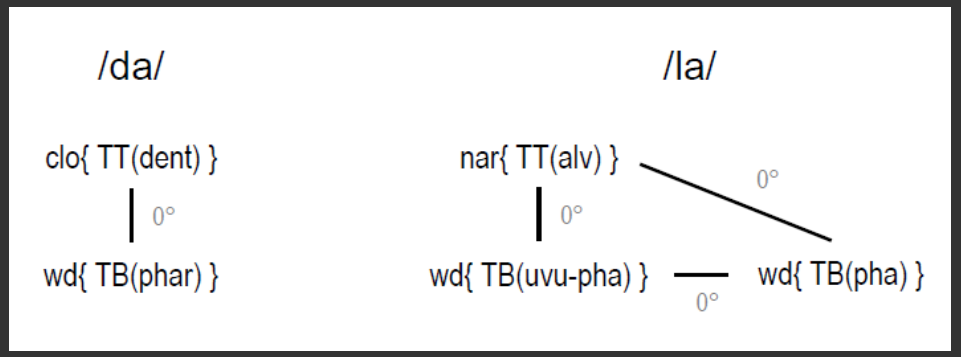
FIGURE 4.33: **Mean locations of Spanish liquid dorsal targets with respect to 'schwa'.** Blue: intervocalic laterals; Red: intervocalic taps; Green: intervocalic trills. Dashed lines indicate mean dorsal displacement from pre-consonantal vocalic center.

Summary – Phonetic Characterization of Spanish Liquids

- Spanish liquids /l/-/ɾ/-/r/ exhibit greater resistance to vocalic coarticulation than obstruent /d/
- Spanish lateral & tap: dorsal advancement before back vowels, stability between mid-front vowels: gestural target ~ [e̞], [ə]
- Spanish trill: dorsal retraction before front vowels, pharyngeal raising: gestural target ~ [o̞]

Articulatory Modeling of Spanish Liquids





TV	/d/	/l/	/r/	/r/
TTCL	dental	dental	alveolar	alveolar
TTCD	closed	narrow	narrow	narrow
TBCL	–	palatal	uvular	uvular-pharyngeal
TBCD	–	wide	wide	wide

TABLE 5.1: Tract variable specifications for Spanish voiced coronal consonants.

Gestural Analysis of Spanish Liquid Phenomena

Insights into:

- rhotic allophony
- vocalization
- cluster realization

Distribution of Spanish Rhotics

Rhotic	Environment	Example
Trill:	# _	['ro.ka]
	C [$_\sigma$ _	['en.re.do]
Tap:	[$_\sigma$C _ V	['gra.mo]
	V _ #V	['se.ra.mi.gos]
Contrastive:	V _ V	['ka.ro] / ['ka.ro]
Variable:	V _]$_\sigma$C	['par.te] ~ ['par.te]
	V _ #C	['ser.po.'e.ta] ~ ['ser.po.'e.ta]
	V _ ##	['ser o 'no 'ser] ~ ['ser o 'no 'ser]

- allophones of single rhotic phoneme (Harris 1969; Mascaró 1976; Wheeler 1979)
- trill: surface realization of a geminate tap:
  /rr/ → [r] (Bonet & Mascaró 1997,Lloret 1997)

Realization of Spanish Rhotics

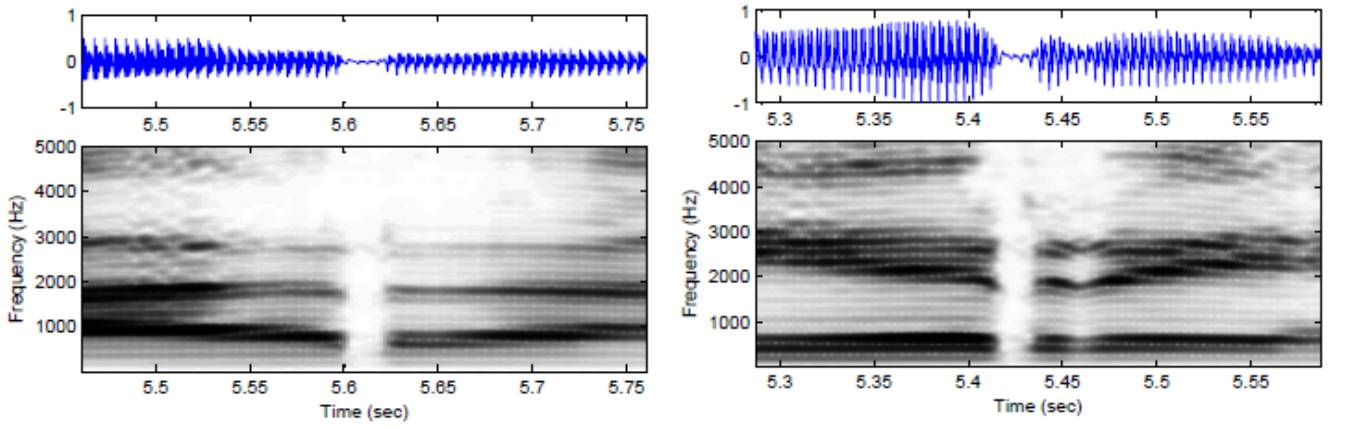


FIGURE 4.9: Spanish intervocalic trill production: **variation in number of closure intervals** – subject W2. Left: single closure ([ara]); right: double closure ([ere]).

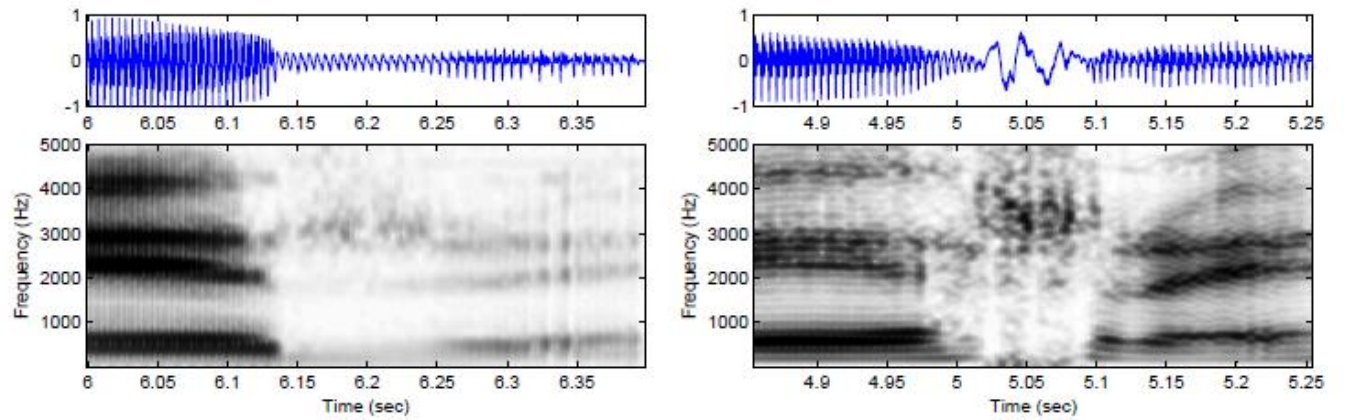


FIGURE 4.10: **Spirantization in Spanish trills** in a mid-front intervocalic context: [ere]. Left: subject W3; right: W4.

Spanish Rhotic Neutralization

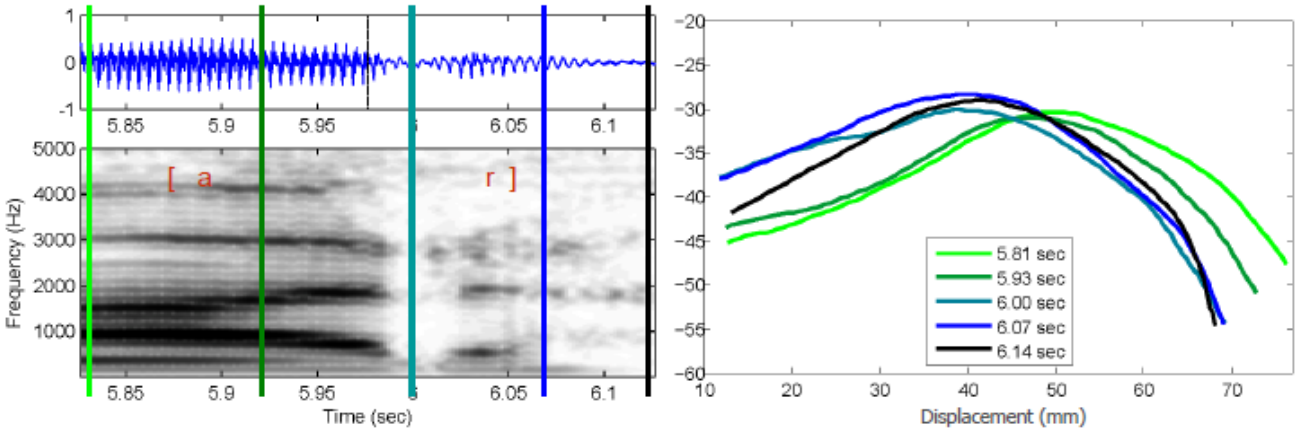


FIGURE 4.37: **Dorsal articulation in tapped word-final rhotic**: [ar˞], subject W3. Left: waveform and spectrum; Right: midsagittal articulation at five points in time.

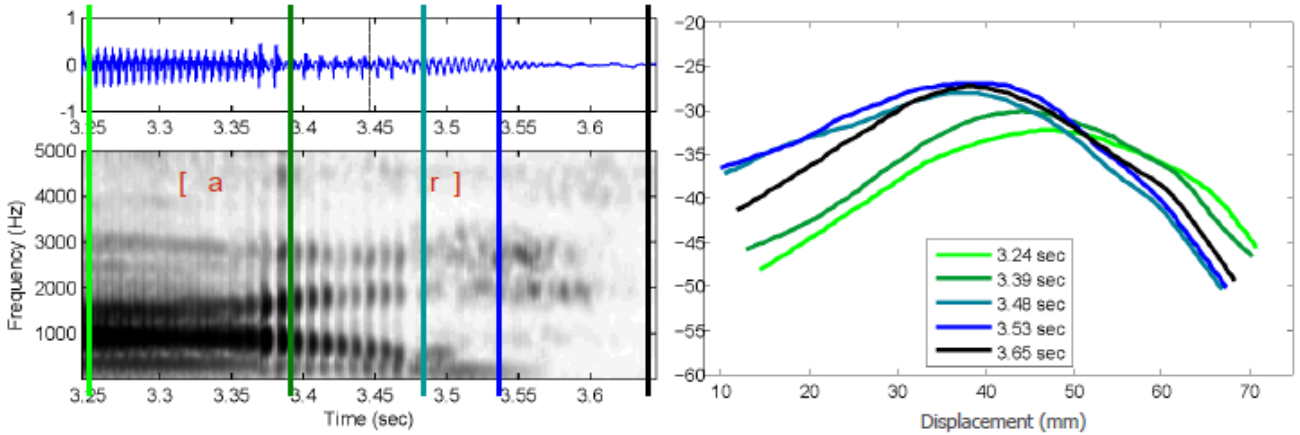
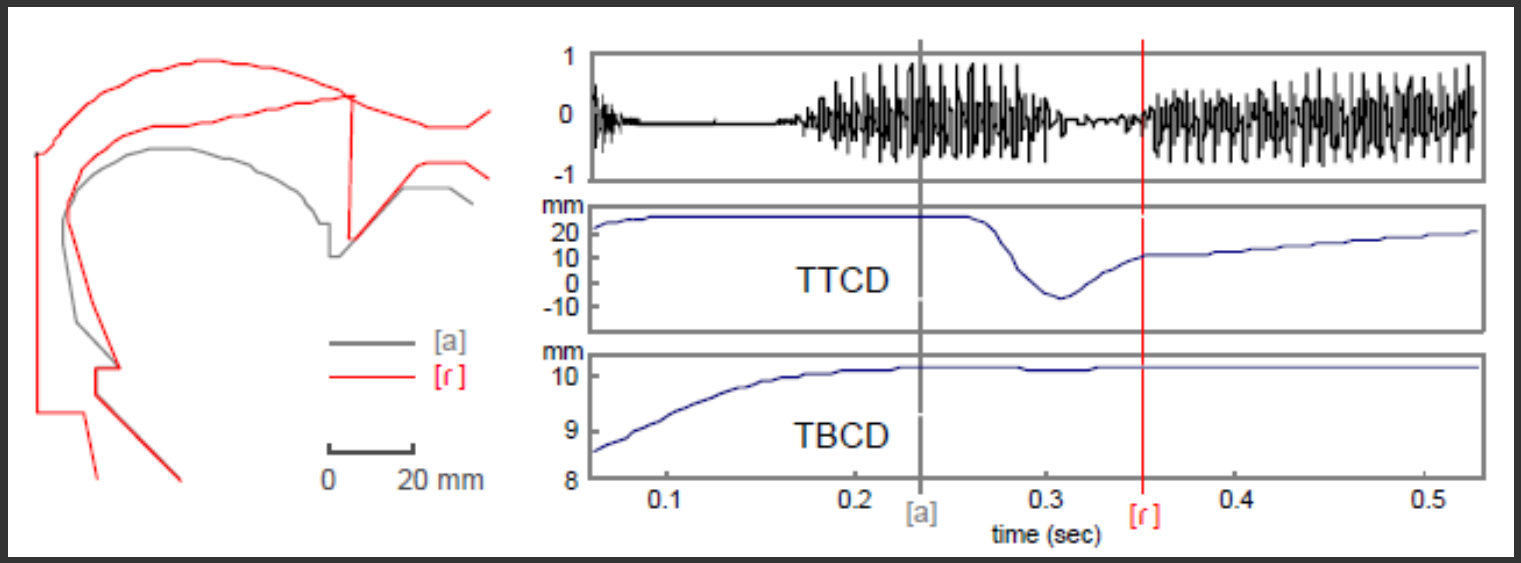
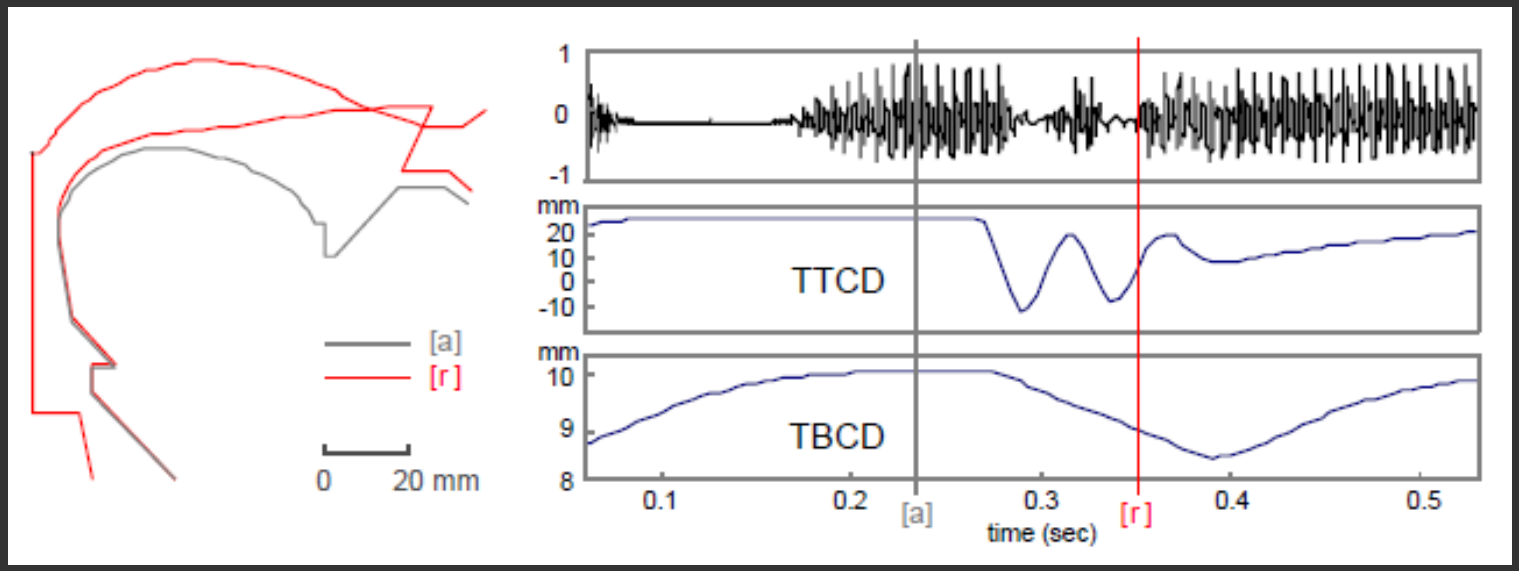


FIGURE 4.38: **Dorsal articulation in spirantized word-final rhotic**: [ar˞], subject W3. Left: waveform and spectrum; Right: midsagittal articulation at five points in time.

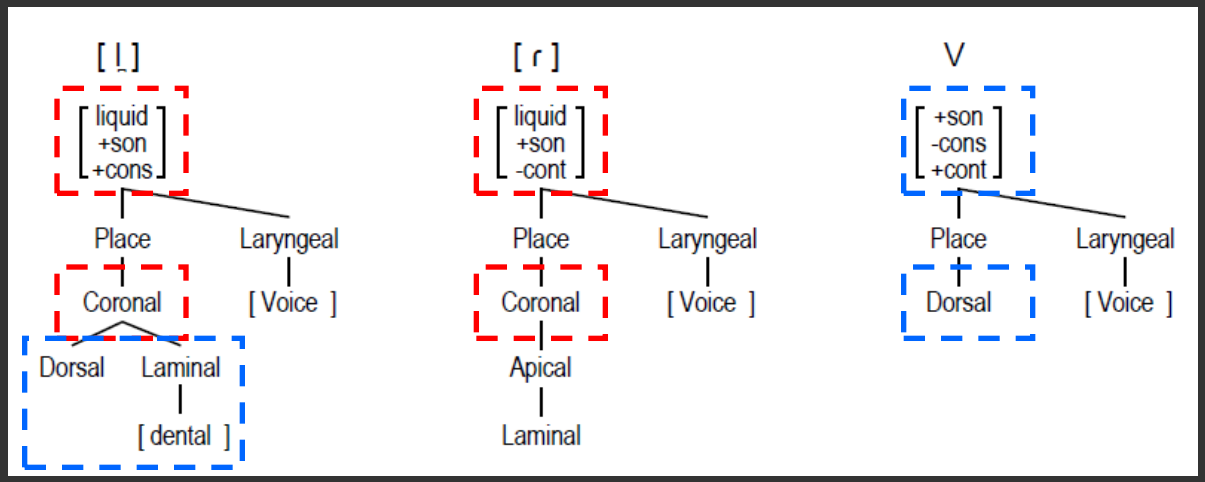
Articulatory Modeling of Spanish Rhotics

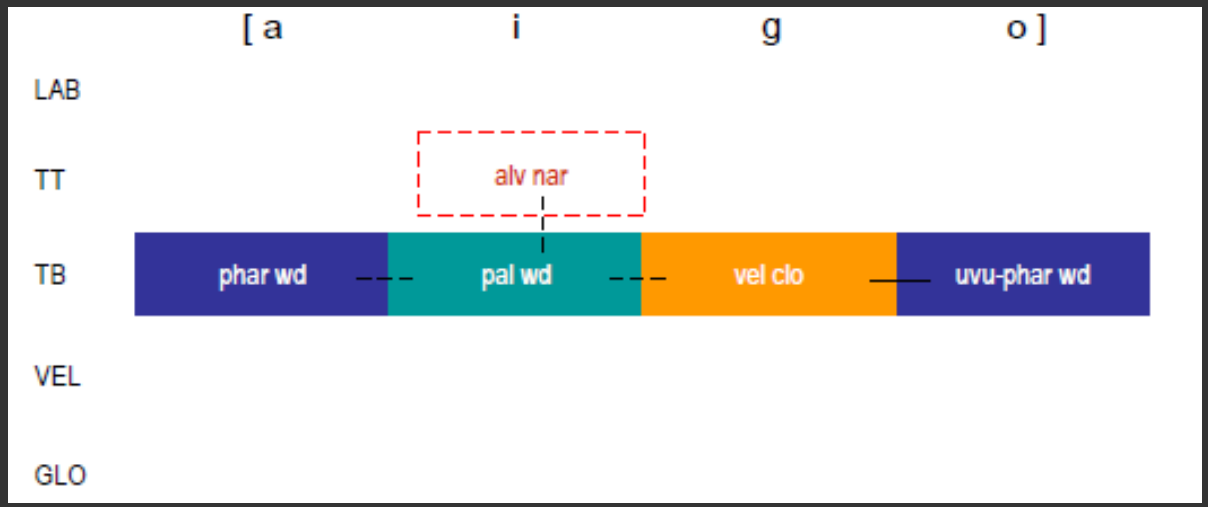




Spanish Liquid Vocalization

- Dominican Republic: vocalization (Alba 1979)
  - /ɾ/, /l/ → [j] *algo* ['ai̯.ɣo] 'something', *mujer* [mu.'hei̯] 'woman'.

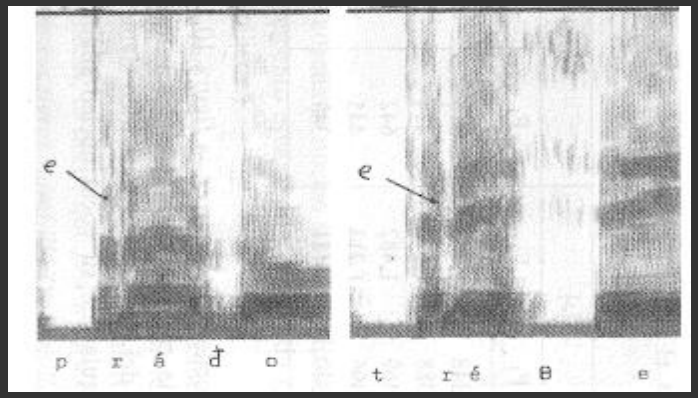




Spanish Cluster Svarabhakti

Navarro Tomás (1918):

árboles	[arᵊ.βo.les]	*'trees'*
verdes	[verᵊ.ð̬es]	*'green'*
cargar	[karᵊ.ɣar]	*'to load'*
fuerzes	[fu̯erᵊ.ses]	*'force'*



Spanish Cluster Svarabhakti

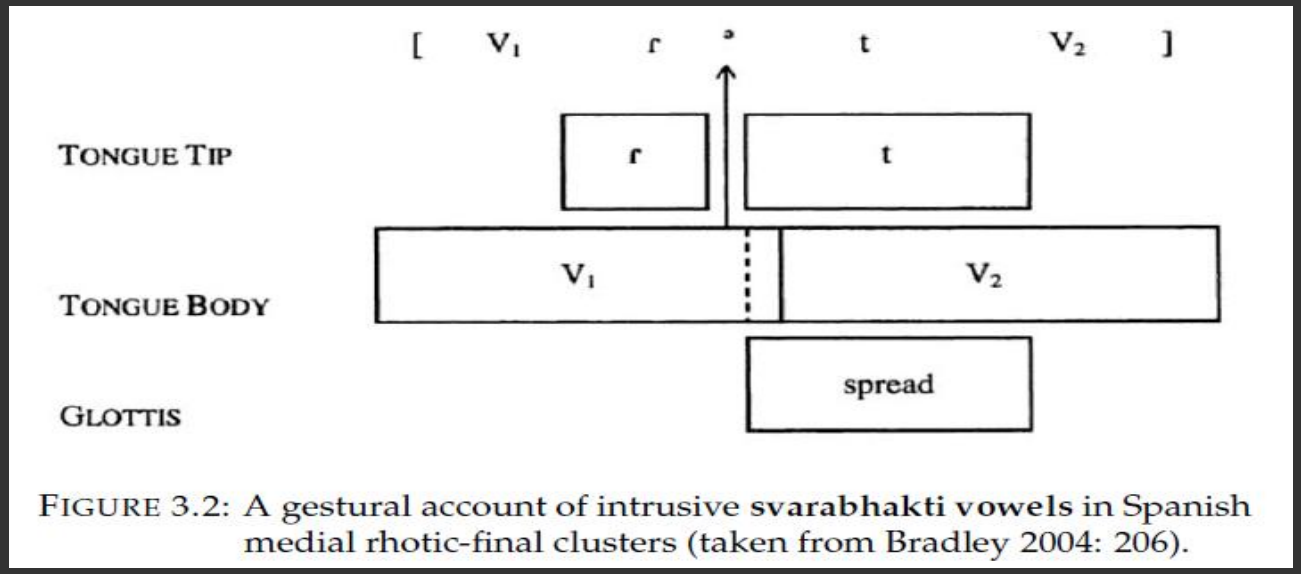
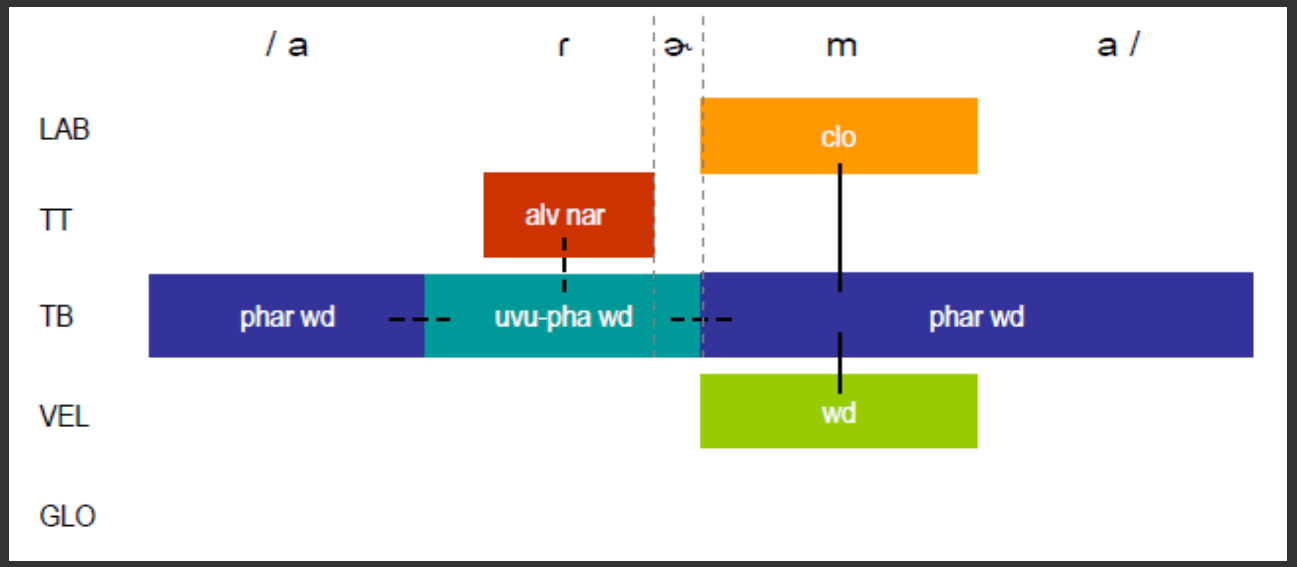


FIGURE 3.2: A gestural account of intrusive **svarabhakti vowels** in Spanish medial rhotic-final clusters (taken from Bradley 2004: 206).



- phonetic characterization of liquids
- articulatory characterization of Spanish liquids
- articulatory characterization of Russian liquids

Ultrasound Study of Russian Liquid Production

- Russian consonants in mutable pairs: palatalized / non-palatalized

- Two pairs of liquids:
  /r/-/rʲ/, /l/-/lʲ/

  лук [luk] *'onion'*
  люк [lʲuk] *'hatch'*
  рад [rat] *'glad'*
  ряд [rʲat] *'row'*

  non-palatalized = [Cˠ]?

	LAB	LDEN	DEN	PA	PAL	VEL	
Stop	p, b pʲ,bʲ		t, d tʲ,dʲ			k, g kʲ	
Affricate			ts	tʃ			
Fricative		f, v fʲ,vʲ	s, z sʲ,zʲ	ʃ, ʒ		x	
Nasal	m mʲ		n nʲ				
Rhotic			r rʲ				
Lateral			l lʲ				
Approximant					j		
Vowel					i e	a	u o

(Timberlake 2004)

Method

- Intervocalic Environments:

front	low	back
[e _ e]	[a _ a]	[u _ u]

- Stimuli:

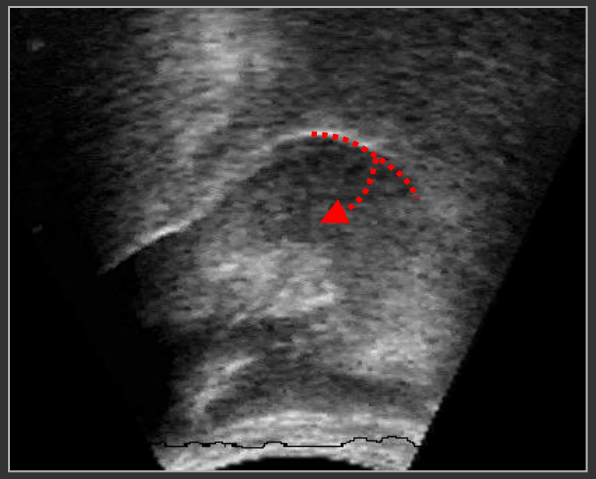
илы	элэ
или	эле
ала	улу
аля	улю

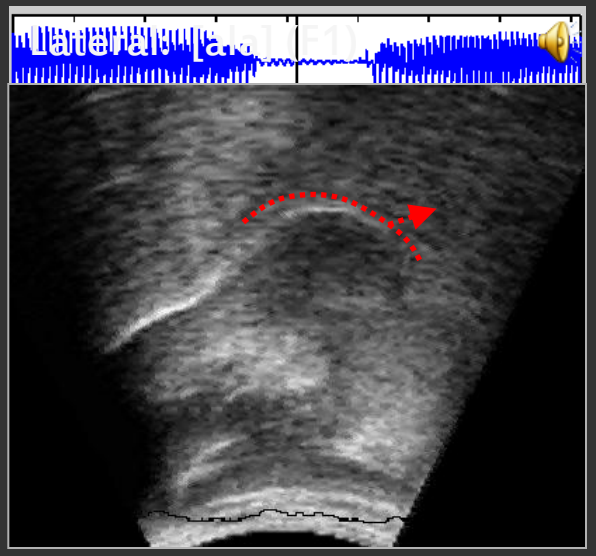
- Subjects:

Subject	Age	Hometown	Other Languages	Time in US
M1	24	Kadamjay, Kyrgyzstan	US English, Turkish	2 years
M2	25	Krasnodar	US English	2.5 years
F1	32	Kiev, Ukraine	Ukrainian, US English	7 years
F2	23	Bishkek, Kyrgyzstan	Kyrgyz, US English	6 months
F3	18	Zelenograd, Russia	US English	16 years

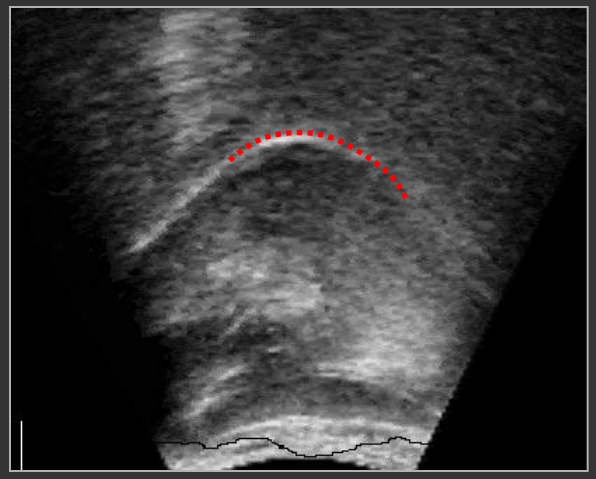
Russian Non-Palatalized Coronals: [a_a]

Stop: [ada] (F1)





Rhotic: [ara] (F1)



Russian Non-Palatalized Coronals: [u_u]

Stop: [udu] (F1)

Lateral: [ulu] (F1)

ɾhotic: [uru] (F1)

Dorsal Articulation in Russian Liquid Production

VrV:

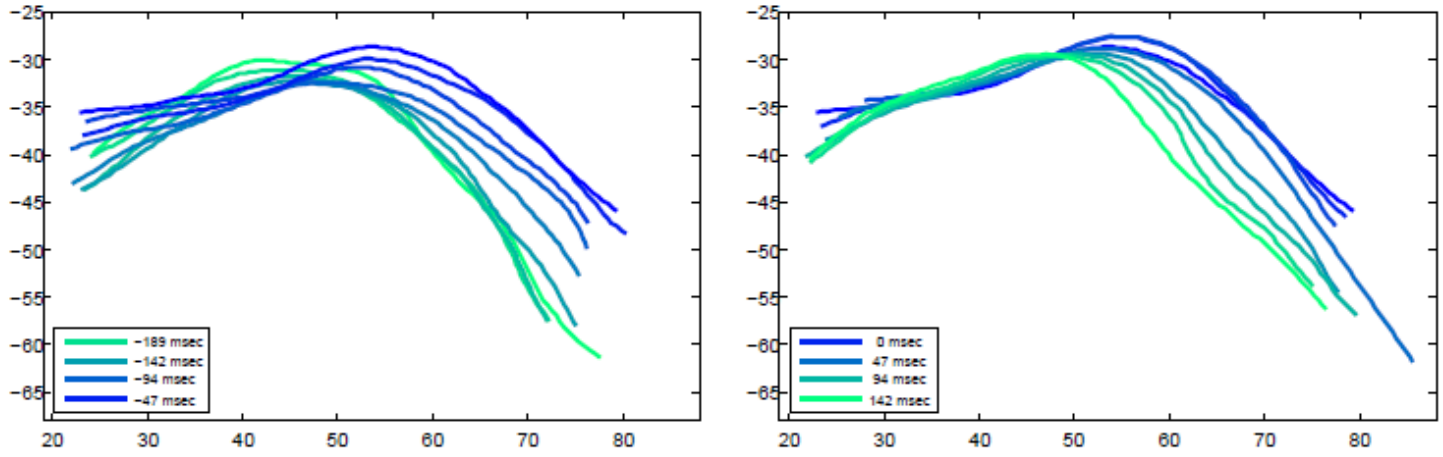


FIGURE 7.5: **Dynamic midsagittal lingual articulation of Russian non-palatalized trill: [ere]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

VlV:

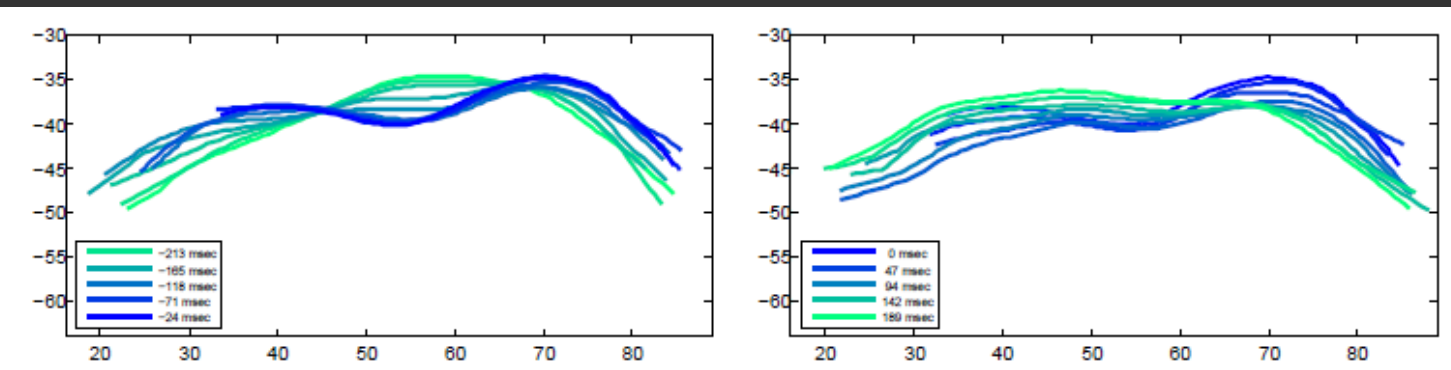
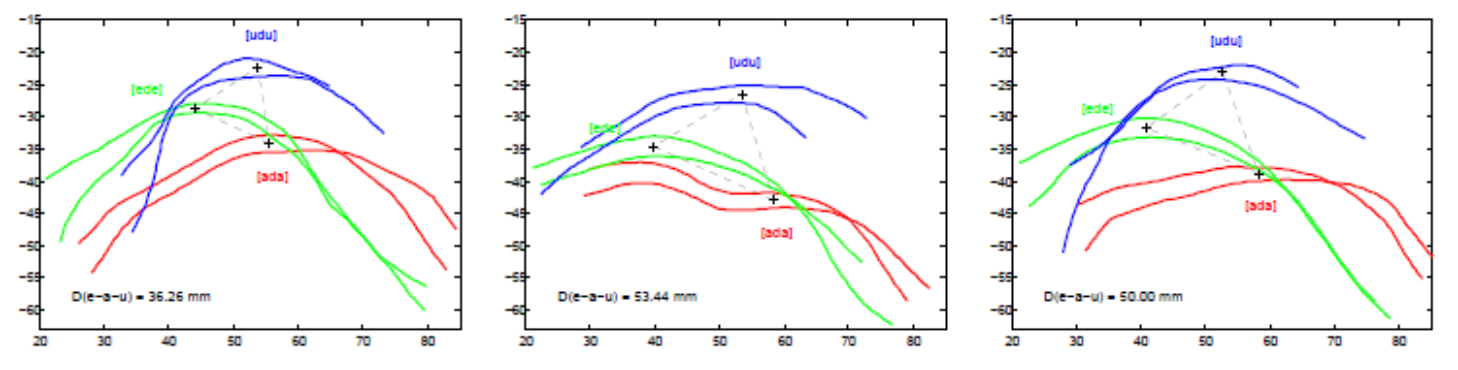


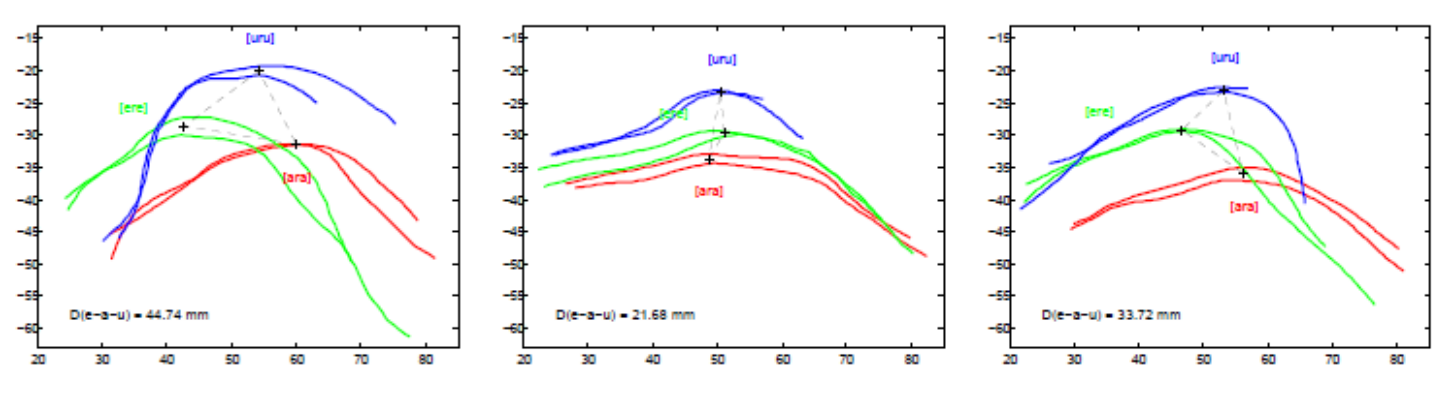
FIGURE 7.6: **Dynamic midsagittal lingual articulation of Russian non-palatalized lateral: [ala]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

Vocalic Coarticulation in Russian Coronals: W3

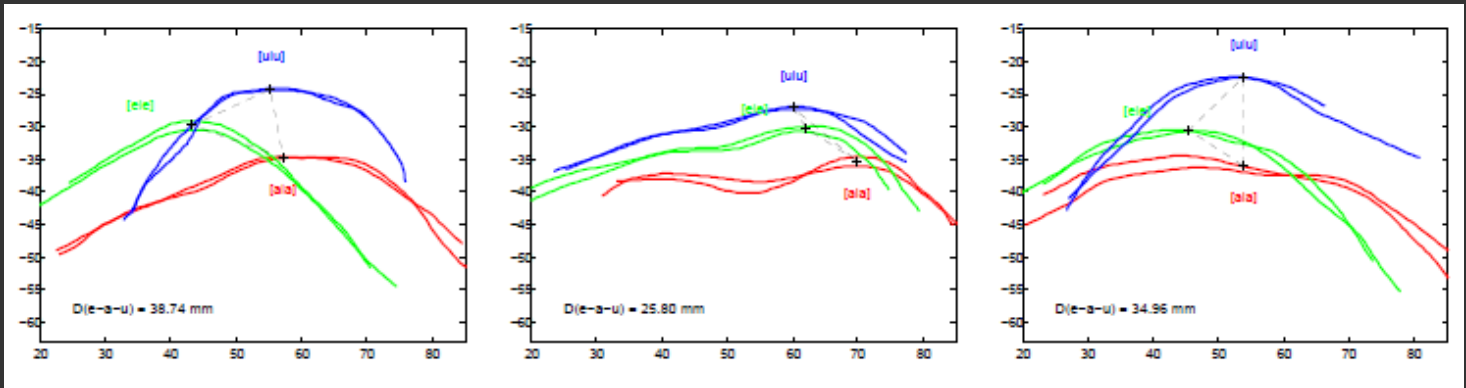
VdV:



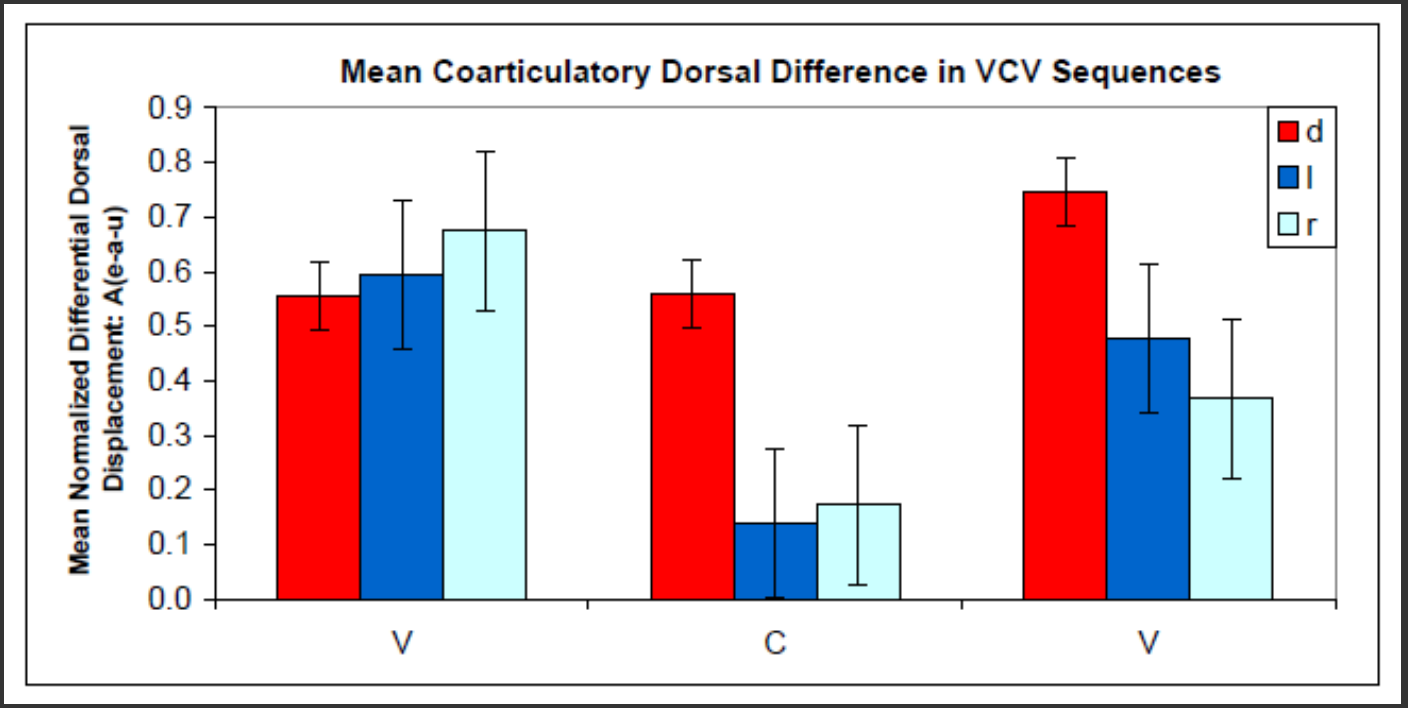
VrV:



VlV:



Quantification of Degree of Coarticulation



TEST	$V1_{stop} = V1_{liq}$	$C_{stop} = C_{liq}$	$V2_{stop} = V2_{liq}$
ANOVA	0 (p=0.2563)	1 (p = 0.0013)	1 (p = 0.0284)
Rank Sum	0 (p=0.2573)	1 (p = 0.0020)	1 (p = 0.0156)

Quantification of Dorsal Constriction Location

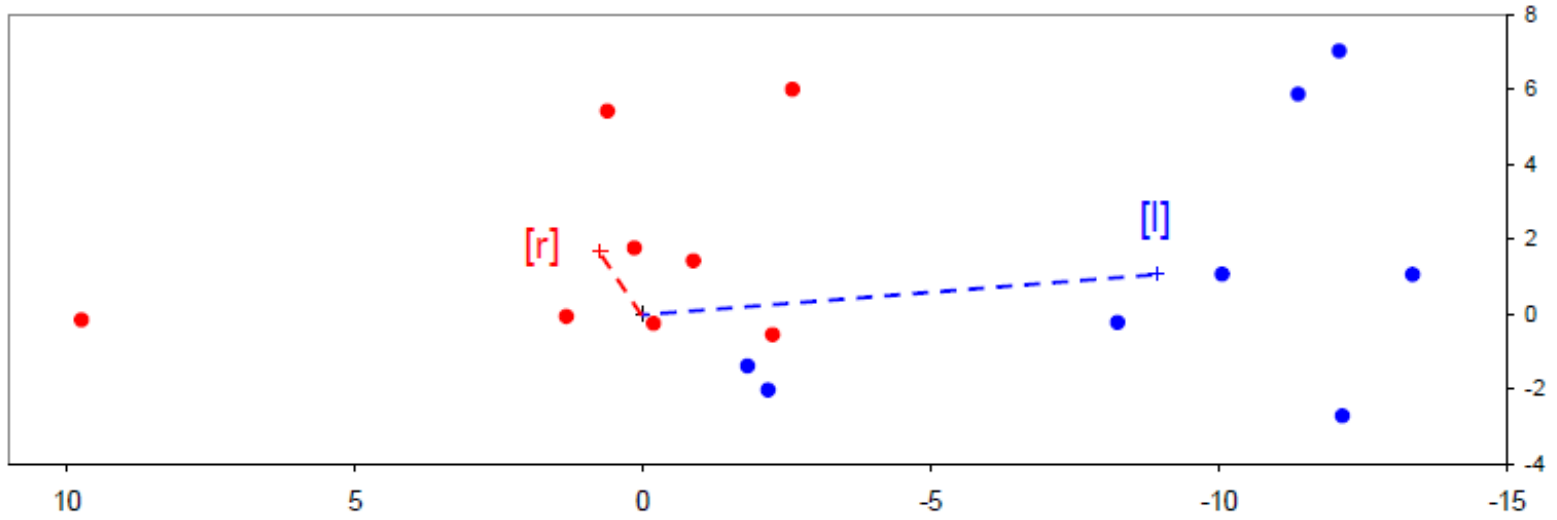


FIGURE 7.14: **Mean locations of Russian non-palatalized liquid dorsal targets with respect to 'schwa'.** Blue: intervocalic laterals; Red: intervocalic trills. Dashed lines indicate mean dorsal displacement from pre-consonantal vocalic center.

Summary – Russian Non-Palatalized Liquids

- Russian liquids [l]-[r] exhibit greater resistance to vocalic coarticulation than obstruent [d]
- Russian trill: dorsal advancement before back vowels, stability between mid-front vowels: gestural target ~ [ə]
- Russian lateral: dorsal retraction, raising before front vowels: gestural target ~ [o]
- of the Russian non-palatalized consonants /r/, /l/ and /d/, only the lateral is produced with a clearly pharyngealized dorsal gesture

Russian Palatalized Coronals – Intervocalic [a_a]

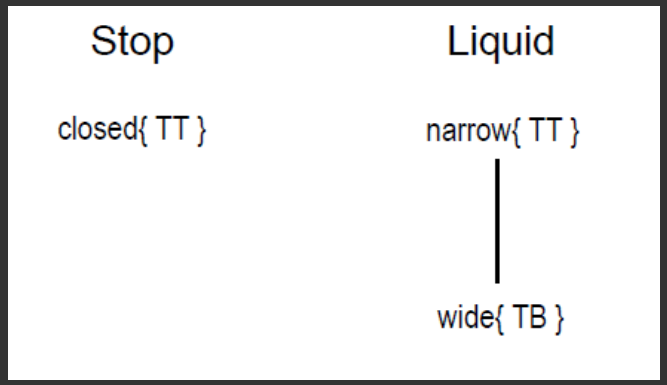
Stop: [adʲa] (F1)

Lateral: [alʲa] (F1)

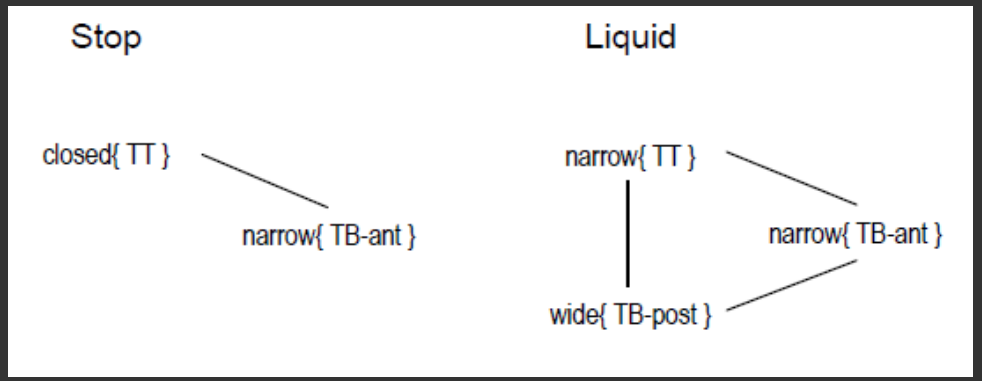
ɾhotic: [arʲa] (F1)

Articulatory Modeling of Russian Liquids

non-palatalized



palatalized coronal consonants



Articulatory Modeling of Russian Liquids

TV	/d/	/l/	/r/
TTCL	dental	alveolar	alveolar
TTCD	closed	narrow	narrow
TBCL	–	uvular-pharyngeal	uvular
TBCD	–	wide	wide

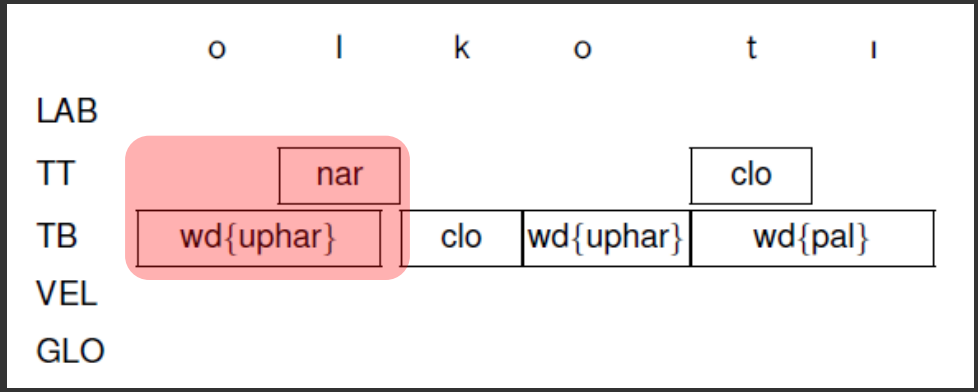
TV	/d^{j}/	/l^{j}/	/r^{j}/
TTCL	dental	alveolar	alveolar
TTCD	closed	narrow	narrow
TBCL	–	uvular-pharyngeal	uvular
TBCD	–	wide	wide
TBCL	palatal	palatal	palatal
TBCD	narrow	narrow	narrow

Russian Liquid Metathesis

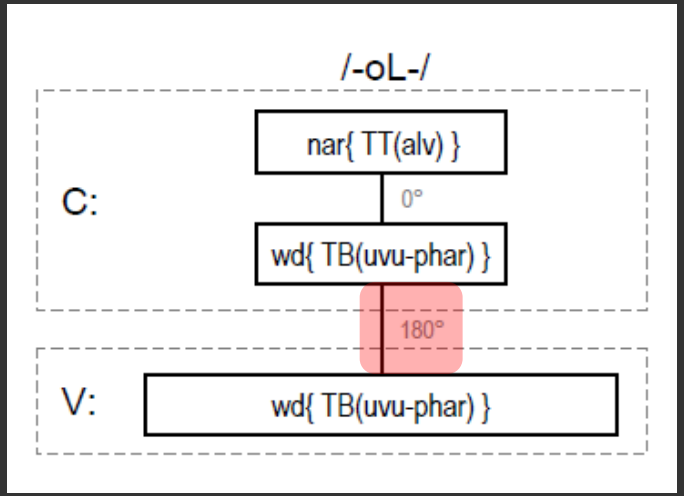
PROTO-SLAVIC	RUSSIAN
*/orv-mʊ/ *'even'*	/rov(e)n/-
*/ordlo/ *'plough'*	/ralo/
*/olkotɪ/ *'elbow'*	/lok(o)t/-
*/olk-omʊ/ *'hungry'*	/lakom/-

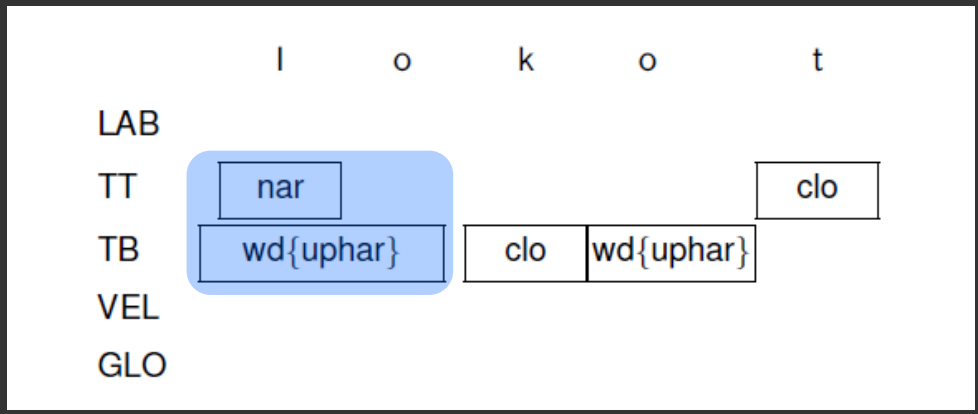
TABLE 6.6: **Metathesis of vowel-liquid sequences in Russian** (adpated from Cubberley 2002)

Gestural Account of Russian Liquid Metathesis

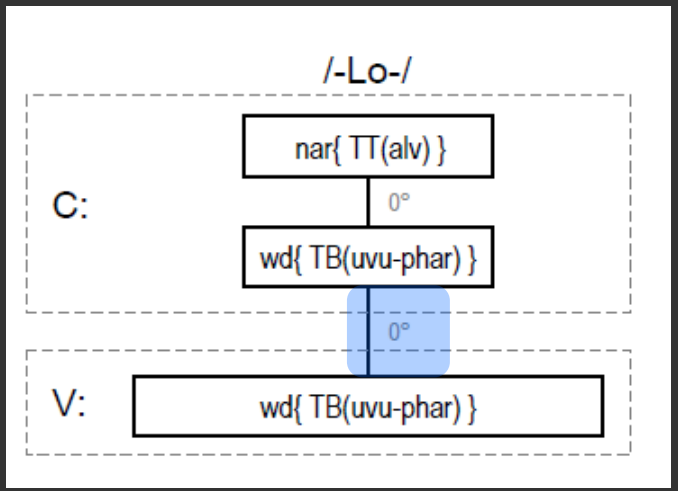


Proto-Slavic **olkotɪ* 'elbow'





Mod. Russian *lok(o)tʲ* 'elbow'



Summary of Claims

- coronal liquids in Spanish, Russian are characterized by the *coordinative production of tongue tip and tongue body gestures*

- clear/dark lateral allophony results *not from the absence of a dorsal gesture* in the clear lateral, but from *differences in tongue body constriction location*

- gestural model of liquids offers insights into:
  - liquid vocalization: *lenition of coronal gesture*
  - liquid neutralization: *loss of distinction between tongue tip or tongue body constriction location or degree*
  - VL metathesis: *change in coupling relationships* between constituent gestures of liquids and nuclei at the level of syllabic organization

Thanks

NIH:	DC-006705; DC-02717
Haskins:	Khalil Iskarous, Doug Whalen, Chris Shadle, Aude Noiray, Leandro Bolaños, Mark Tiede, Tine Mooshammer
Yale:	Dasha Kavitskaya, Jelena Krivokapić, Stephen Anderson, Erich Round, Phonetics & CLAY Groups
USC:	Louis Goldstein, Shri Narayanan, SPAN & SAIL Groups, Dani Byrd, Phonetics Lab, Rachel Walker