Towards an Articulatory Characterization of Liquids – evidence from Spanish and Russian

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Goal

Aim of this study: compare dynamic articulation of liquid consonants in Spanish and Russian in pursuit of unifying phonetic properties which characterize the class, and differentiate liquids from obstruents.

The Class of Liquids

Liquids – rhotics and laterals – share many phonological properties which suggest that they form a phonological class.

Liquids pattern together in their distribution (clustering, syllabicity, *wd-initial), and behaviour (disimilation, metathesis, merger, allophony, post-vocalic, etc.)

Capturing phonological behaviour of rhotics, laterals and liquids under feature-based phonological theory has proven difficult. [1]

Most important phonotactic property: cluster-enabling segments:

Romance: only liquid-internal clusters (Spanish: *pronto*, *pluma*, *crema*, *clima*)
Germanic: only liquid-internal 3C clusters (Dutch: *spr-, spl-, str-, skr-, skl-, sxl-*)
Slavic: only liquid-internal 4C onsets (Russian: *fspl-, fstr-, fskr-, fspr-, fsxl-*, etc.)
(but note also anti-SSP: *rta* 'mouth-GEN.SG', *lba* 'forehead-GEN.SG')

Phonetic Characterisation of Liquids

Phonetically diverse group of sounds – alveolar, retroflex, uvular & pharyngeal; trills, taps, flaps, approximants & fricatives [2]. Acoustically: lowered F3 characteristic of many rhotics [3], but not true of all types of /r/.

Liquids may share more in the articulatory domain; eg. English:
/l/: produced with coronal + dorsal constrictions [4]
/ɹ/: produced with tongue tip + pharyngeal approximation [5]

Lack of broad typological data: unclear whether similar common articulatory properties exist among different types of liquids which also pattern together.

Russian Liquids

Russian consonants in mutable pairs: palatalized / non-palatalized [6]

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

Contrastive word-initially, intervocalically, in heterorganic medial codas + word-finally:

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

	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

Is there an *articulatory basis to the class of liquids* in a language with *contrastive palatalization*?

Spanish Liquids

Three liquids: /**r**/ - /r/ - /l/
Contrastive intervocalically.
Rhotics neutralize elsewhere: [7]

Rhotic	Environment	Example
Trill:	# _ C [r, _	['ro.ka] ['en.re.do]
Tap:	[_C _V V _ #V	['gra.mo] ['se.ɾa.mi.gos]
Contrastive:	V _ V	['ka.ro] / ['ka.ɾo]
Variable:	V _ [_C V _ #C V _ ##	['par.te] ~ ['par.te] ['ser.po.'e.ta] ~ ['ser.po.'e.ta] ['ser o 'no 'ser] ~ ['ser o 'no 'ser]

	Lab	LD	Den	Alv	PA	Pal	Vel
Stop	p b		t̪ d̪				k g
Nasal	m		n̪			ɲ	
Affricate					tʃ		
Fricative		f		s ʂ		(j)	x
Rhotic					r ɾ		
Lateral				l			
Vowel						i e a	u o

Lateral always 'clear': no [ɬ] allophone: does [l] have a dorsal gesture?

Is there an articulatory basis to rhotic neutralization?

Method – Corpora, Subjects

Liquids + voiced stop elicited in contrasting intervocalic environments: seek patterns of articulatory stability characterizing production. [8]

Environment		Russian Stimuli	Spanish Stimuli
front:	[e _ e]:	*эрэ, эре, элэ, эле, эдэ, эде*	*ere, erre, ele, ede*
low:	[a _ a]:	*ара, аря, ала, аля, ада, адя*	*para, parra, pala, capada*
back:	[u _ u]:	*уру, урю, улу, улю, уду, удю*	*guru, acurruca, pulula, vudú*

Russian Subjects

ID	Age	Hometown	Time in US
RM1	24	Kadamjay, Kyrgyzstan	2 years
RM2	25	Krasnodar, Russia	2.5 years
RW1	32	Kiev, Ukraine	7 years
RW2	23	Bishkek, Kyrgyzstan	6 months
RW3	18	Zelenograd, Russia	16 years

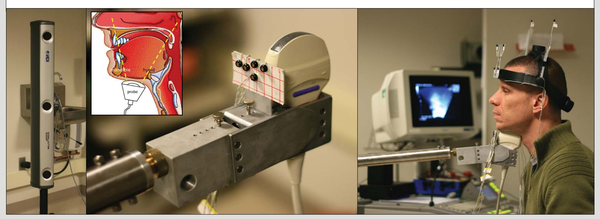
Spanish Subjects

ID	Age	Hometown	Variety	Time in US
SM1	25	Managua	Nicaraguan	15 years
SW1	21	Guaynabo	Puerto Rican	3.5 years
SW2	20	Quito	Ecuadoran	19 years
SW3	20	Miami, USA	Cuban	20 years
SW4	19	Sto. Domingo	Dominican	15 years

Method – Ultrasound

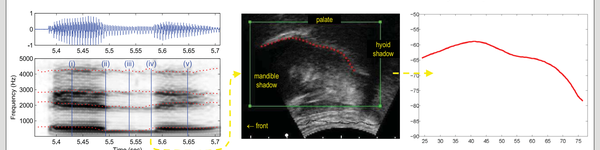
HOCUS: Haskins Optically-Corrected Ultrasound System. [9]

- ultrasound: 127 frames/sec. midsagittal lingual articulation
- audio: 22,000 Hz synchronized acoustic recording
- OptoTrak: 127 frames/sec. 3D location of anatomical markers



Method – Acoustic & Articulatory Analysis

For each consonant, acoustic landmarks selected as analysis pts:



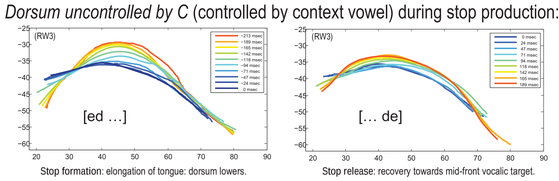
[e l e]

EdgeTrak (Li et al. 2004)

Edge extraction (Matlab)

Results – Russian Liquid Articulation

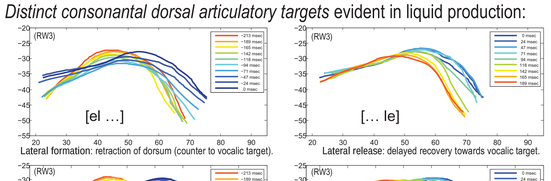
Dorsum uncontrolled by C (controlled by context vowel) during stop production:



Stop formation: elongation of tongue: dorsum lowers.

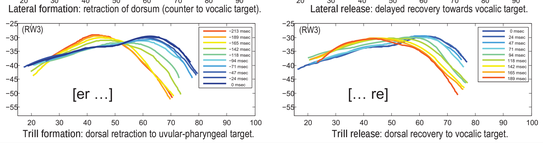
Stop release: recovery towards mid-front vocalic target.

Distinct consonantal dorsal articulatory targets evident in liquid production:



Lateral formation: retraction of dorsum (counter to vocalic target).

Lateral release: delayed recovery towards vocalic target.

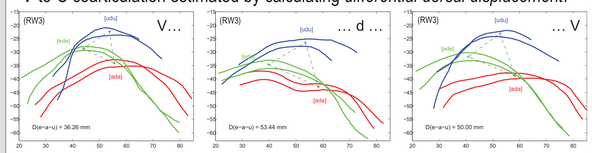


Trill formation: dorsal retraction to uvular-pharyngeal target.

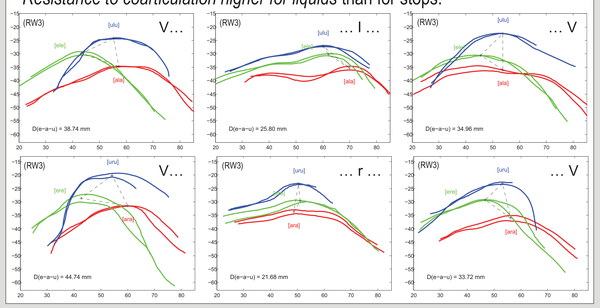
Trill release: dorsal recovery to vocalic target.

Results – Russian Coarticulation

V-to-C coarticulation estimated by calculating *differential dorsal displacement*:

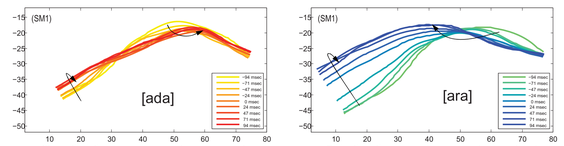


Resistance to coarticulation higher for liquids than for stops:



Results – Spanish Liquid Articulation

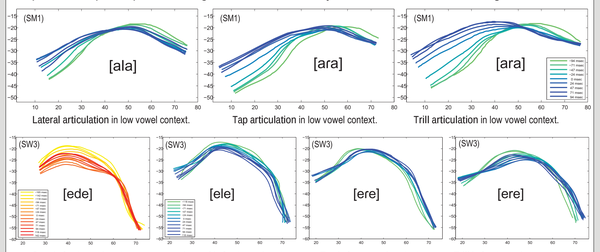
Dorsal target of trill evident in low vowel context, cf. uncontrolled stop dorsum:



Stop articulation: dorsum lowers with lingual elongation.

Trill articulation: mid-central consonantal dorsal target.

Spanish liquids pattern together articulatorily: mid-central dorsal target:



Lateral articulation in low vowel context.

Tap articulation in low vowel context.

Trill articulation in low vowel context.

Stop in front vowel context.

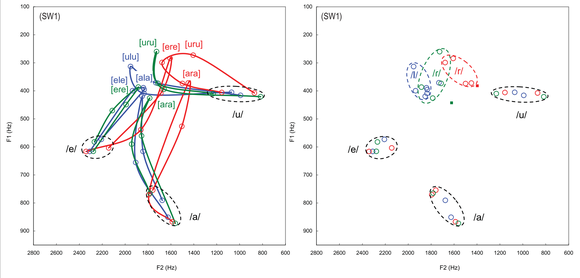
Lateral in front vowel context.

Tap in front vowel context.

Trill in front vowel context.

Results – Spanish Liquid Acoustics

Formant trajectories of intervocalic liquids convergent on acoustic targets in F1-F2 space, consistent with central vowel-like dorsal articulatory targets.

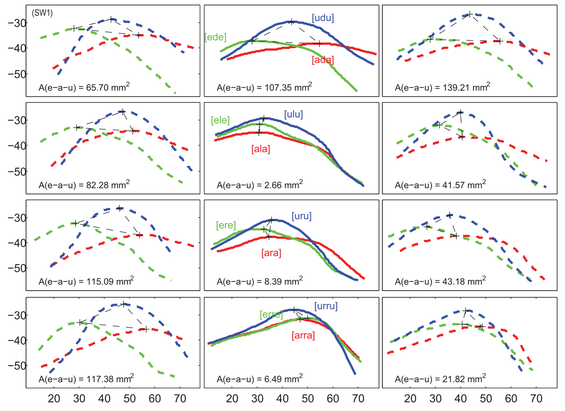


Liquid formant trajectories: frequencies (Hz) sampled at five points: from centre of pre- to centre of post-consonantal vowel.

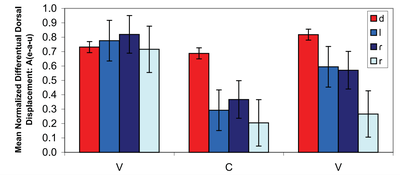
Acoustic targets of Spanish liquids: mid-consonantal formant frequencies in three vowel contexts.

Results – Spanish Coarticulation

Spanish liquids – including the tap /r/ – characterized by resistance to vocalic coarticulation and distinct dorsal targets, unlike voiced coronal stop /d/:



Mean Dorsal Displacement in VCV Sequences



Coarticulatory effects robust across all five subjects. Hierarchy of resistance to intervocalic coarticulation emerges:

/r/ > /l/ > /ɾ/ > /d/

Conclusions

Liquids differ from stops in both Russian & Spanish in their control of dorsum: distinct dorsal targets evident for each rhotic and lateral.

Spanish 'clear' lateral distinguished from Russian (& English) [ɬ] by location (not absence) of dorsal gesture (c.f. German [10]).

Spanish tap /**ɾ**/ shows less resistance to vocalic coarticulation than trill /r/ (c.f. Catalan [11]) but greater resistance than stop /d/ (c.f. [12]). For most speakers in study, dorsal gesture of tap resembles that of lateral.

Discussion

Class of liquids characterized by consonants whose production involves more global control of lingual articulation. When this takes form of a central dorsal gesture, characteristic phonological properties result: inherent sonority, potential for syllabicity, temporal-stability, allophony, asymmetry in clusters.

Vocalic nature of dorsal gestures may account for post-nuclear phenomena, eg. Dominican coda liquid vocalization: *algo* [aj.ɣo], *mujer* [mu.hej]. [13]

Similarity of gestural targets in Spanish liquids may account for coda neutralization (*puerta* → [pueˈl.ta] [7]); dissimilation (L: *arbor* > *arbol*).

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