# Towards an Articulatory Characterization of Liquids


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## Goals

This research is part of a broader typological study examining liquids in Russian, Tamil, French and Spanish, characterizing phonological behavior and phonetic properties of liquids.

Aim of this study: compare the phonetic behavior of Russian liquids with obstruents in pursuit of a unifying phonetic property.

## Background

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

A **phonetically diverse** group of sounds – alveolar, retroflex, uvular & pharyngeal; trills, taps, flaps, approximants & fricatives [1]. It is unclear what phonetic properties liquids share, if any. **Acoustically**, a **lowered F3** has been proposed as the unifying characteristic of rhotics [2], but not true of all types of /r/. [3]

Liquids **may share more in the articulatory domain**: (English) laterals are produced with both coronal and dorsal constrictions; [4] /ɹ/ is produced with both tongue tip and pharyngeal approximation. [5]

**Lack of broad typological data**: it is unclear whether common articulatory properties can be identified among the groups of liquids which pattern together in a wider variety of languages.

Phonetic studies have characterized acoustic [6] and midsagittal articulation [7] of Russian liquids, but little data on **dynamic behavior**.

## Liquid Classhood

**Phonologically-defined class**: rhotics & laterals pattern together in their **distribution** (clustering, syllabicity) and **behavior** (assimilation, dissimilation, metathesis, merger, allophony, vocalic lengthening).

Capturing phonological behavior of rhotics, laterals and liquids under feature-based phonological theory has proven difficult.

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')

## Russian Liquids

Russian consonants in mutable pairs: **palatalized/non-palatalized** [8]

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

minimally contrastive:

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

| | Lab | LDen | Den | PA | Pal | Vel |
|---|---|---|---|---|---|---|
| Stop | p, b<br>pʲ, bʲ | | t, d<br>tʲ, dʲ<br>ts | | | k, g<br>kʲ |
| Affricate | | | | tʃ | | |
| Fricative | | f, v<br>fʲ, vʲ | s, z<br>sʲ, zʲ | ʃ, ʒ | | x |
| Nasal | m<br>mʲ | | n<br>nʲ | | | |
| Rhotic | | | r<br>rʲ | | | |
| Lateral | | | l<br>lʲ | | | |
| Approximant | | | | | j | |
| Vowel | | | | i<br>e | | u<br>o<br>a |

## Method – Corpus

Liquids /r-rʲ-l-lʲ/ each elicited in **four phonological environments**, compared with voiced stop and fricative in same context to seek **patterns of articulatory stability** which **characterize production**.

Four sets of artificial Russian stimuli presented in Cyrillic orthography: **balanced phonological environments**, ↓ lexical, prosodic effects.

| | high | front | low | back |
|---|---|---|---|---|
| • word-initial onset: | [# _ iʲ] | [# _ e] | [# _ a] | [# _ u] |
| • medial onset: | [i _ iʲ] | [e _ e] | [a _ a] | [u _ u] |
| • medial coda: | [i _ ki] | [e _ ke] | [a _ ka] | [u _ ku] |
| • word-final coda: | [i _ #] | [e _ #] | [a _ #] | [u _ #] |

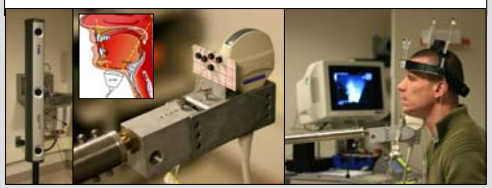
## Method – Ultrasound

HOCUS: Haskins Optically-Corrected Ultrasound System.

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

⇒ high resolution **dynamic lingual articulatory** data, synchronized with high-fidelity **acoustic speech** signal.

Midsagittal lingual articulation imaging: alveolar → pharyngeal region.



## Method – Subjects

| Subject | Age | Hometown | Other Languages | Time in US |
|---|---|---|---|---|
| M1 | 24 | Kadamjay, Kyrgyzstan | US English, Turkish | 2 years |
| F1 | 32 | Kiev, Ukraine | Ukrainian, US English | 7 years |
| F3 | 18 | Zelenograd, Russia | US English | 16 years |

## Method – Acoustic & Articulatory Analysis

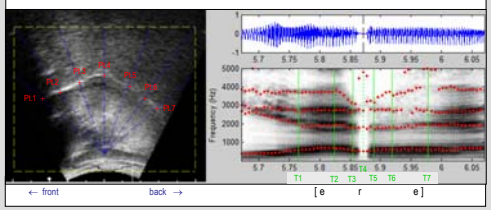
For each consonant, 7 **acoustic landmarks** selected as analysis pts:

| | | |
|---|---|---|
| T1-T3: | -100ms, -40ms, -5ms | before closure |
| T4: | 0ms (center of consonant) | midpoint of closure |
| T5-T7: | +5ms, +40ms, +100ms | after closure |

**Lingual analysis**: origin chosen at tongue root (above probe centre). Radial analysis grid constructed with seven rays corresponding to:

1. Alv 2. P-Alv 3. Pal 4. Vel 5. Uvu 6. U-Pha 7. L-Pha

Articulation characterized by finding intersection of tongue edge with rays, calculating distance from origin, quantifying change over time.

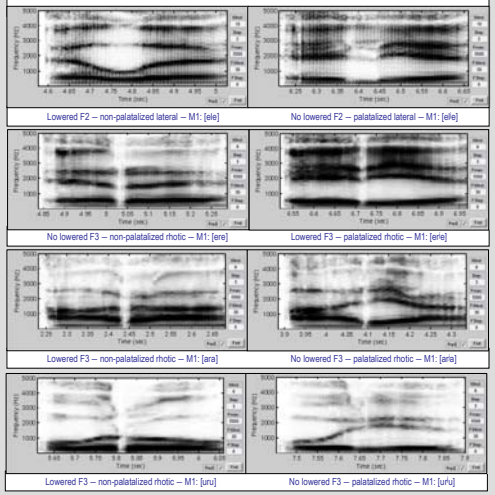



## Results – Spectral Characterization

Liquid formant transitions less abrupt than stops, resemble glides.

Distinct formant structures evident throughout laterals, between trill taps.

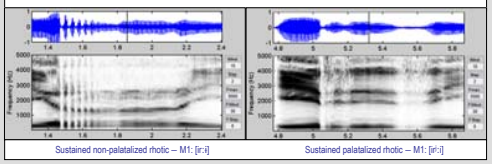
**F2, F3 not invariant**: liquid formants reflect vocalic context, palatalization.




## Results – Liquid Continuance

Non-palatalized liquids [r:], [l:] sustained more easily than [rʲ:], [lʲ:]

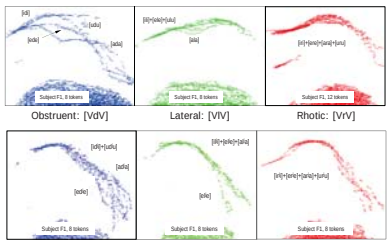
- non-coronal articulation of [r], [l] differs from [rʲ], [lʲ]; affects stability, continuance [9]
- sonorant properties of [r] dorsum evident in formants: resemble central vowels




## Results – Dorsal Articulation

Dorsal articulation of **obstruent strongly influenced by vocalic context**.

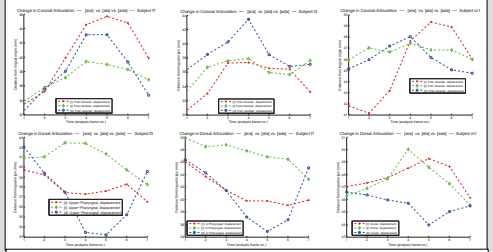
Dorsal articulation of **rhotic & lateral highly consistent** across contexts.



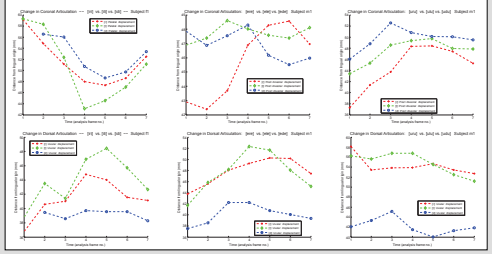

## Results – Dynamic Articulation

**Coronal** articulatory trajectory **similar** for obstruent, rhotic and lateral
**Dorsal** articulation of **rhotic and lateral differs from obstruent**:

Articulation of intervocalic consonants – low-back vowel context [a_a]:



high-front context [i_i]: front context [e_e]: high-back context [u_u]:



## Conclusions

The class of Russian liquids cannot be captured by a common set of specific acoustic properties.

Russian laterals & rhotics exhibit **articulatory stability** at the back of the tongue, resisting vocalic coarticulation more than obstruent.

Russian laterals & rhotics exhibit **articulatory independence** from adjacent vowels, observed in lingual retraction before front vowels.

## Discussion

If the class of liquids consists of consonants whose production involves a **sonorant dorsal articulatory component**, many properties of liquids might arise from the influence of this gesture:

inherent sonority, potential for syllabicity, temporal-stability, allophony, asymmetry in clusters with respect to place in syllable.

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