Towards a computational articulatory model of Spanish Phonology

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Issues in feature-based Spanish Phonology

Spirantization of /b, d, g/
spreading of [+continuant]?
how to explain both stop-spirant alternation and sub-allophonic variation?

Liquids
/r - r/ allophony
liquid coda neutralization
what defines the class of liquids?
Our proposal: an articulatory alternative

Proposal: Some phonological processes best explained via dynamical interactions of articulatory gestures

Current work: Development of a computational articulatory model of Spanish to test our proposal

Ultimate goal: A full formal model of a Spanish Articulatory Phonology
Outline

AP, Task Dynamics, & TaDA

Spirantization in Spanish stops

Spanish liquids

Demonstration
Outline

AP, Task Dynamics, & TaDA

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Demonstration
Articulatory gestures: the basic building blocks

Constriction device
  - Lip Aperture, Tongue Tip, Tongue Dorsum, Velum, Glottis, etc.

Constriction degree (CD)

Constriction location (CL)

Duration
Gestures are coordinated into gestural constellations

Lip Aperture
Tongue Tip
Tongue Body
Velum

“dama”

Lip Aperture
Tongue Tip
Tongue Body
Velum

“nava”
TaDA, the Task Dynamics Application

MATLAB implementation of Task Dynamics and Articulatory Phonology (Browman & Goldstein, 1995; Nam et al. 2004; Saltzman & Munhall, 1989)

Generates gestures and their coordination from a gestural dictionary

Can manipulate all gestural parameters

Audio generated from HLSyn (Hansen & Stevens 2002)
TaDA step 1: orthography to syllabified ARPABET

**input:** “grande”

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$\rightarrow (G \text{ R-A1}_N)(D-E0)$
## TaDA step 2: ARPABET to gesture

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TaDA step 3: gestural specifications to articulation and acoustics

“dama”
TaDA: Output compared against measured data

Articulatory trajectories

EMA, MRI, Ultrasound, etc.

Acoustic recordings

Real-world data

TADA

Acoustic output
Outline

AP, Task Dynamics, & TaDA

Spirantization in Spanish stops

Spanish liquids

Demonstration
What is spirantization?

Spanish /b, d, g/ are produced with full closure in phrase-initial position, or after a nasal

Elsewhere, /b, d, g/ are produced as approximants

BUT lots of variation in production
The dynamics of spirantization

There is articulatory evidence that:

duration influences degree of spirantization (undershoot)

/b, d, g/ have a different CD target than /p, t, k/

(Parrell, 2010)
Spanish produced CD for /b/ (EMA)
Approximating control targets for /b, d, g/

Focus on manipulating **duration** and **target CD**

Duration: 50 to 180 ms (10 ms steps)

Target CD: -2 to 0.5 mm (1 mm steps)
Synthetic produced CD for /b/ (TaDA)

Produced Lip Aperture

complete closure
CD < -0.1

CD target for /b/: ~ -0.5 mm
TaDA acoustics for CD target of -0.5 agree with experimental results

80 ms

200 ms

Phrase medial

Phrase initial
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Spanish Liquids

/l/-/ɾ/-/ɾ/ exhibit many class-like behaviors:

- cluster phonotactics
- coda neutralization
- dissimilation
- metathesis
- late, parallel acquisition

What is the basis of liquid classhood in Spanish?
Gestural Characterization of Liquids

Hypothesis:

Spanish liquid segment = coordinated structure: 

vowel-like TB gesture + consonant-like TT gesture

Puerto Rican Spanish Trill: [ere]

22
Evidence for Gestural Hypothesis

VdV:

VlV:

VrV:

VrV:
Phonetic Properties of Spanish Liquids

/l/: dorsal advancement between back vowels
dorsal stability between mid-front vowels
⇒ gestural target ~ [e]

/r/: dorsal advancement between back vowels
dorsal stability between mid-front vowels
⇒ gestural target ~ [Ə]

/r/: dorsal retraction between front vowels
pharyngeal raising all environments
⇒ gestural target ~ [o]
Articulatory Modeling of Spanish Liquids

/də/  /lə/
Articulatory Modeling of Spanish Liquids

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Articulatory Modeling of Spanish Laterals
Articulatory Modeling of Spanish Laterals

[pala] (TADA)  [pala] (Subj. 1: female)  [pala] (Subj. 2: male)

Synthesized F1, F2 trajectories match acoustic data

⇒ supports hypothesis that Spanish laterals are articulated with intrinsic advanced dorsal gesture
Outline

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Demonstration
Conclusions

Spirantization patterns of /b, d, g/ can be accurately modeled with a CD target of -0.5 mm.

Spanish liquids have a TB constriction as well as a TT constriction.

Modeling and comparison with experimental data can refine our phonological analyses.
TaDA available from Haskins Labs at: http://www.haskins.yale.edu/tada_download/index.html

Email parrell@usc.edu for Spanish dictionary package
References


Articulatory Modeling of Spanish Rhotics
Spanish Liquid Vocalization

Dominican Republic: vocalization (Alba 1979)


[Diagram of vocalization with annotations and phonetic symbols]