Acoustics of coronal stops in Spanish-English bilingual speech

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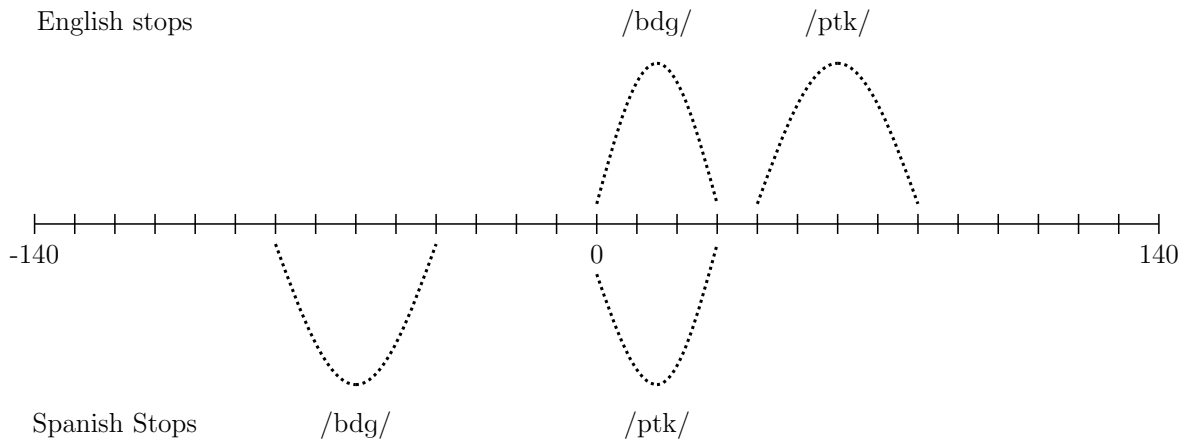
Overview

- Spanish and English both have /d/ and /t/
- Phonetic descriptions differ as a function of language
  - Spanish /d t/ described as dental
  - English /d t/ described as alveolar
- Present study is concerned with:
  - description of acoustics of /d t/ at release
  - comparisons of monolinguals and bilinguals
  - comparisons of two languages of a bilingual

Introduction

- Spanish and English contrast between /p t k/ and /b d g/
- The phonetics of 'voicing' in stop differs
  - Spanish /d/ is prevoiced and /t/ is voiceless
  - English /d/ is voiceless and /t/ is aspirated



Introduction

- Spanish and English coronal stops (/d t/) also differ in **place of articulation**
  - Spanish /d/ and /t/ are described as dental
  - English /d/ and /t/ are described as alveolar
- Some articulatory data are available
- **How is this reflected on the acoustic signal?**

Introduction

- Jongman et al. (1985)
  - for Malayalam, which contrasts dental and alveolar stops, and Dutch (dental) vs. English (alveolar) stops
- Stoel-Gamon et al. (1994)
  - for Swedish (dental) vs. English (alveolar) stops
- Sundara (2005, 2006)
  - for Canadian French and Canadian English and French-English bilinguals

Introduction

- At release burst, alveolar stops are louder than dental stops (relative amplitude, intensity)[1]
- Spectral envelope of burst captures differences between alveolar and dental stops[2]
  - center of gravity of spectrum, higher for alveolars
  - standard deviation of spectrum, more compact for alveolars
  - kurtosis of spectrum, more peaked for alveolars

[1] Jongman et al., 1985; Stoel-Gamon et al., 1994; Sundara, 2005, 2006
[2] Stoel-Gamon et al., 1994; Sundara, 2005, 2006

Introduction

- Malayalam, which contrasts alveolars and dentals, uses 'strict' acoustic correlates for both consonant types; i.e., there is little overlap between acoustic distributions[3]
- Languages tend to have *either* dental *or* alveolar; i.e., few languages contrast dentals and alveolars
- In languages with no contrast, acoustic correlates are more variable, flexible (leading to more overlap)
  - what happens in bilingualism?
  - one individual = dental + alveolar

[3] Jongman, 1985

Introduction

- In bilingualism, links are formed between sound categories in the two languages
- Interlingual links lead to assimilations, compromise
- Caramazza et al., 1973:
  - French-English bilinguals in Montréal, Québec
  - bilinguals use VOT differently in their two languages
  - but values ‘compromised’ between two languages
- Bilinguals with dental and alveolar stops might compromise their place of articulation for [coronal] stops
  - articulatory difference is small
  - acoustic difference is unstable

Introduction

- Sundara, 2005 (simultaneous bilinguals)
  - French-English bilinguals in Montréal, Québec
  - French /d t/ (dental) vs. English /d t/ (alveolar)
  - Bilinguals keep languages separate, but they also differ from monolinguals (acoustic correlates not fully distinctive)

Introduction

- Some early and simultaneous bilinguals use language-specific phonetics consistently
- Bilinguals might have separate phonetic (sub)systems
- Magloire and Green, 1999:
  - early Spanish-English bilinguals from Arizona
  - recruited in unilingual sessions (Spanish, English)
  - in production of VOT categories, bilinguals did not differ from monolinguals in any language and any condition
- **Perhaps this population allows for the study of dental-alveolar place in within-subjects design**

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Participants

- **32 participants, all of them females**
  - 8 Spanish-speaking monolinguals from Majorca, Spain
  - 8 English-speaking monolinguals from Tucson, Arizona
  - 16 Spanish-English bilinguals from Tucson, Arizona
    - 8 dominant in Spanish
    - 8 dominant in English
- **Bilingual Language Profile {BLP} questionnaire**[4]
- Young adults: ages 18–25

[4] Birdsong, Amengual, Gertken, 2012

Participants

- **Bilingual Language Profile** has four components:
  - history (6 questions)
  - use (5 questions)
  - competency (4 questions)
  - attitudes (4 questions)
- Responses are numeric[5]
  - score assigned to each language
  - dominance score obtained by subtraction (-218 to 218)
    - Negative values = dominant in English (M = **-33.37**)
    - Positive values = dominant in Spanish (M = **30**)

[5] age of learning, years of use, percentages of use, Likert-type scales, etc.

Participants

General Profiles

- Monolinguals
  - some exposure (and knowledge) of other language
  - no proficiency in other language
- Bilinguals
  - *latinos*, born and raised in Arizona
  - social networks in both languages
  - highly proficient in both languages (note BLPs)
  - raised by Spanish- or English-dominant families (bilingual)

Materials

- words with /d/ or /t/ in utterance-initial position
- words in carrier sentence
  - '*tanto* es la palabra'
  - '*tantrum* is the word'
- lexical stress, controlled (stressed, prestressed)
- first vowel, controlled (always low: /a/ or /æ/)
  - Spanish: *danza* (12), *tanto* (12)
  - English: *dancing* (12), *tantrum* (12)

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Procedure

- **Delayed shadowing technique**
  - auditory stimuli: male speech
  - six male “talkers” (3 Spanish, 3 English) recorded stimuli
  - stimuli played in random order to the speakers[6]
  - speakers “listened and repeated sentences”
- **Who produced what?**
  - Spanish monolinguals, only Spanish materials
  - English monolinguals, only English materials
  - Spanish-English bilinguals, both languages
    - both languages in one block
    - random order

[6] ‘talkers’ were monolinguals from Spain (Spanish) or Texas (English)

Data

- **24** (words) $\times$ **3** (iterations) $\times$ **2** (languages)
  - 576 tokens, Spanish monolinguals
  - 576 tokens, English bilinguals
  - 1152 tokens, Spanish-dominant bilinguals
  - 1152 tokens, English-dominant bilinguals
- Total: 3,456 (- 76 errors) = **3380** tokens in dataset

Acoustic analyses

- **Voice Onset Times (ms)**
  - onset of burst minus onset of modal voicing
  - from negative (lead VOT) to positive (long-lag VOT)
- **Gaussian window left-aligned with burst onset**
  - if VOT positive, but less than 20 ms, analysis window equals VOT
  - if VOT positive, but more than 20m, analysis window equals 20 ms
  - if VOT negative, analysis window equals 20 ms
- **Power spectrum from gaussian window**

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Acoustic analyses

- **VOTs (ms)**
- **Spectral characteristics of burst**
  - Center of Gravity (Hz)
  - Standard Deviation
  - Skewness
  - Kurtosis
- **Relative burst intensity**
  - Intensity of burst (dB) minus intensity at vowel midpoint

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Statistical analyses

- Linear mixed-effects regression
- Here, by-subject (mixed-design) ANOVAs
  - response: VOT, COG, RI separately
  - factors: language (2), voicing (2), group (4)

Statistical analyses

- How do English and Spanish /d t/ differ?
  - only monolingual productions
  - 2 (voicing) $\times$ 2 (language) $\times$ 2 (group)
- How do monolinguals and bilinguals differ?
  - only Spanish productions
  - 2 (voicing) $\times$ 3 (group)
- How do monolinguals and bilinguals differ?
  - only English productions
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- How do the two languages of a bilingual differ?
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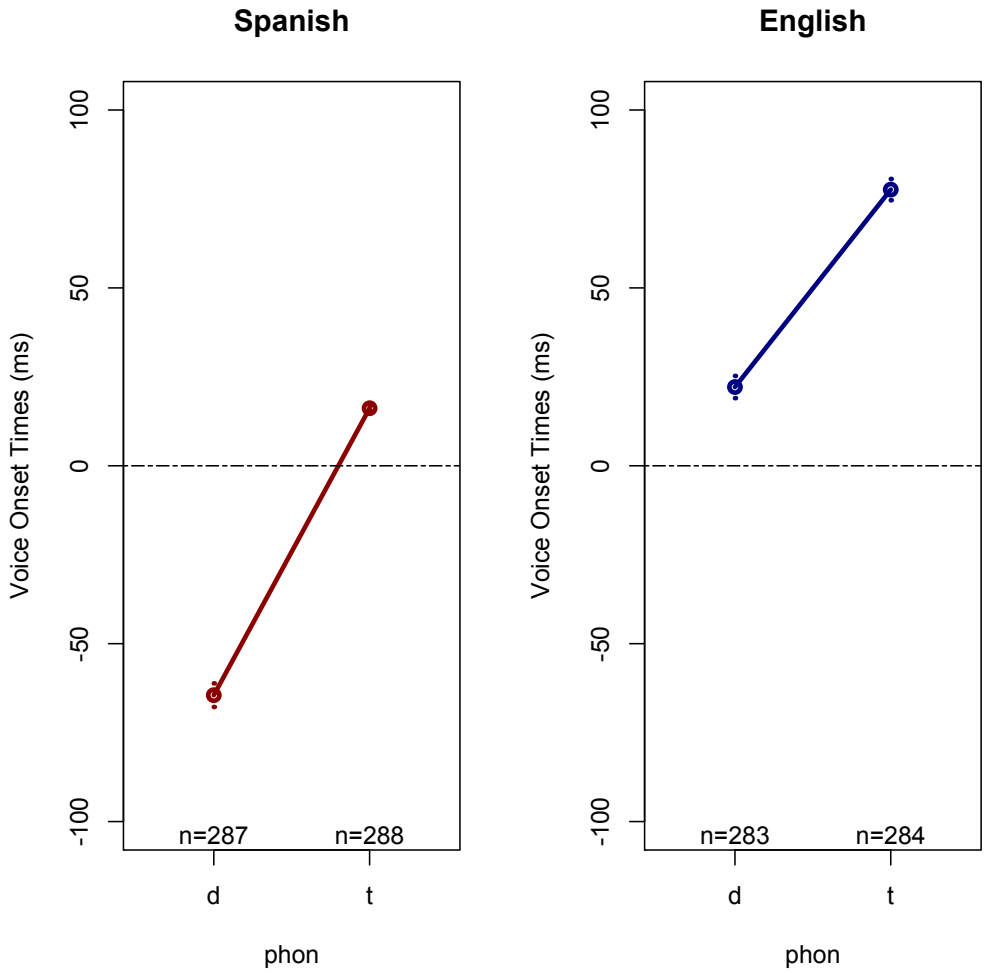
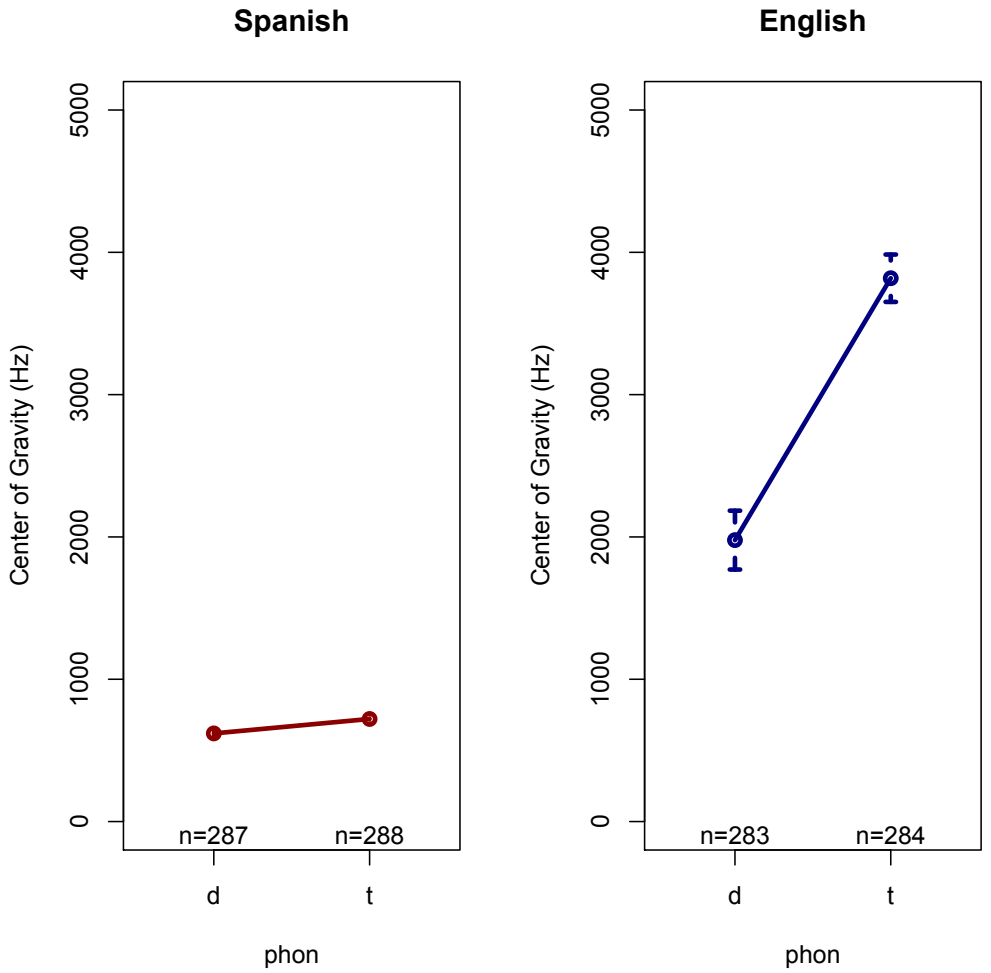
Spanish *vs.* English /d t/ in monolinguals

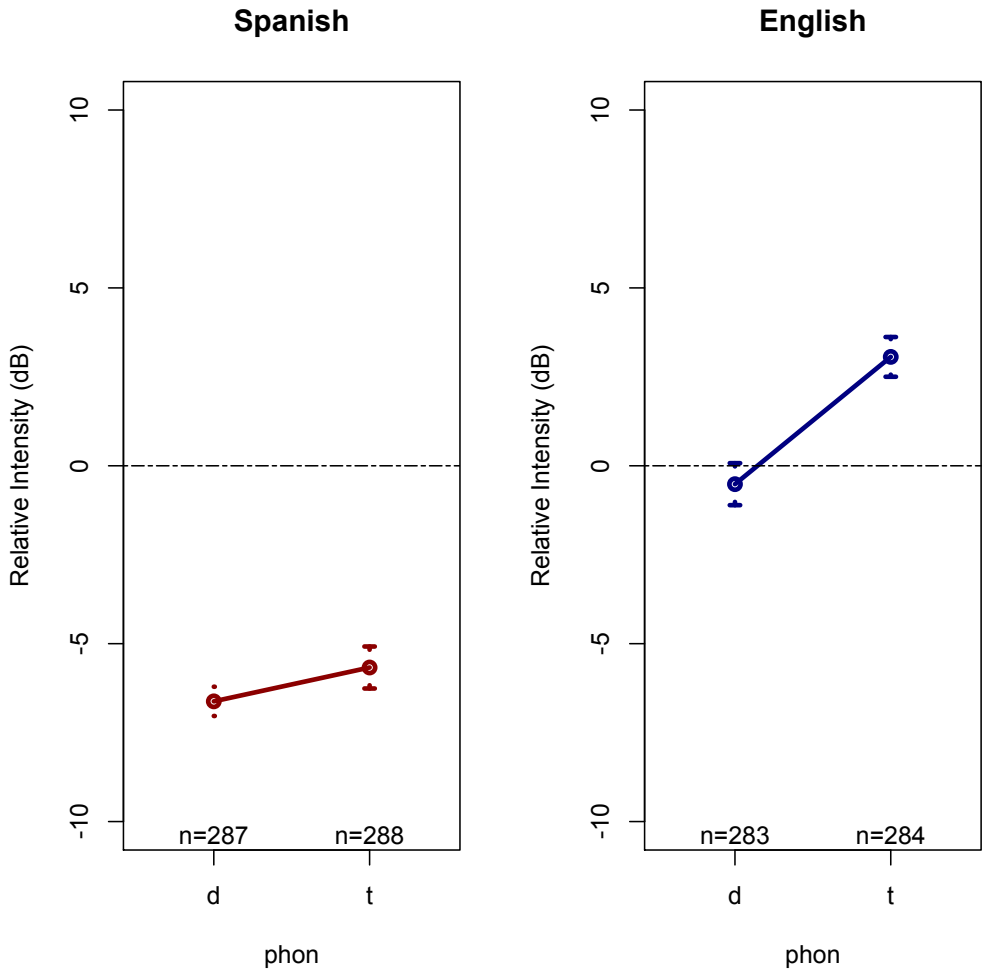
Voice Onset Times (ms)



Center of Gravity (Hz)



Relative Intensity (dB)



Summary of findings

- **VOT (ms)**
  - Spanish /d/ is prevoiced
  - English /t/ is aspirated
  - Spanish /t/ and English /d/ are voiceless
- Center of Gravity (Hz)
  - Spanish /d t/ have low-frequency resonances (< 1 kHz)
  - English /d/ has mid-frequency resonances (~ 2 kHz)
  - English /t/ has high-frequency resonances (~ 4 kHz)
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  - Spanish /d t/ have low-amplitude bursts
  - English /d t/ have bursts as loud as vowels

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Spanish /d t/ across groups

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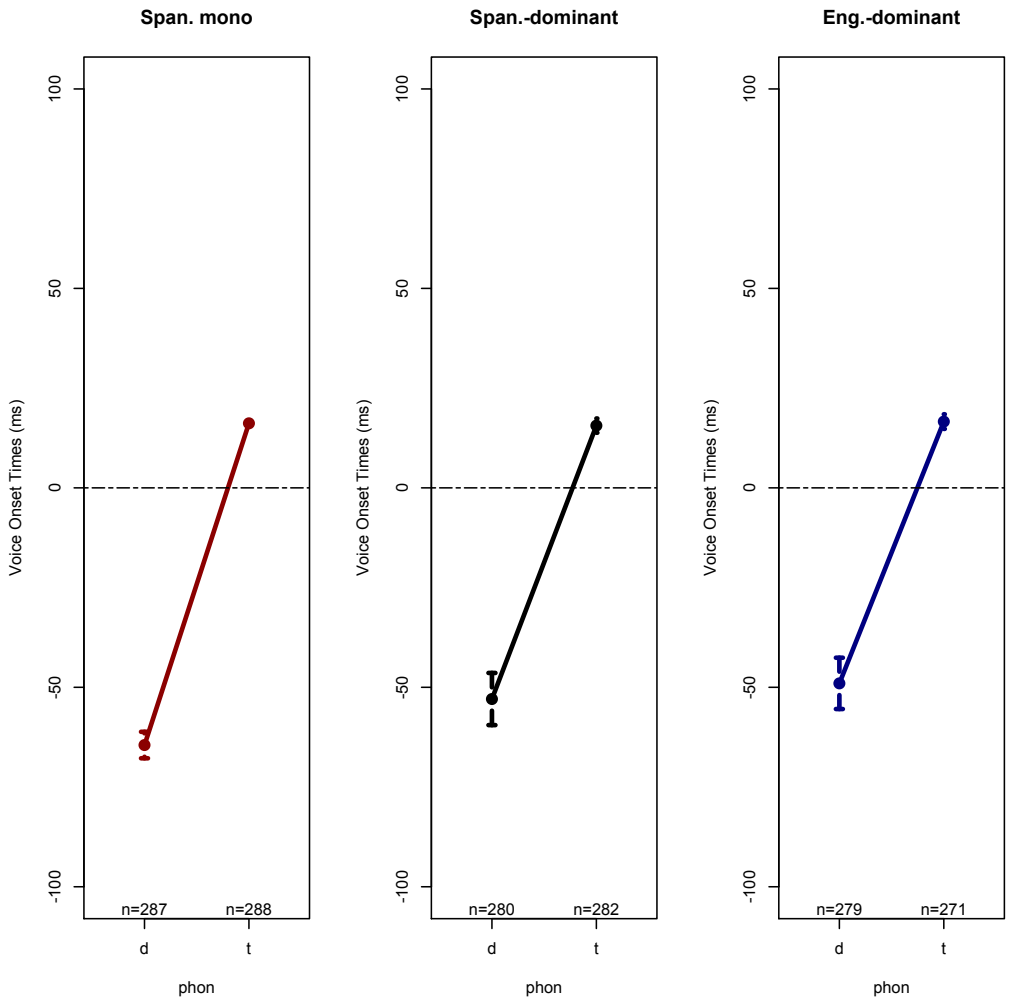

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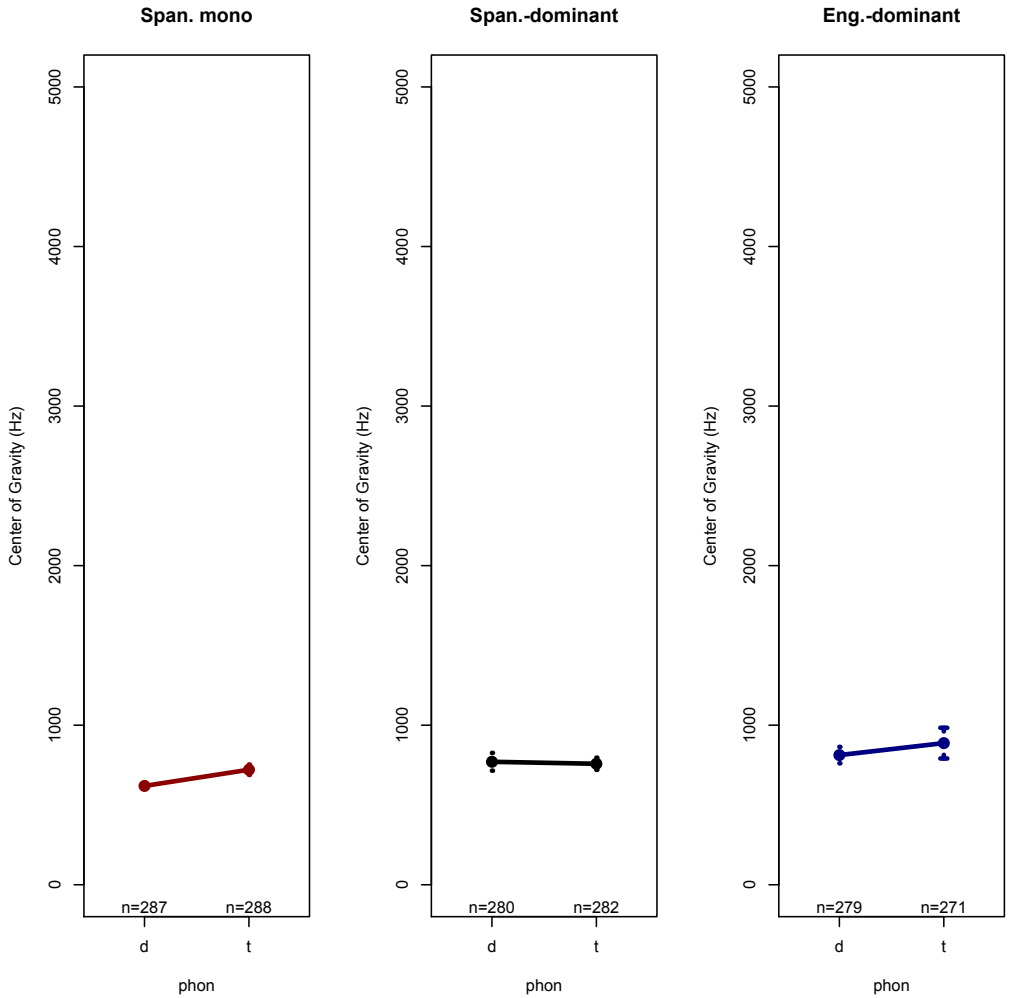

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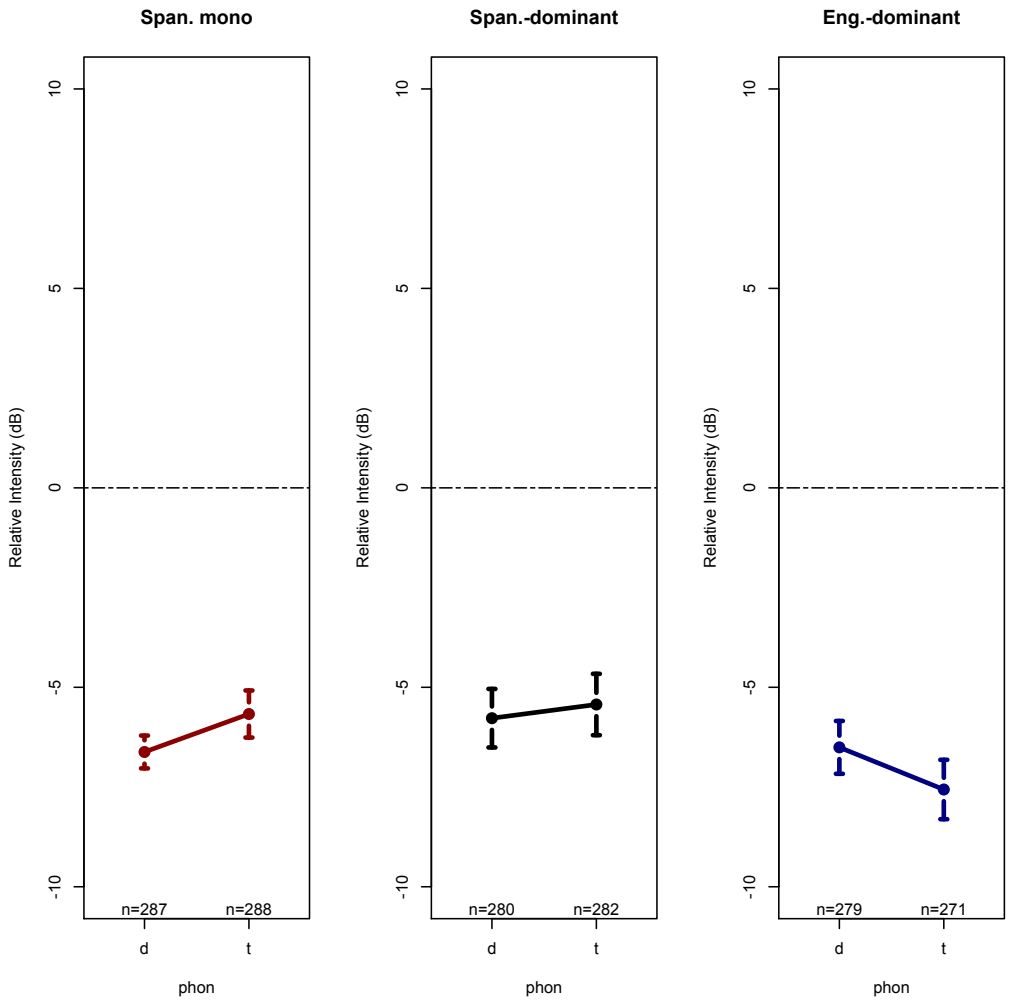

Summary of findings

- **VOT (ms)**
  - monolinguals and bilinguals do not differ
  - native productions for both /d t/
- Center of Gravity (Hz)
  - monolinguals and bilinguals differ very slightly
  - bilinguals have slightly higher resonant frequencies at burst
  - values for all individuals below 1 kHz
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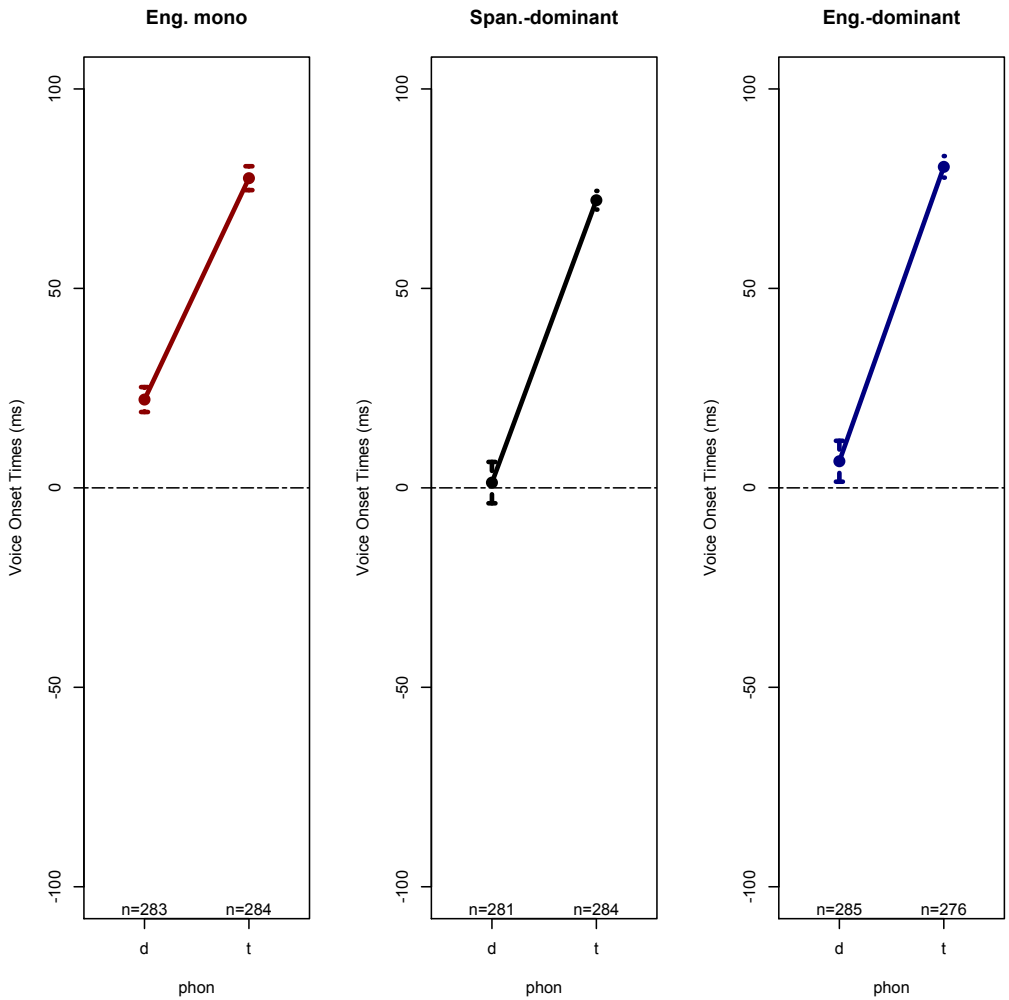

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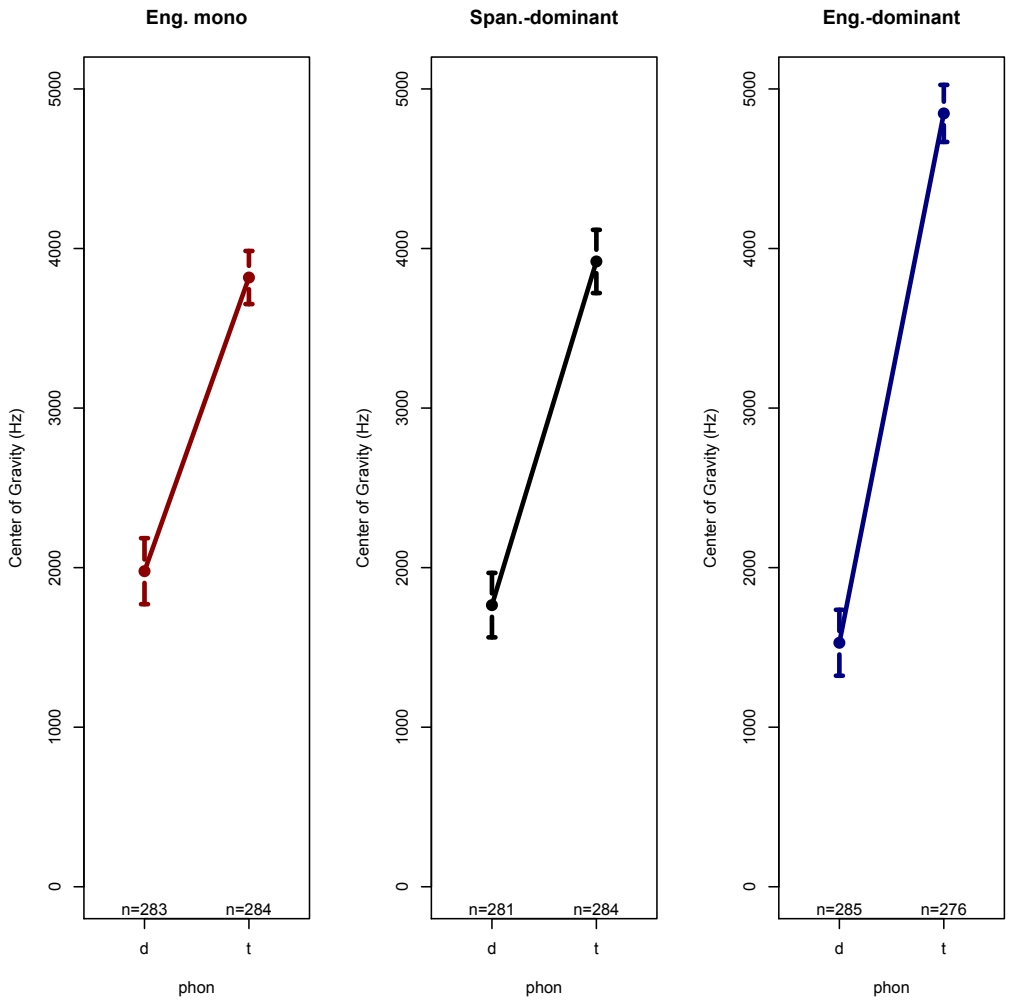

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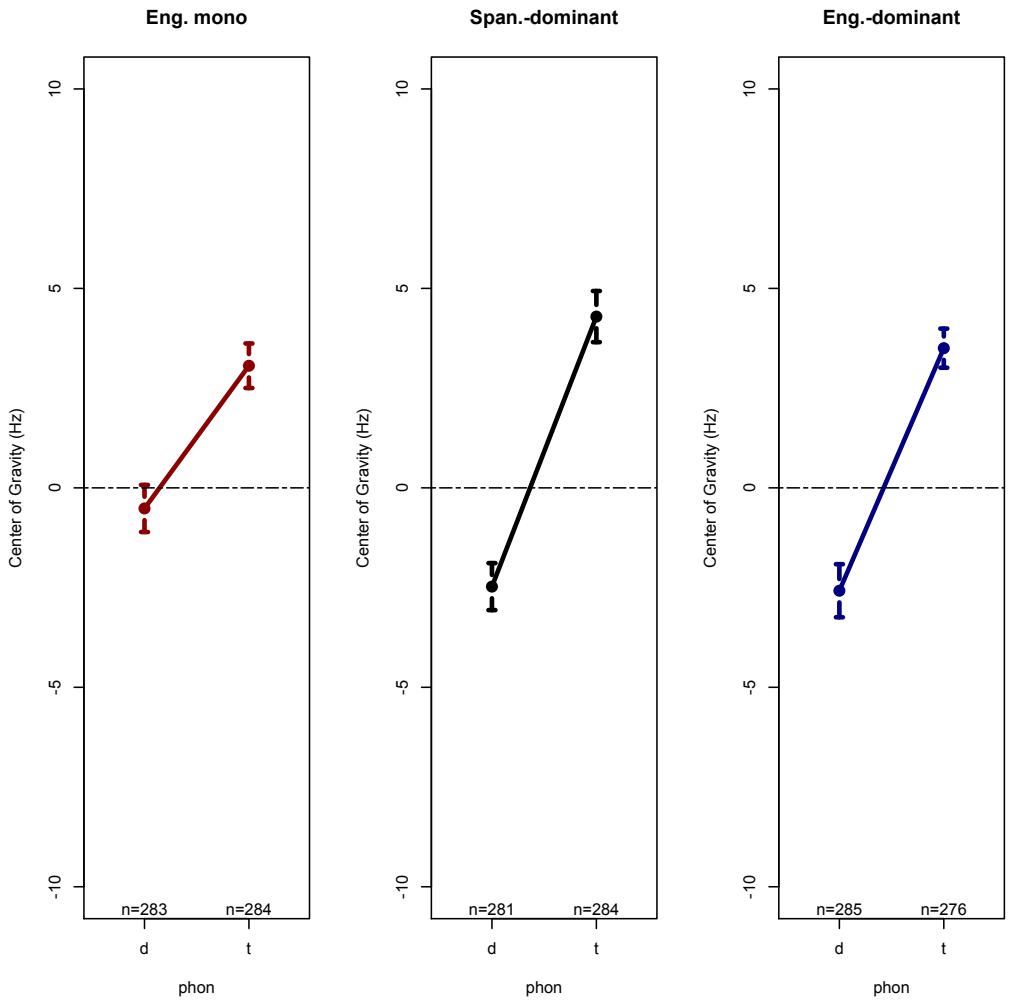

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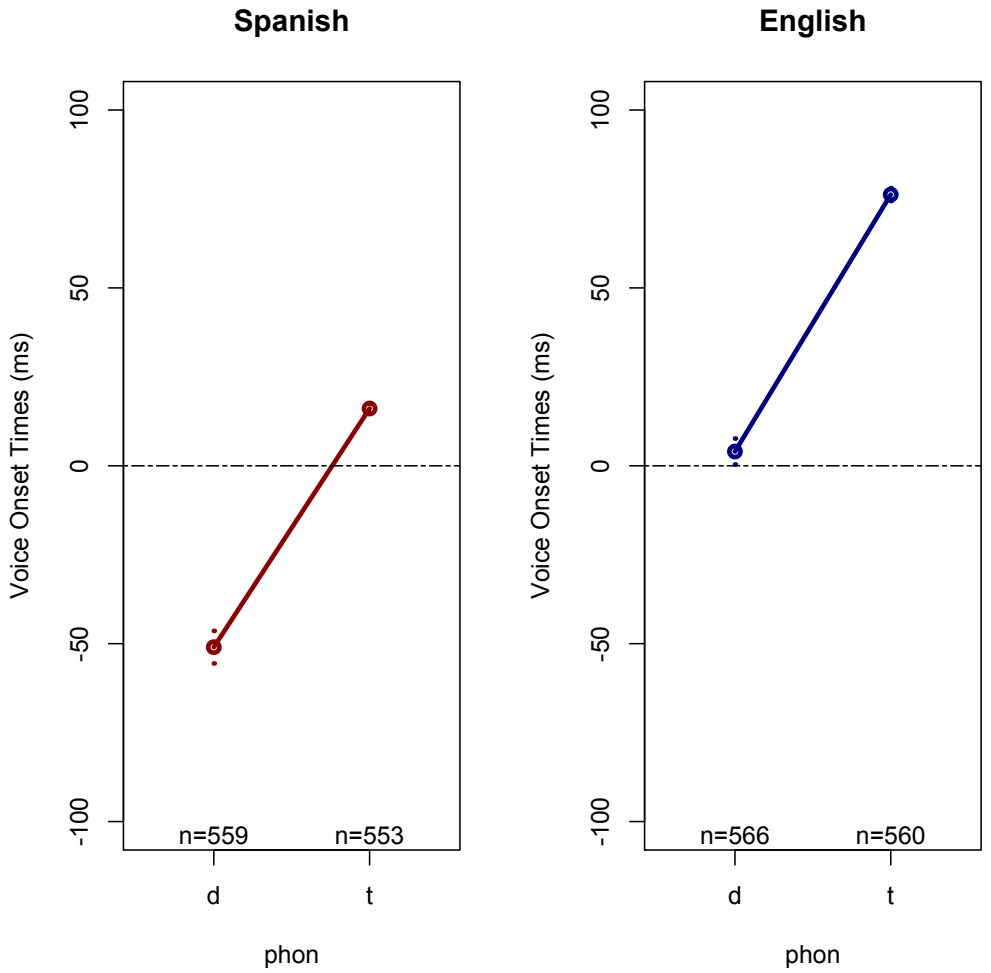

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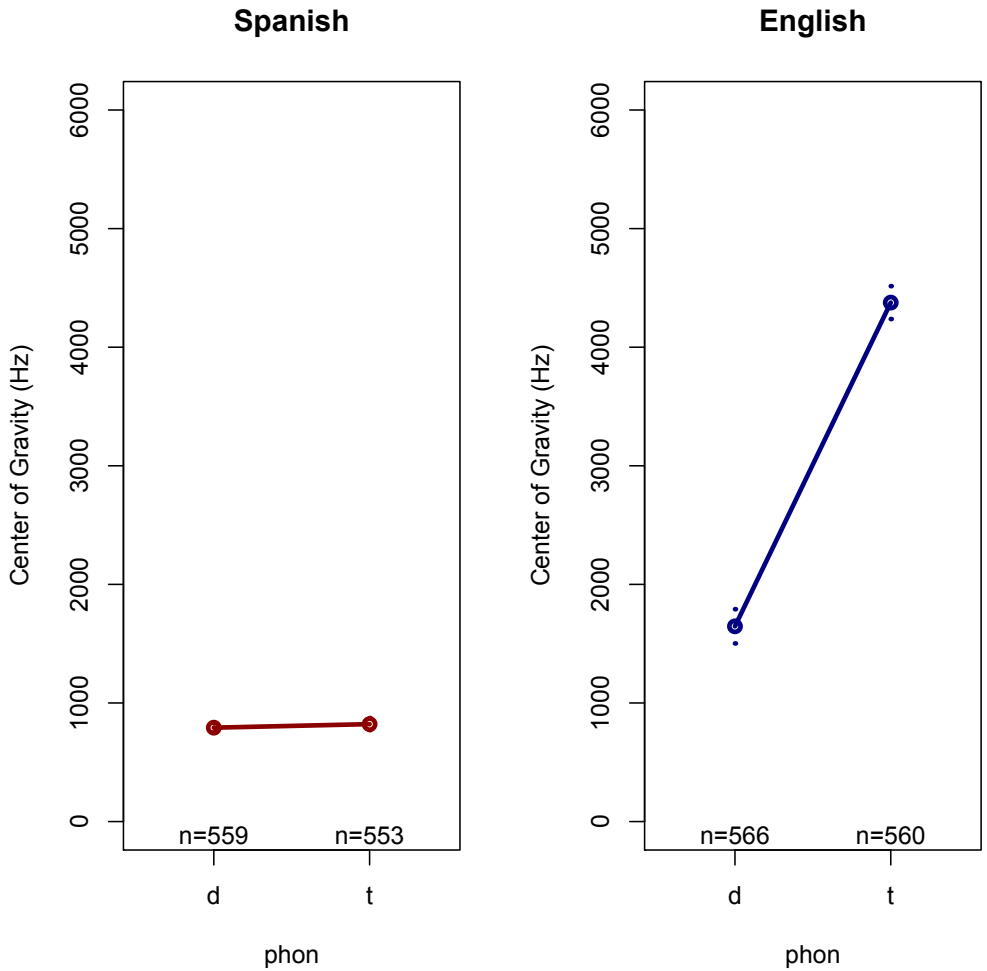

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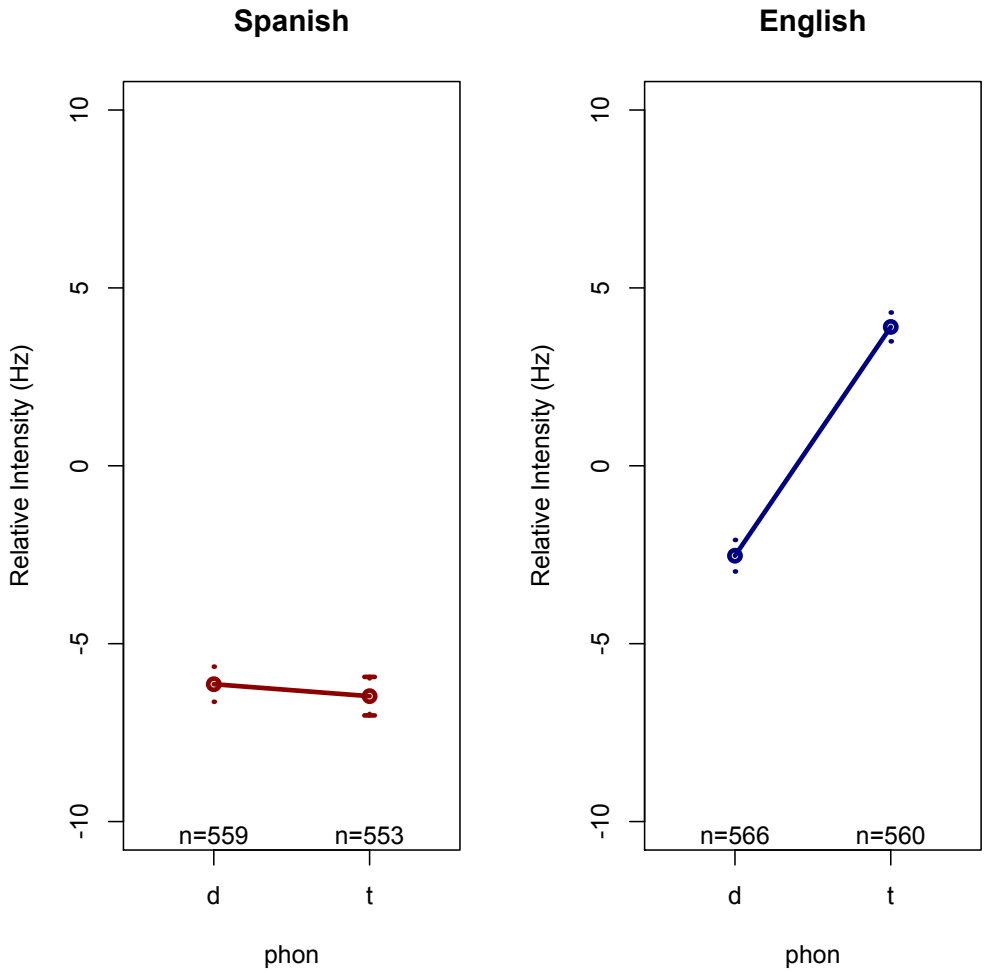

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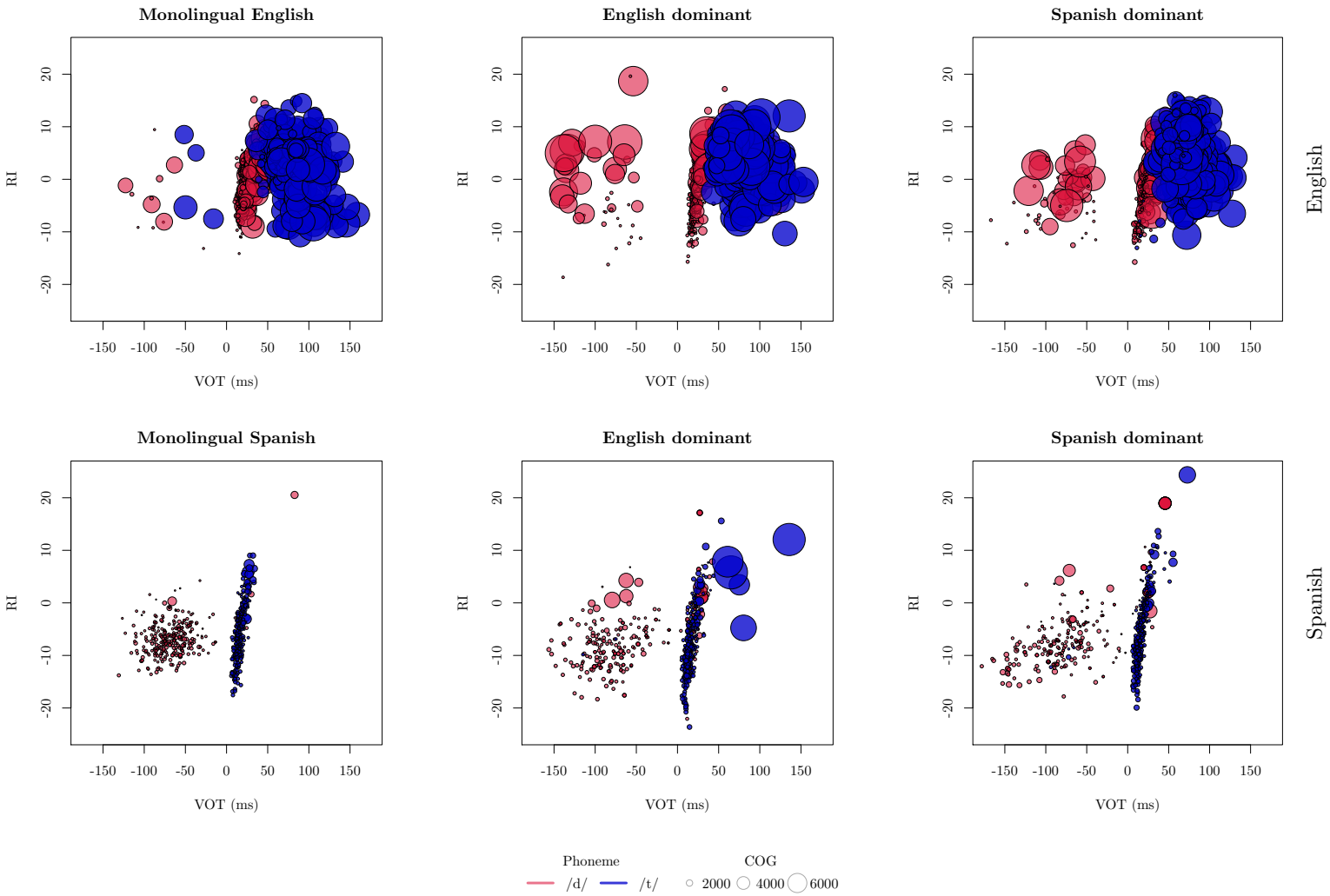
Monolingual English
English dominant
Spanish dominant
Monolingual Spanish
English dominant
Spanish dominant
English
Spanish
RI
VOT (ms)
-150 -100 -50 0 50 100 150
-20 -10 0 10 20
Phoneme
/d/
/t/
COG
2000
4000
6000

Findings

- **Spanish and English coronal stops (/d t/) differ in their acoustic characteristics**
  - differences in use of VOT for *fortis-lenis* contrast
  - differences in resonant frequencies at burst
  - differences in amplitude of burst
- **Spanish /d t/**
  - have softer bursts with lower resonance frequencies
- **English /d t/**
  - have louder bursts with higher resonance frequencies

Findings

- **Spanish and English coronal stops (/d t/) differ in their acoustic characteristics**
  - differences hold across across individuals (languages) when monolingual speakers are compared
  - and they hold within individuals when bilingual speakers are compared
- bilinguals differ from monolinguals only very slightly
- **bilinguals have separate (sub)systems for stops in their two languages**

Context

Findings in line with...

- Jongman et al. (1985)
  - for Malayalam, which contrasts dental and alveolar stops, and Dutch (dental) vs. English (alveolar) stops
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- Sundara (2005, 2006)
  - for Canadian French and Canadian English and French-English bilinguals
- Spanish /d t/ pattern with French, Dutch and Swedish
  Spanish /d t/ are (probably) dental or laminal

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Context

- Sundara (2006): dentals vs. alveolars in bilingualism
  - subjects kept two separate (sub)systems but differed from monolinguals in several acoustic correlates
- our speakers do not differ from monolinguals (not robustly)

Acoustics and articulation

- **burst amplitude differences**
  - perhaps laminal (dental) constrictions, which have more contact surface, are released more slowly than apical (alveolar) constrictions
  - perhaps path of airstrem after constriction differs and it hits more of an obstacle (teeth) in alveolars than in dentals
- resonance frequencies
  - if dental contact is more fronted than alveolar contact, we expect higher resonance frequencies for dentals because the size of the front cavity would be smaller for dentals
  - not the obtained pattern (pattern is consistently reversed)
  - at release, there must not be a difference in fronting of constriction

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Contrastive features

Features of Spanish and English /d/ and /t/

- Place
  - /d t/ are [coronal] in both languages
- Voicing
  - Spanish /d/ is [voice]
  - English /t/ is [spread glottis]
  - Spanish /t/ and English /d/ are neither[7]
- Lingual contact
  - Spanish /d t/ dental stops are [+ distributed], laminal
  - English /d t/ alveolar stops are not [− distributed], apical

[7] Beckman, Helgason, McMurray and Ringen, 2011

Contrastive features

- no evidence of a compromise in bilingualism
- bilinguals have full Spanish and English phonological systems
- compared to a monolingual Spanish speaker
  - a bilingual has [− distributed] and [spread glottis]
- compared to a monolingual English speaker
  - a bilingual has [+ distributed] and [voice]

Conclusion

- **Acoustics of Spanish and English coronal stops differ**
  - attested differences in line with prior descriptions of dental vs. alveolar stops, within and across languages
  - articulatory-acoustic link continues to be a mistery
- **Early, proficient Spanish-English bilinguals from Arizona keep separate (sub)systems for their coronal consonants**
  - sometimes *the bilingual is two monolinguals in one person*[8]

[8] Grosjean, 1989

Thank you

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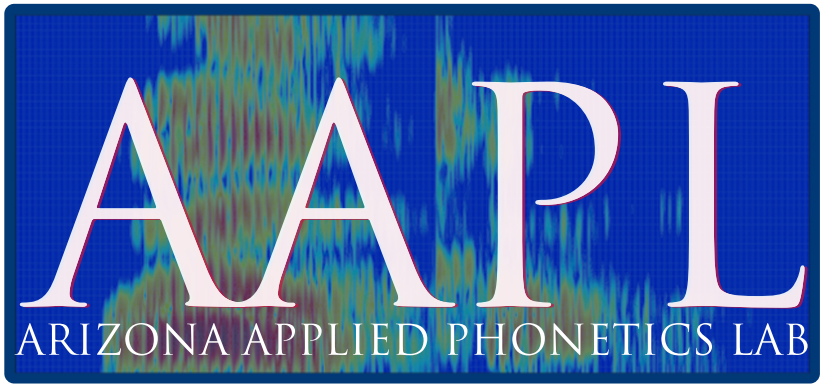

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