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# Asymmetries in Spanish-English Gestural Drift: Data and Model

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# Gestural Drift

- *Perceptually guided changes in speech production* (Sancier & Fowler, 1997)
- Initial finding:
  - Changes in the Voice Onset Times (VOTs) of a Portuguese-English speaker's voiceless stops.
  - VOTs attuned to the VOTs of her Ambient Language (henceforth AL)

# Symmetrical Drift

- Speaker's VOTs attuned to the VOTs of her AL
  - Longer in an English-speaking context
  - Shorter in a Portuguese-speaking context
- The pattern was observed in BOTH of the speaker's languages
- Explanations:
  - Interference
    - Similar phonological categories in L1 and L2 influence each other
    - Bilingual speakers' phonetic categories are assimilated or coupled and drift together

Flege (1996)

# Spanish-English Gestural Drift

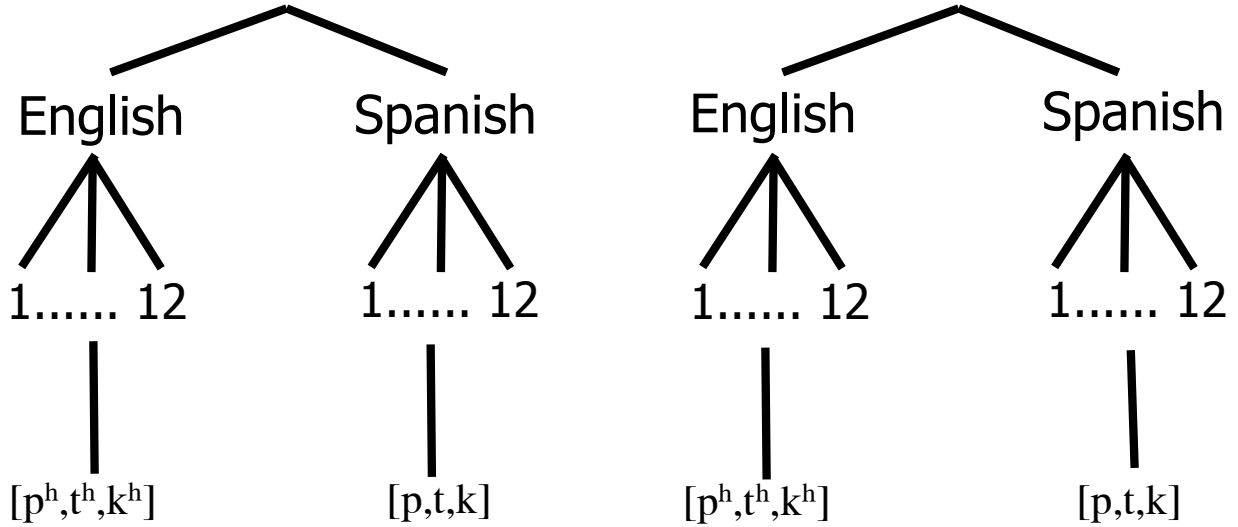
- 5 Spanish(L1)-English(L2) speakers
  - Design
  - Recorded after
    - Min. 5 months in Connecticut
    - Min. 3 weeks in a Spanish-speaking country
  - VOTs of [p], [t] and [k] measured
  - 12 sentences x 5 repetitions x 2 languages
    - 120 tokens of each C in each recording

# Asymmetrical Drift

- No main effect of AL
  - Interaction of *language* & *AL*
- Drift had occurred only in **English**
- Spanish VOTs did not change
  - These participants actively use Spanish in the US
- Hypothesis:
  - Variation in the extent of use of a language fosters drifts in its phonetic categories

# Design & Stimuli

**Ambient Language (2):** **English** **Spanish**



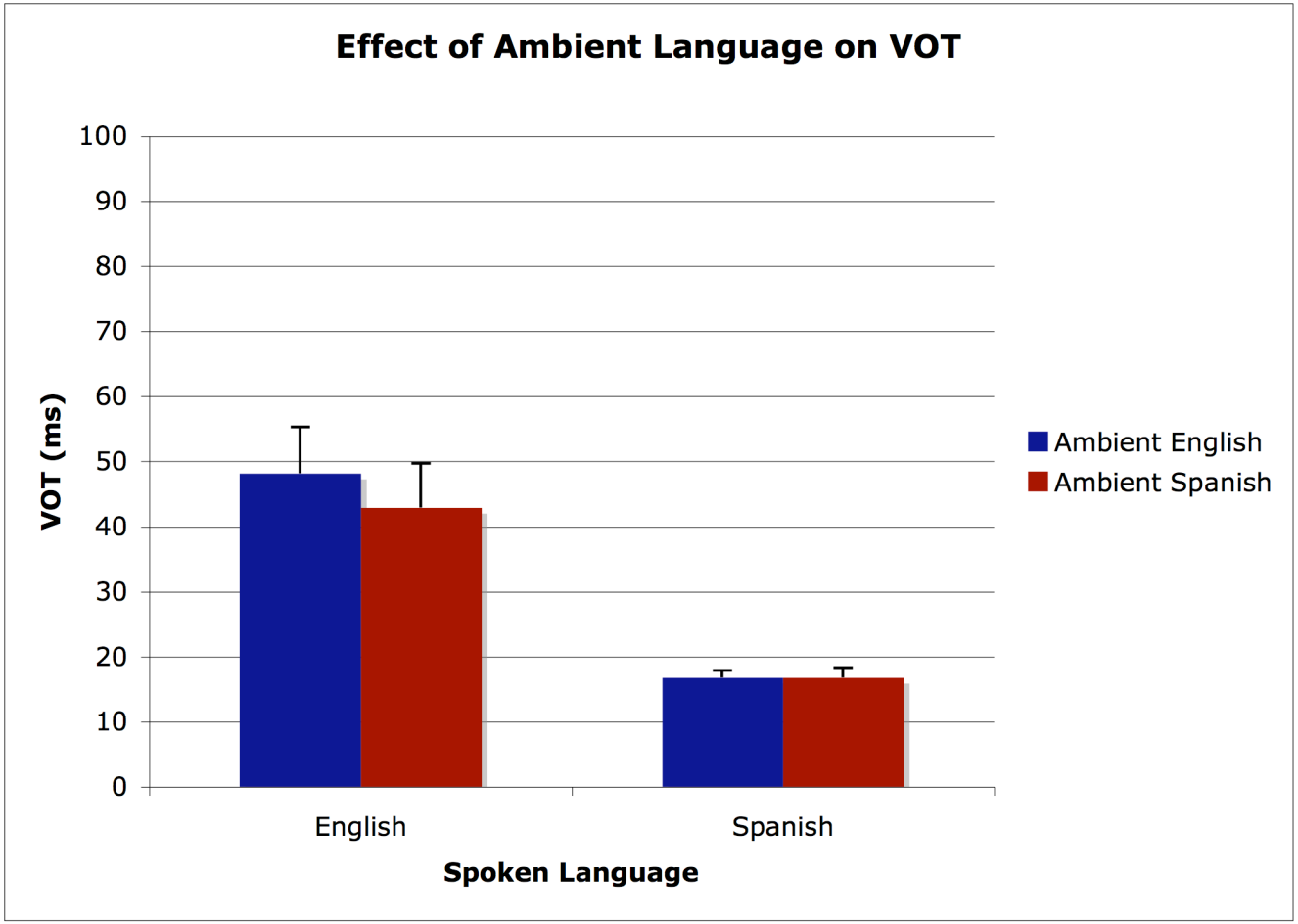

**English** *John had soup and **t**ea at B**o**b & **P**ete's **c**afe.*
[tʰ pʰ kʰ]

**Spanish** *El sonido de la or**qu**esta rusa resonó **p**or **t**oda la sala.*
[k p t]

# New Analyses

- RM ANOVA with 2 more participants (7)
- Significant effects:
  - Language $F(1,6) = 16.196$, $p = .007$
  - Consonant $F(2,12) = 52.639$, $p < .001$
  - AL x Language
    $F(1,6) = 9.797$, $p = .020$

# Interaction of AL & Language



# Individual Participant ANOVAs: I

- Effect of AL on [p] VOT

| Ptp | df1 | df2 | *F* | *p* | AL*Lang | English post-hoc | Spanish post-hoc |
|---|---|---|---|---|---|---|---|
| **1** | 1 | 230 | 6.237 | .013 | | *t*(57)=2.36, n.s. | *t*(59)=1.60, n.s. |
| **2** | 1 | 236 | 17.890 | <.001 | | *t*(59)=6.78,p<.001 | *t*(59)=5.54,p<.001 |
| **3** | 1 | 232 | .960 | .328 | | | |
| **4** | 1 | 236 | 2.135 | .145 | | | |
| **5** | 1 | 225 | 6.132 | .014 | | *t*(57)=-1.33, n.s. | *t*(58)=-3.88,p<.001 |
| **7** | 1 | 236 | 7.667 | .006 | * | *t*(59)=5.47,p<.001 | *t*(59)=-1.52, n.s. |
| **8** | 1 | 236 | 1.576 | .211 | | | |

Positive *t* values expected

# Individual Participant ANOVAs: II

- Effect of AL on [t] VOT

| Ptp | df1 | df2 | *F* | *p* | AL*Lang | English post-hoc | Spanish post-hoc |
|---|---|---|---|---|---|---|---|
| **1** | 1 | 230 | .067 | .796 | | | |
| **2** | 1 | 236 | 25.342 | <.001 | * | *t*(59)=5.71,p<.001 | *t*(59)=3.67,p=.001 |
| **3** | 1 | 232 | 2.004 | .158 | | | |
| **4** | 1 | 236 | .027 | .870 | | | |
| **5** | 1 | 225 | 1.525 | .218 | | *t*(58)=.033, n.s. | *t*(59)=-4.18,p<.001 |
| **7** | 1 | 236 | 2.439 | .120 | * | *t*(59)=3.94,p<.001 | *t*(59)=-3.28,p=.002 |
| **8** | 1 | 236 | .313 | .577 | | | |

Positive *t* values expected

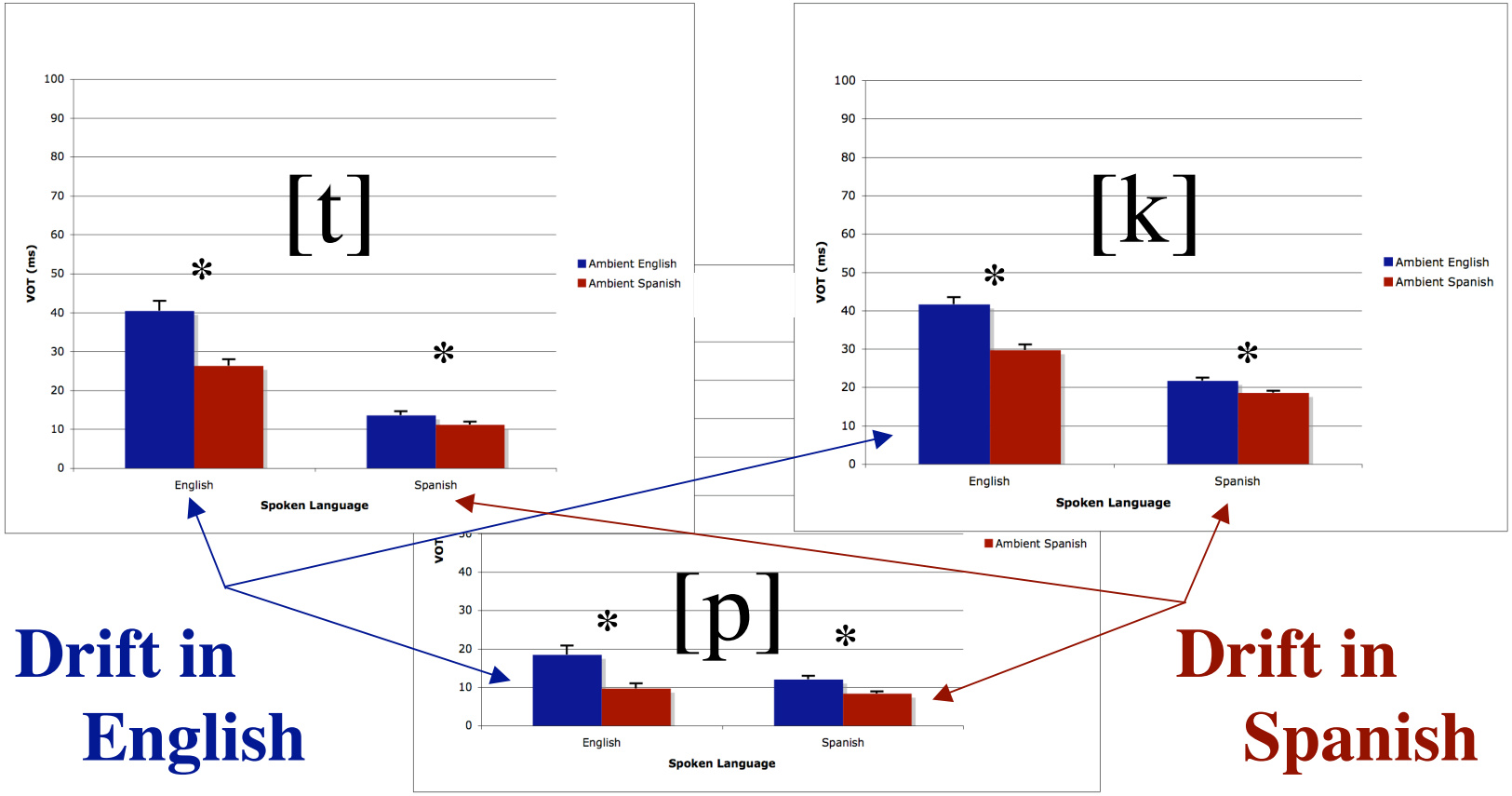
# Individual Participant ANOVAs: III

- Effect of AL on [k] VOT

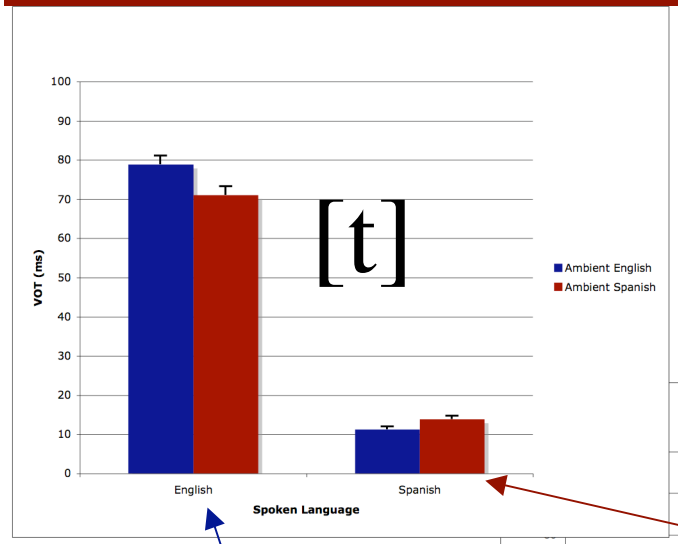
| Ptp | df1 | df2 | *F* | *p* | AL*Lang | English post-hoc | Spanish post-hoc |
|---|---|---|---|---|---|---|---|
| **1** | 1 | 230 | 5.457 | .020 | | *t*(58)=2.88,p=.006 | *t*(59)=.97,n.s. |
| **2** | 1 | 236 | 38.742 | <.001 | * | *t*(59)=8.10,p<.001 | *t*(59)=5.24,p<.001 |
| **3** | 1 | 232 | 6.244 | .013 | * | *t*(59)=4.15,p<.001 | *t*(59)=-.56,n.s. |
| **4** | 1 | 236 | .164 | .686 | | | |
| **5** | 1 | 225 | 6.925 | .009 | | *t*(59)=-2.04, n.s. | *t*(52)=-1.35, n.s. |
| **7** | 1 | 236 | 22.630 | <.001 | * | *t*(59)=7.18,p<.001 | *t*(59)=-1.46, n.s. |
| **8** | 1 | 236 | 1.155 | .284 | | | |

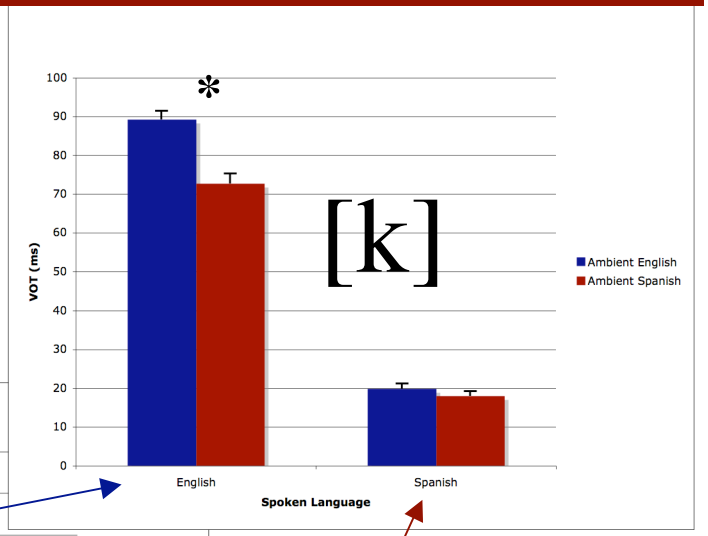
Positive *t* values expected

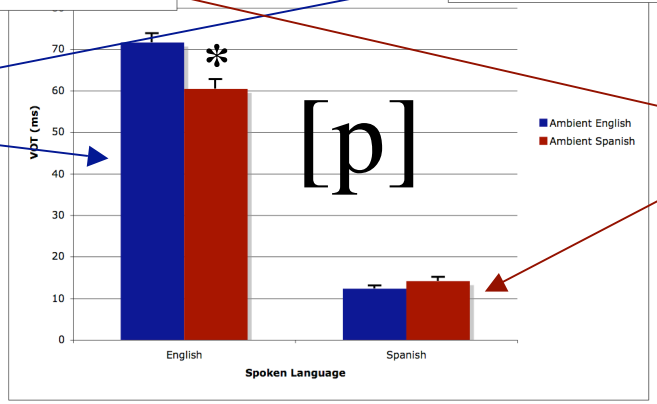
# Participant 2



# Participant 7




**Drift in English**

**No consistent drift in Spanish**

# Individual Variation

- Individual analyses reveal variation in
  - whether speakers drift or not
  - the language(s) in which drift occurs
  - the magnitude of drift
- Possible sources of variation include
  - Duration of English language training
  - Total time spent in ambient English
  - Proficiency in English

# Divergence from Native English VOT

- Measures of proficiency (e.g. LEAPQ) Marian et al. 2007
  - may be too general to capture changes in VOT
- VOT difference scores
  - (Native English $VOT_1$) - (Participant $VOT_2$)
    - $_1$From Fowler et al.'s (2008) 94 monolingual English speakers (CT, Ottawa and Quebec)
    - $_2$From participant's ambient English condition
- Drift difference scores
  - (Ambient English VOT) - (Ambient Spanish VOT)
    - Calculated by language, sentence and consonant

# Correlation

- Pearson's Correlation
  - computed to assess relationship between VOT diff. scores and Drift diff. scores
  - ***r* = -.219, *n* = 84, *p* = .045**
  - Longer, English-like VOTs led to greater drift than shorter, Spanish-like ones

# Modeling of gestural drift

- Nonlinear dynamics can capture
  - Discreteness of phonology
  - Continuity of phonetics
- Phonological categories modeled as modes in a distribution
  - Modes are Gaussian functions
  - e.g. Dynamic field theory (Erlhagen & Schöner, 2002)
- Modes may result from competition between different modes
  - A language's outcome VOT results from competition between the underlying modes of two languages with different VOTs

# Gaussian function for VOT

$$G(x) = ae^{-\frac{(x-b)^2}{2c^2}}$$

- a: magnitude of mode

  proportional to VOT difference score
- b: location of mode

  Spanish ≈ 0 ms, English ≈ 50 ms
- c: width of mode

  constant across simulations

# Modeling of VOT shift

Language 1
**underlying**
VOT distribution

$$G_1(x) = a_1 e^{-\frac{(x-b_1)^2}{2c_1^2}}$$

Language 2
**underlying**
VOT distribution

$$G_2(x) = a_2 e^{-\frac{(x-b_2)^2}{2c_2^2}}$$

Language *i*
**outcome** VOT
distribution
(*i* = 1, 2)

$$G_i'(x) = a_i e^{-\frac{(x-b)^2}{2c_i^2}}$$

$$b = \max_x (s_i p_i G_i(x) + p_j G_j(x))$$

*s = sustainability (s >1) (currently, s equal to a)*
*p = exposure period (p >1)*

# Spanish VOT mode

Speaker w/ short English VOT

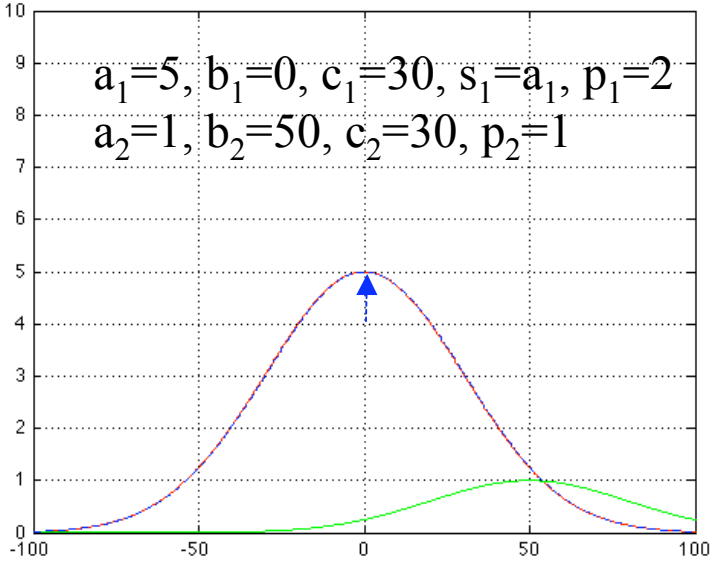
Speaker w/ long English VOT

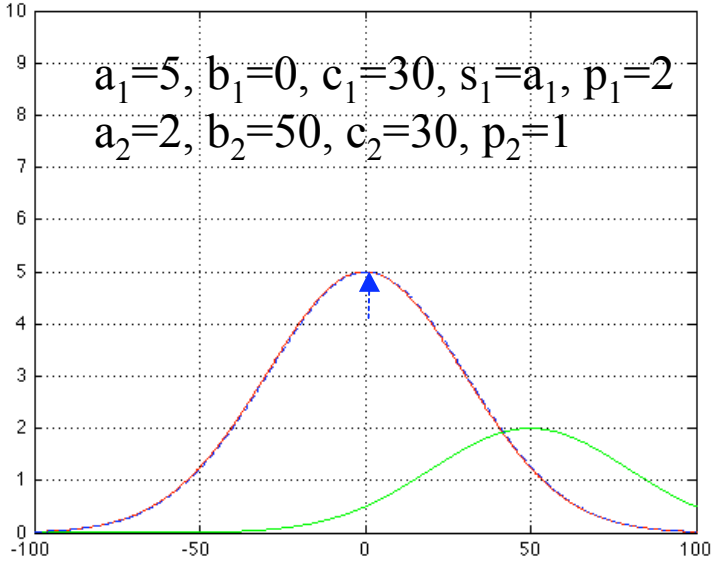
**Spanish**
Environment

underlying Spanish

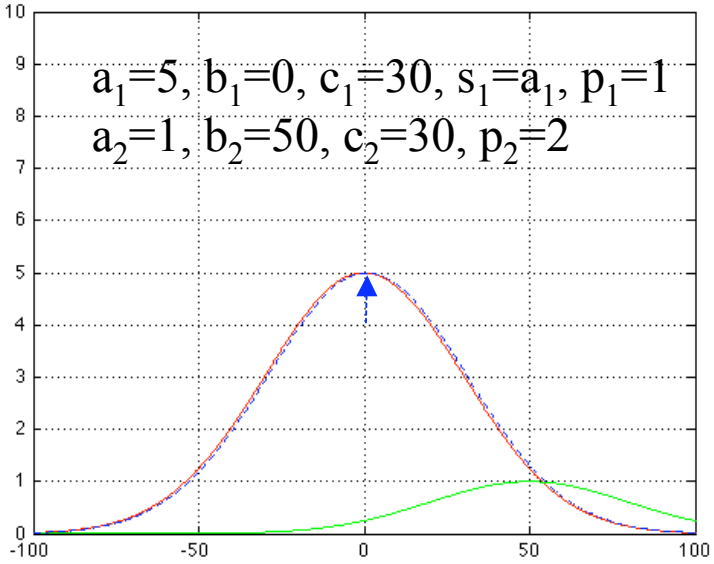
underlying English

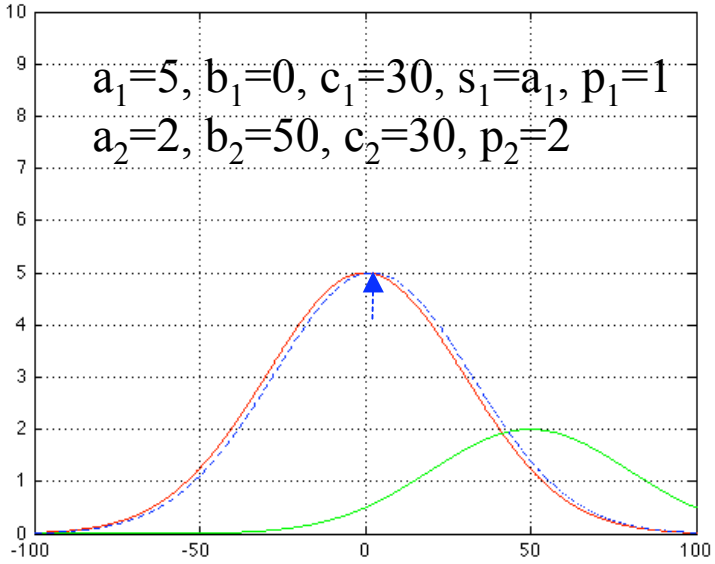
outcome English




**English**
Environment



# English VOT mode

Speaker w/ short English VOT

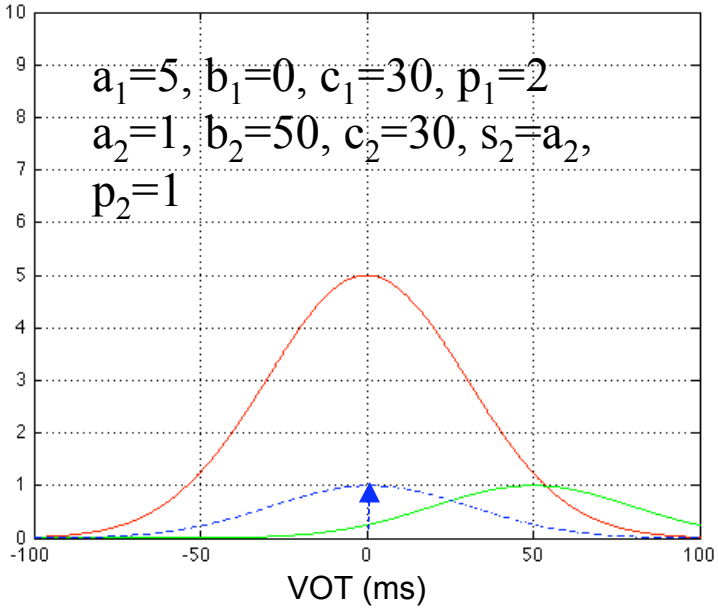
Speaker w/ long English VOT

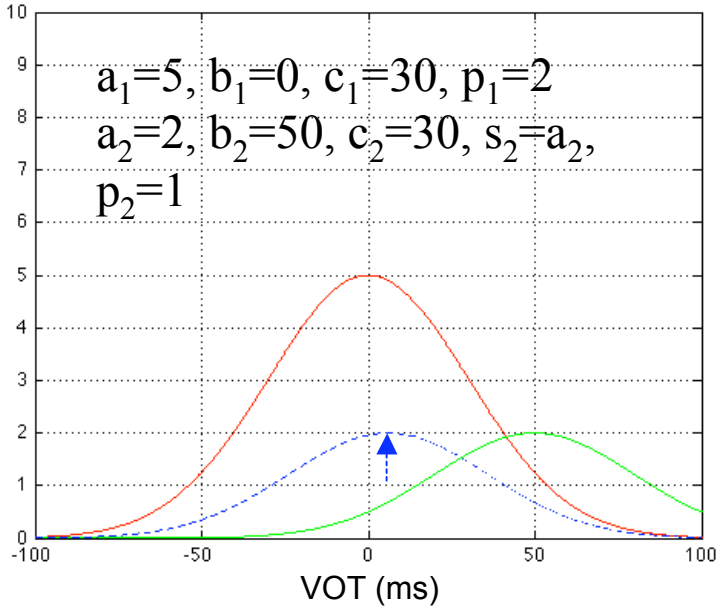
**Spanish**
Environment

underlying Spanish

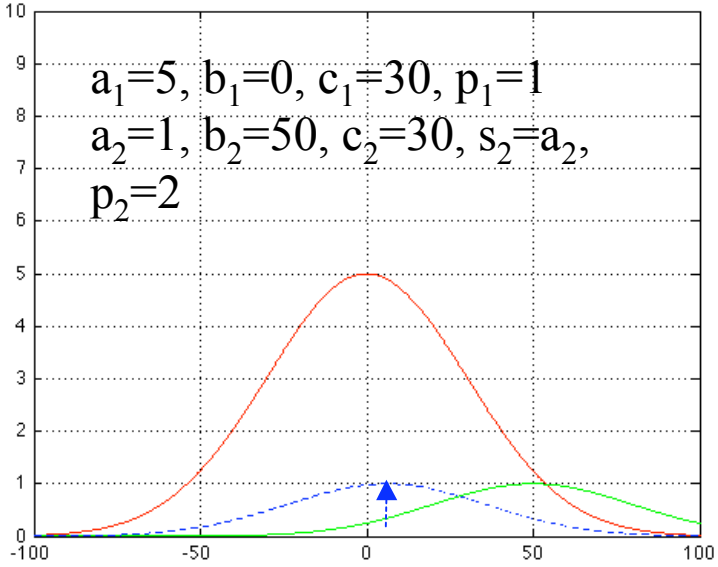
underlying English

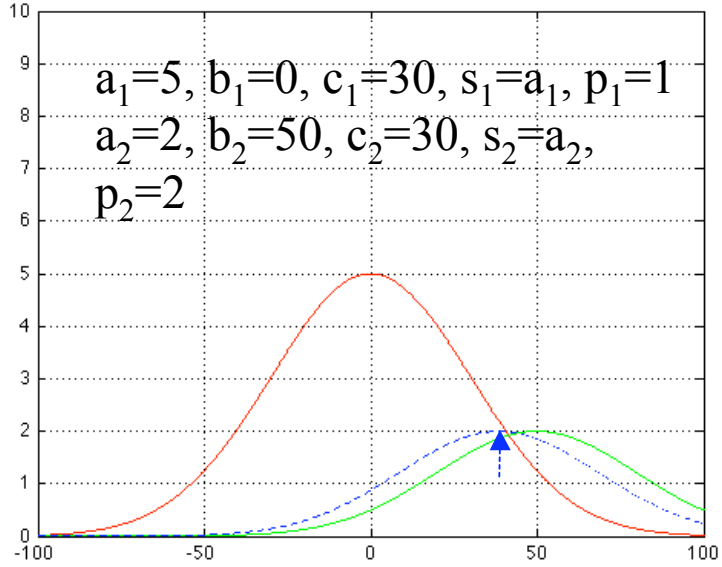
outcome English




**English**
Environment



# Observations

- VOT shift found more in English
  - Less in Spanish
- Smaller VOT difference scores (larger mode) yield greater drift.
  - Larger VOT difference scores yield less drift.

# Discussion

- Non-linear dynamics
  - successfully used to model subcategorical phenomenon
- Language-specific drift
  - Are categories coupled in these cases?
  - Perhaps not, or perhaps weakly
  - Does proximity to in-phase timing (0 VOT) inhibit drift?
    - The (highly) aspirated stops of Korean may be used to test this claim.

# Other factors that may affect drift

- Years of exposure to English
- Sensitivity to sound
- Personality type
  - 5 factor model OCEAN:
    - **Openness**, Conscientiousness, **Extraversion**, **Agreeableness**, Neuroticism