Utilizing density-controlled vowel space area to examine the role of language dominance in the acquisition of Spanish and English vowel reduction patterns

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Goals

• Motivate and explain method of calculating vowel space area using formant trajectories and local densities
• Apply to acquisition of L2 phonetics and phonology
Vowel space

• Interspeaker variation
  – L1 clear speech, talker characteristics (Bradlow et al. 1996; McCloy et al. 2012)
  – Bilingual vowel reduction, language profile (Menke & Face 2010; Ronquest 2013)
Vowel space

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  – L1 clear speech, talker characteristics (Bradlow et al. 1996; McCloy et al. 2012)
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• Intraspaker variation
  – L1 clear speech, task type (Story & Bunton 2017)
  – Bilingual vowel reduction, task type (Ronquest 2016)
Vowel space

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  - L1 clear speech, talker characteristics (Bradlow et al. 1996; McCloy et al. 2012)
  - Bilingual vowel reduction, language profile (Menke & Face 2010; Ronquest 2013)
  - L1/L2 vowel reduction, language dominance

- **Intraspeaker variation**
  - L1 clear speech, task type (Story & Bunton 2017)
  - Bilingual vowel reduction, task type (Ronquest 2016)
Vowel space

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Heritage Spanish vowel reduction

- Centralization of individual vowels in unstressed syllables (Elias et al. 2017; Menke & Face 2010; Ronquest 2013)
Heritage Spanish vowel reduction

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• Centralization of individual vowels after English code-switch (Elias et al. 2017)
Heritage Spanish vowel reduction

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Heritage Spanish vowel reduction

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- Decreased dispersion of vowels in less-monitored speech (Ronquest 2016)
- Potential cross-linguistic influence from English
Vowel reduction

• Methodological issues:
  – Impressionistic coding (Varela 1992)
  – Measurements taken from one point during vowel production (Elias et al. 2017; Menke & Face 2010; Ronquest 2013, 2016)
Vowel reduction

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• Solution (Story & Bunton 2017)
  – Use entire formant trajectory
  – Weight regions of vowel space based on frequency of occurrence
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• Novel application to L1/L2 vowel reduction
  – Interspeaker comparison: language dominance
  – Intraspeaker comparison: language of task
Case study

- Corpora
  - DIMEx100 for Spanish monolingual speakers (Mexico City)
  - CBAS for Spanish-English bilinguals (California Bay Area)
Case study

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• Language dominance
  – Bilingual Language Profile (Birdsong et al. 2012)
Case study

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Language dominance
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![Diagram showing binned groups and dominance (BLP)]
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- **Lexical stress**
Case study

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- Language dominance
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- Lexical stress
- Average vowel duration by speaker by language
Step-by-step methodology

1. F1 and F2 measurements at 5 ms intervals
2. Removal of outliers, median scaling
3. Creation of empty grids with discretized dimensions
4. Local density calculations with field-of-view
5. Scale density measures
6. Convex hull at specified scaled density → DV
7. Creation of heat maps → Visual
Step-by-step methodology

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Median scaling

\[ F'_n = \frac{F_n - \overline{F}_n}{\overline{F}_n}, \quad \overline{F}_n = \text{median} \]
Median scaling

- $F'_n = \frac{F_n - \bar{F}_n}{\bar{F}_n}$, $\bar{F}_n = \text{median}$

- Transformed data:
  - Median = 0
  - Median dev. = 1
Step-by-step methodology

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Grid with discretized dimensions

- Simplified visual
Grid with discretized dimensions

- Simplified visual
Grid with discretized dimensions

- Simplified visual
- Python:
  - 2-dimensional array with tuples of coordinates
  - Increments of 0.01
  - shape (201, 201)
Step-by-step methodology

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7. Creation of heat maps \( \rightarrow \) Visual
Field-of-view

- Each coordinate pair in grid
- Number of F1/F2 measurements in field-of-view of radius 0.05
Field-of-view

- Each coordinate pair in grid
- Number of F1/F2 measurements in field-of-view of radius 0.05
- *Right:* local density of 3
Field-of-view

- Each coordinate pair in grid
- Number of F1/F2 measurements in field-of-view of radius 0.05
- Right: local density of 3
- Local density stored in each grid point
Field-of-view

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Scaled density

- All density measurements range from 0 to 1

\[ \text{density}^\prime = \frac{\text{density}}{\text{max}(\text{density})} \]
Step-by-step methodology

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Convex hull area (DV)

- Area of set of measurements enclosed by shape
Convex hull area (DV)

- Area of set of measurements enclosed by shape
- Conditional on scaled local density of grid points

- = scaled dens. < 0.25
- = scaled dens. > 0.25
Convex hull area (DV)

- Area of set of measurements enclosed by shape
- Conditional on local density of grid points
- Scaled density of 0.25 recommended by Story & Bunton
Convex hull area (DV)

- Area of set of measurements enclosed by shape
- Conditional on local density of grid points
- Scaled density of 0.25 recommended by Story & Bunton
- Areas at scaled density thresholds of 0.1, 0.15, 0.2, 0.25, and 0.3 to demonstrate sensitivity
- Area in units of squared std dev
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Heatmap (Visual)

Spanish stressed area = 3.838042
Only Spanish

Spanish monolingual  Balanced bilingual  L2 bilingual
• Language dominance and stress are not significant
  • Impressionistically, L2 bilingual has larger Spanish VSA
  • Impressionistically, bilinguals show slight centralization
Only bilinguals

Balanced bilingual

L2 bilingual
Only bilinguals

- Stress only significant in English
• Stress only significant in English
• Language dominance is not significant
  • Impressionistically, L2 bilingual has larger Spanish VSA
Discussion: methodology

- Visual aid, more representative of dynamic vowel production
Discussion: methodology

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- Built-in capability for handling outliers
Discussion: methodology

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• Can be used to COMPLEMENT vowel-specific analyses (e.g., Spanish/Catalan mid vowels)
Discussion: methodology

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- Can be used to COMPLEMENT vowel-specific analyses (e.g., Spanish/Catalan mid vowels)
- Further analysis of scaled density grids (e.g., KL divergence)
Discussion: methodology

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• Can be used to COMPLEMENT vowel-specific analyses (e.g., Spanish/Catalan mid vowels)
• Further analysis of scaled density grids (e.g., KL divergence)
• Application to L2 suprasegmental acquisition (acoustic consequences of lexical stress)
Acknowledgments

• Ernesto Gutiérrez Topete (UC Berkeley)
• Justin Davidson (UC Berkeley)
• Keith Johnson (UC Berkeley)

Send me comments and questions!

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References


