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)
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Heritage Spanish vowel reduction

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

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

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

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- Solution (Story & Bunton 2017)
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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)

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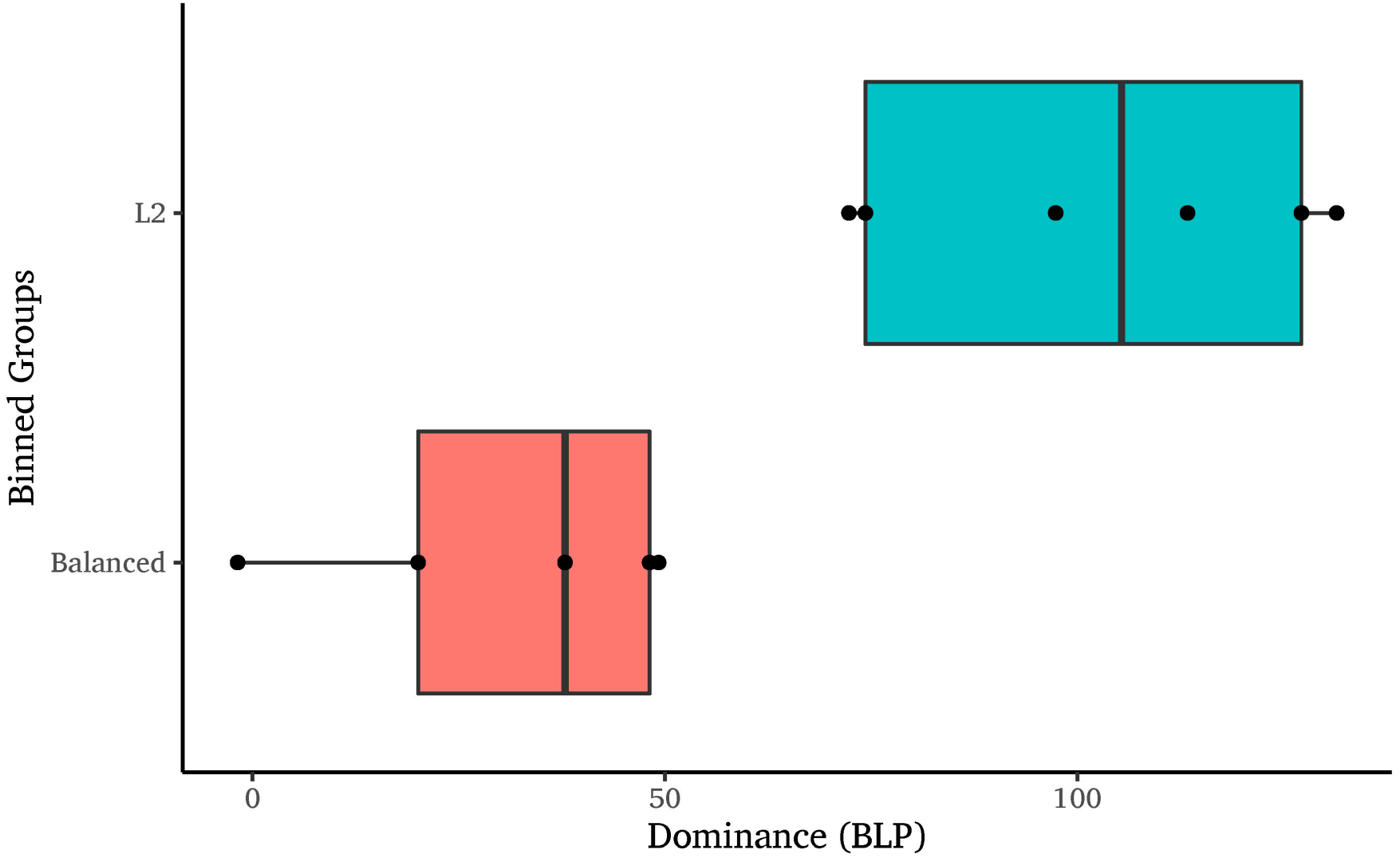
L2
Balanced
Binned Groups
0
50
100
Dominance (BLP)

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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

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Median scaling

- $F_n' = \frac{F_n - \widetilde{F_n}}{\widetilde{F_n}}$, $\widetilde{F_n}$ = *median*

Median scaling

- $F_n' = \frac{F_n - \widetilde{F_n}}{\widetilde{F_n}}$, $\widetilde{F_n}$ = *median*
- Transformed data:
  - Median = 0
  - Median dev. = 1

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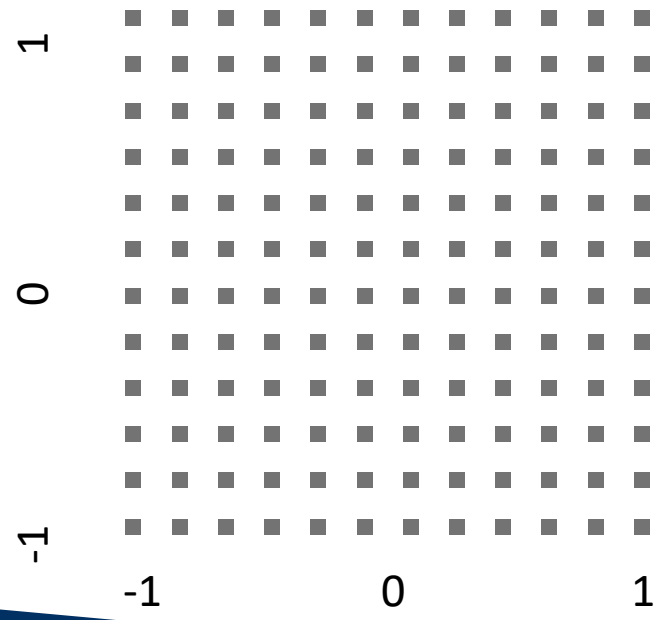
Grid with discretized dimensions

- 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)

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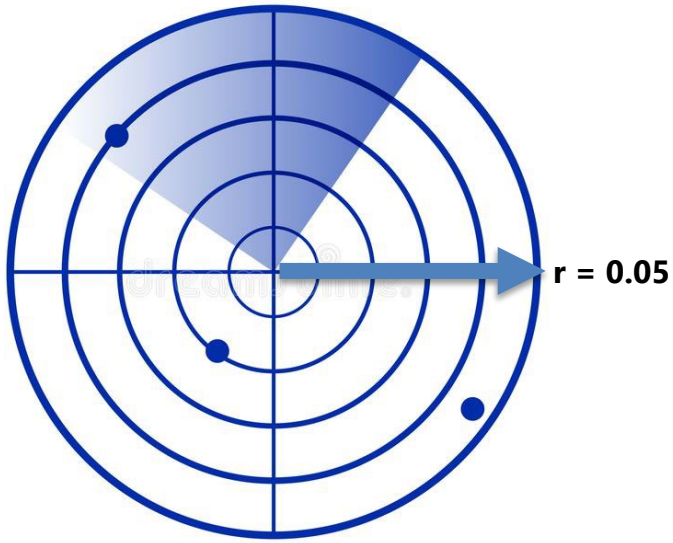
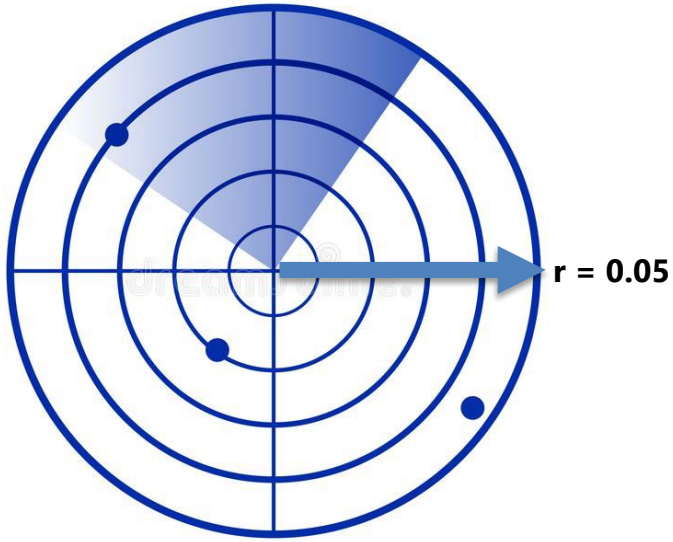
Field-of-view

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



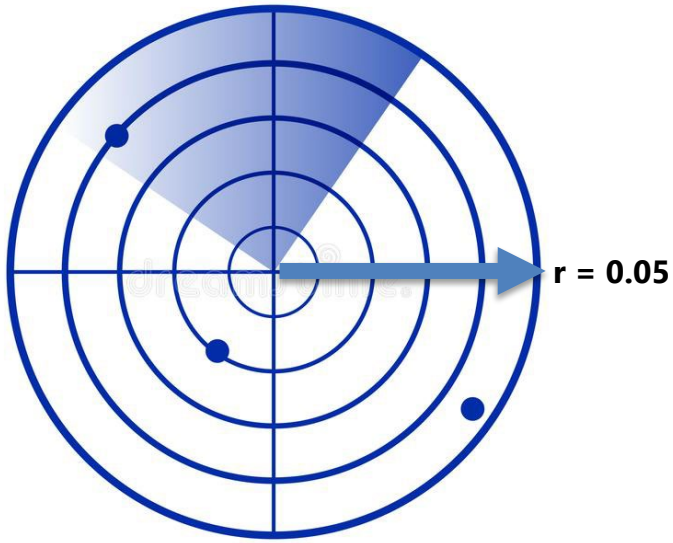
Field-of-view

- 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

5	9	23	32	33	0	0	0	0	0	0
3	28	30	47	0	0	0	0	0	0	0
7	1	3	0	0	0	0	0	0	0	0
14	21	20	25	27	38	40	0	0	0	0
18	29	0	0	0	0	0	0	0	0	0
12	13	15	0	0	0	0	0	0	0	0
20	26	27	11	25	38	40	0	0	0	0
32	33	34	0	0	0	0	0	0	0	0
29	18	0	0	0	0	0	0	0	0	0
5	9	8	24	0	0	0	0	0	0	0
28	16	17	0	0	0	0	0	0	0	0
18	29	0	0	0	0	0	0	0	0	0
25	26	20	11	0	0	0	0	0	0	0
7	1	3	0	0	0	0	0	0	0	0
33	32	9	5	23	0	0	0	0	0	0
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Scaled density

- All density measurements range from 0 to 1

$$density' = \frac{density}{\max(density)}$$

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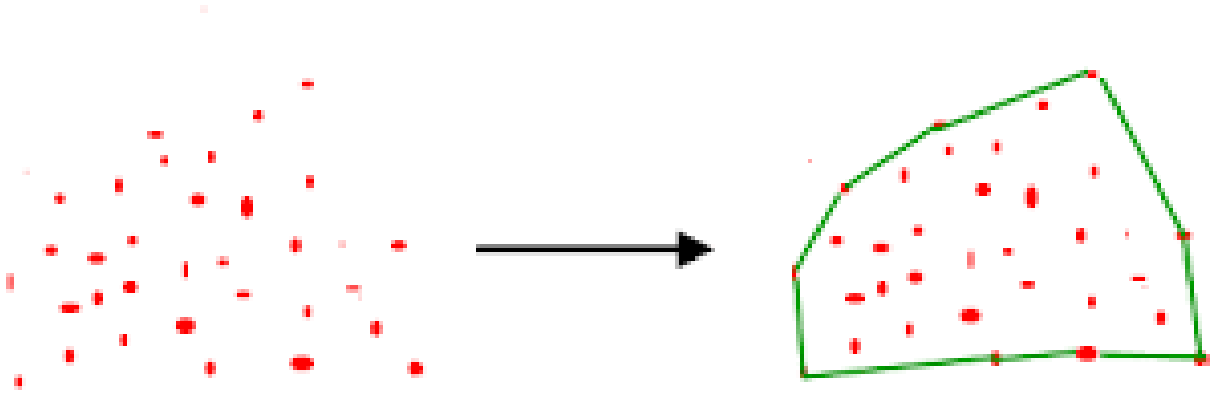
Convex hull area (DV)

- Area of set of measurements enclosed by shape



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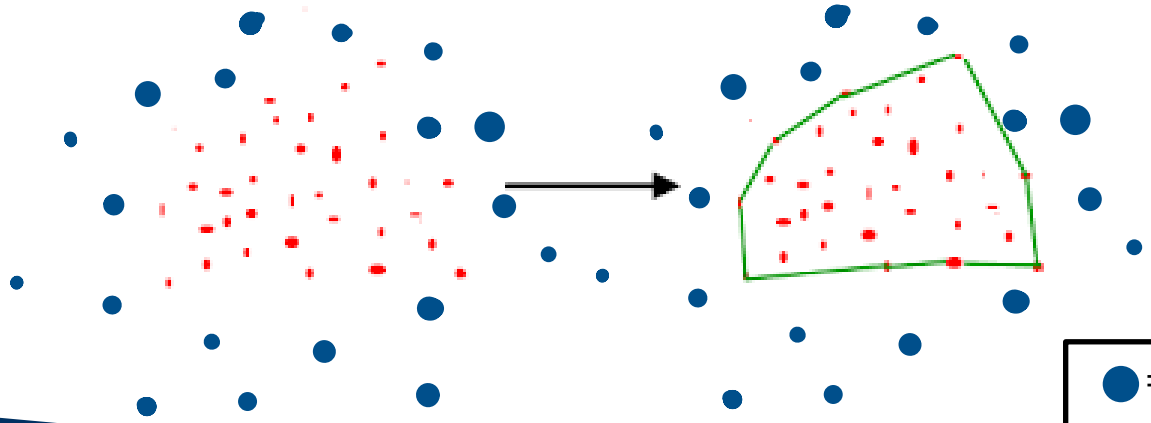
- Area of set of measurements enclosed by shape
- Conditional on scaled local density of grid points



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- 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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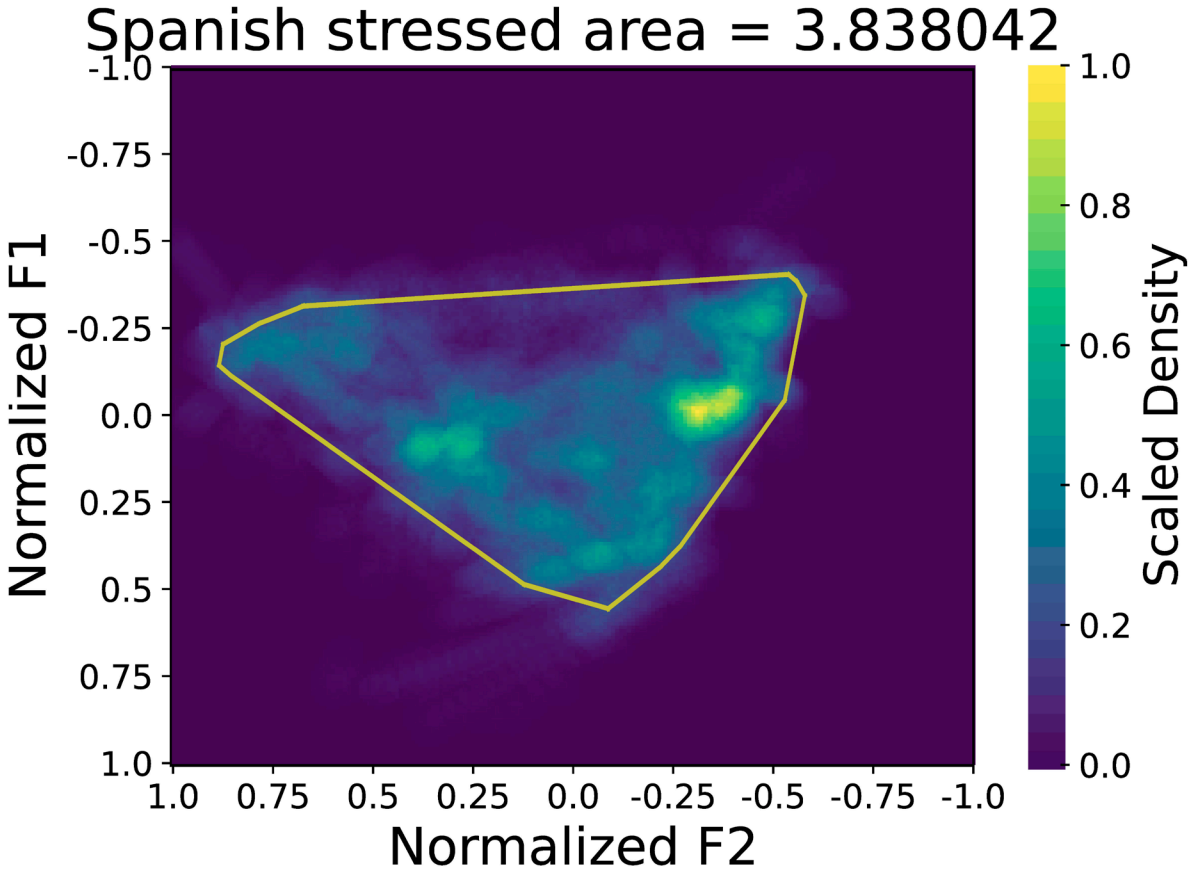
Heatmap (Visual)



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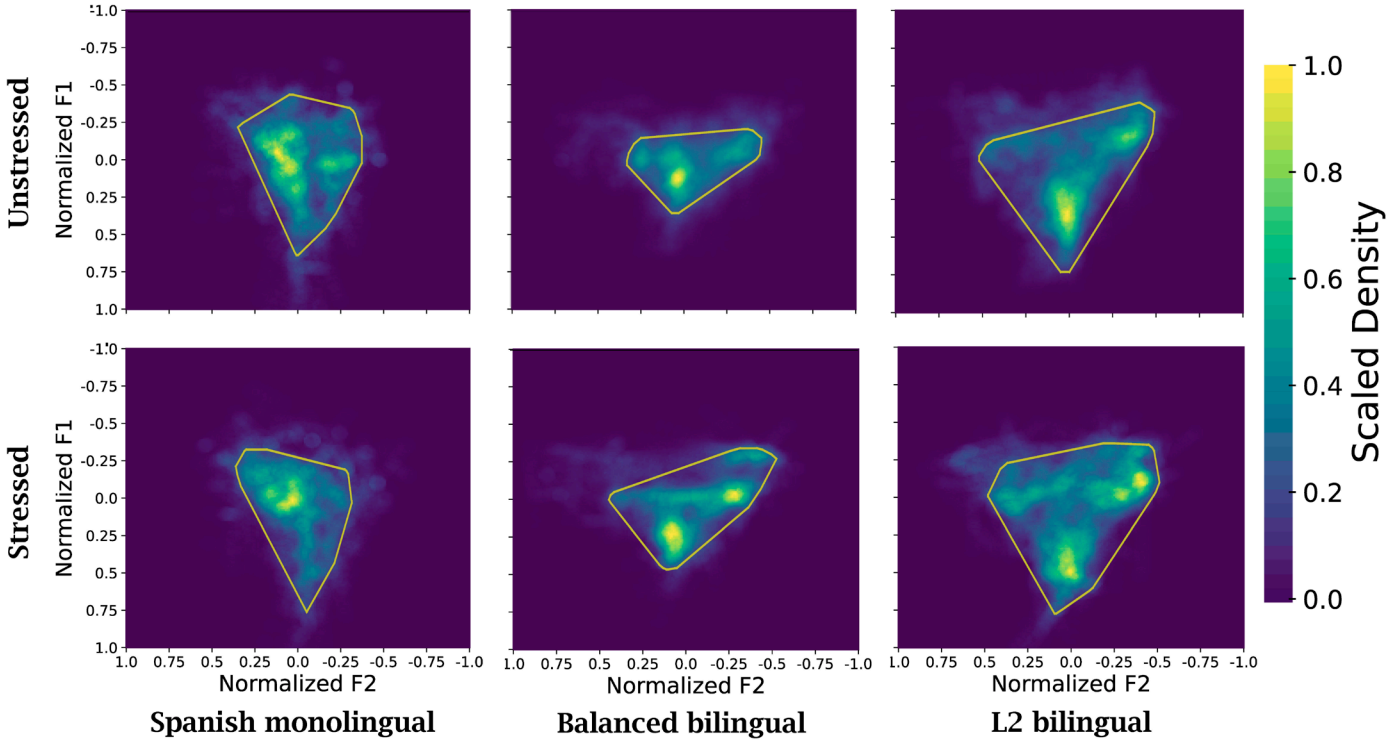
Only Spanish



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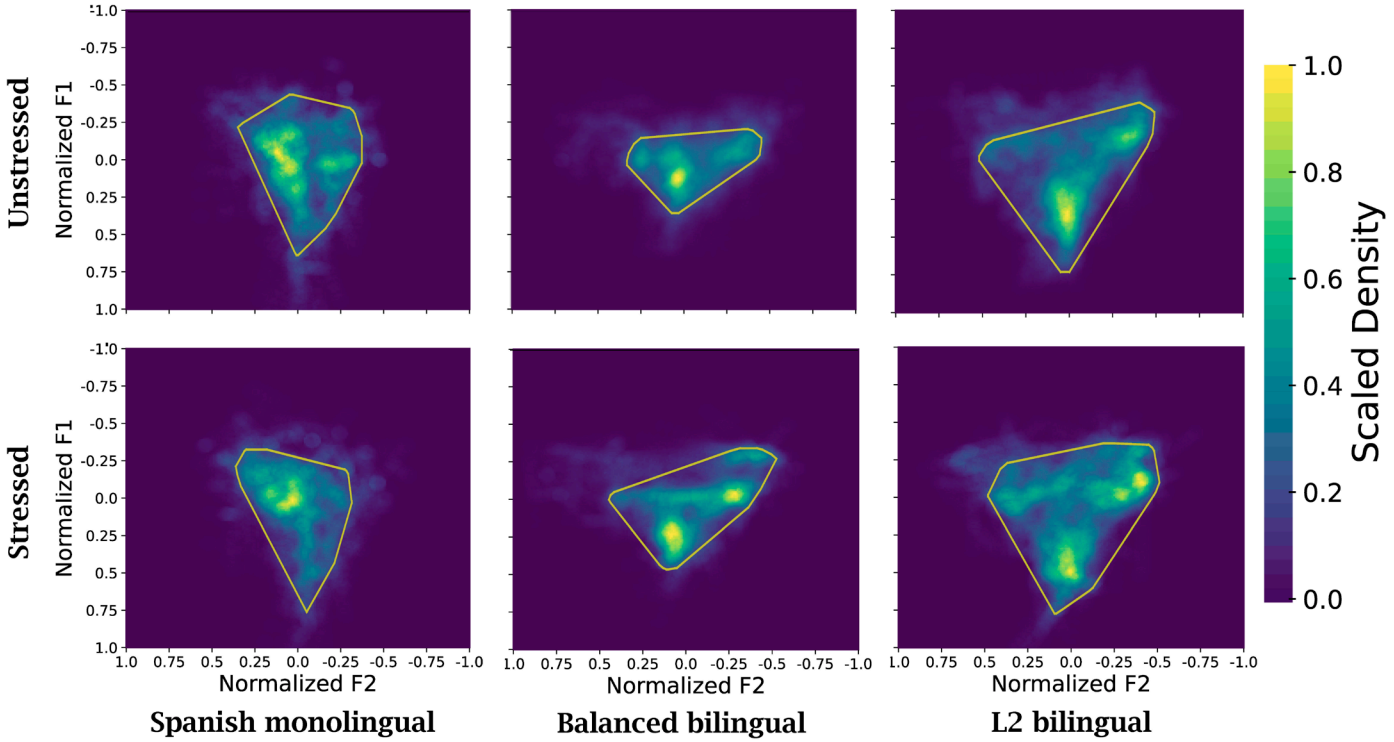
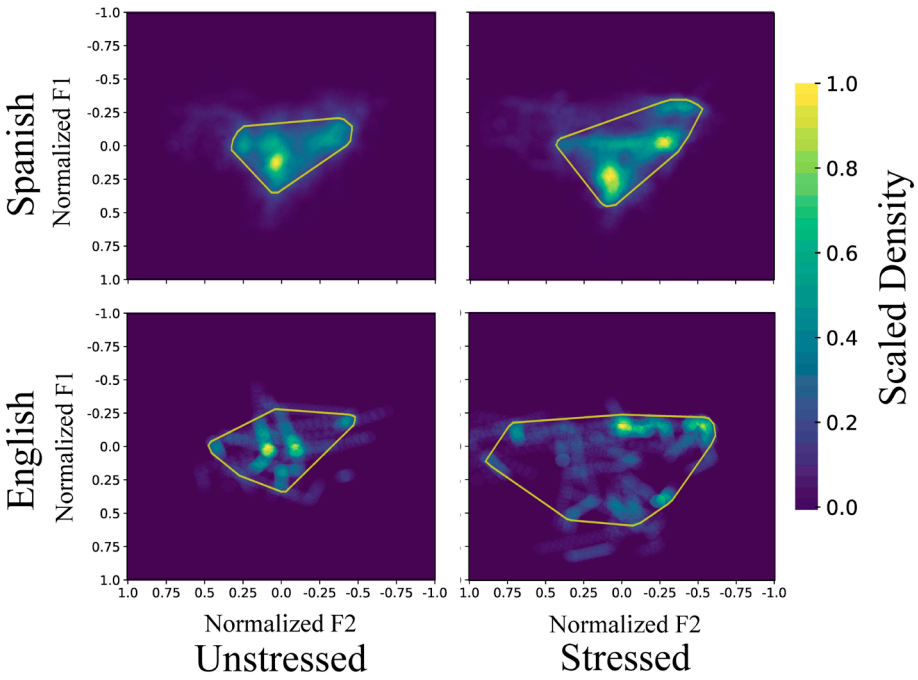
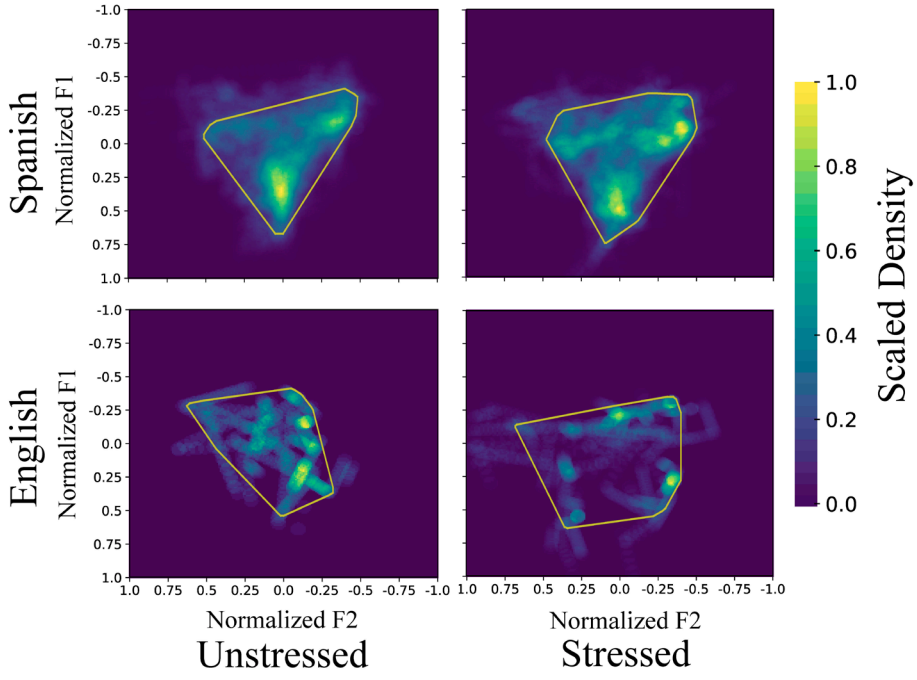


- Language dominance and stress are not significant
  - Impressionistically, L2 bilingual has larger Spanish VSA
  - Impressionistically, bilinguals show slight centralization

Only bilinguals

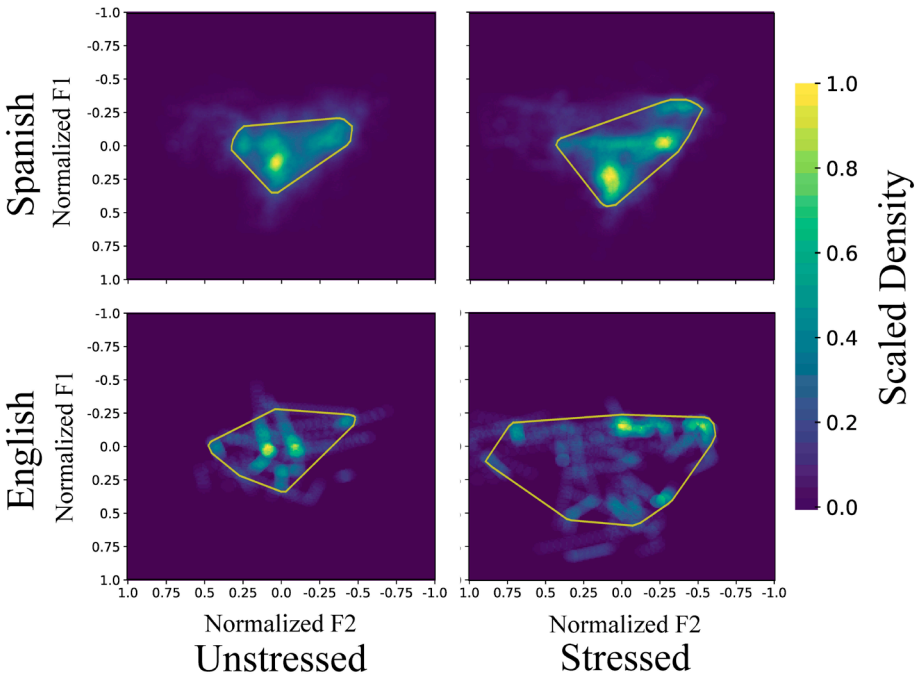


Balanced bilingual



L2 bilingual

Only bilinguals



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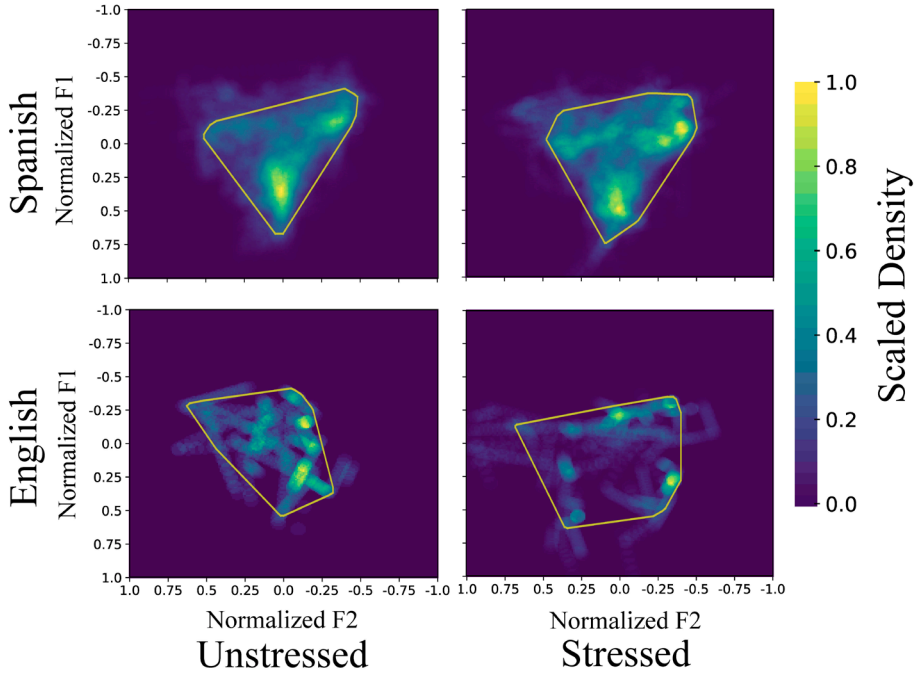
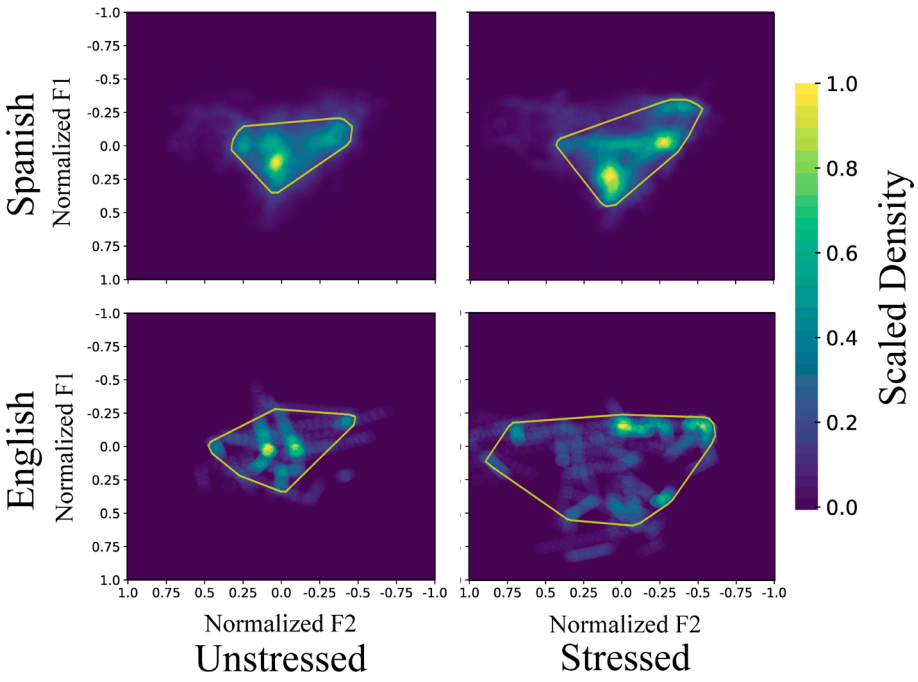


L2 bilingual

- Stress only significant in English

Only bilinguals



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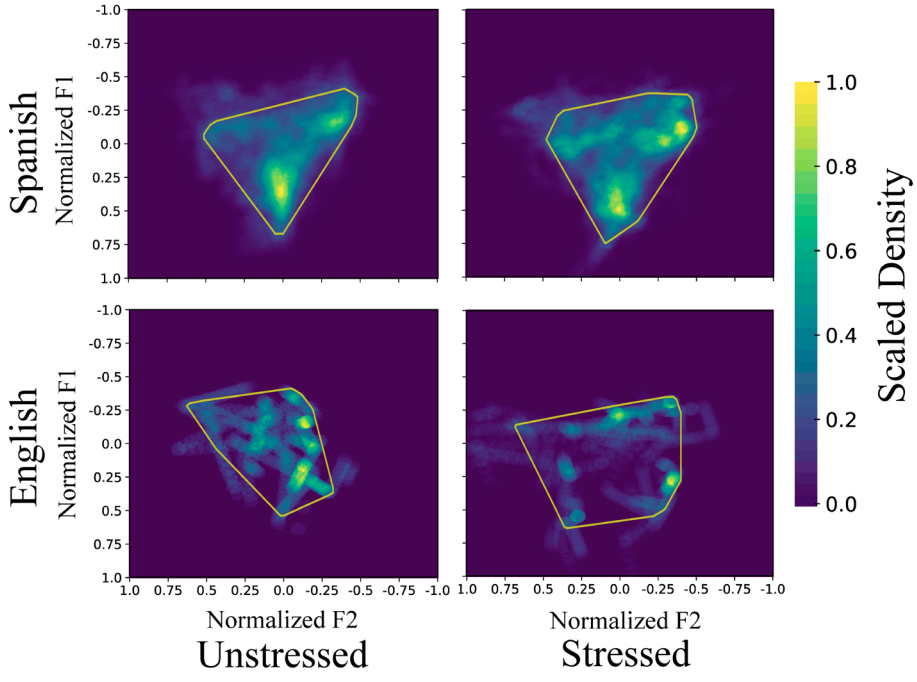

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- Can be used to COMPLEMENT vowel-specific analyses (e.g., Spanish/Catalan mid vowels)
- Further analysis of scaled density grids (e.g., KL divergence)
- Application to L2 suprasegmental acquisition (acoustic consequences of lexical stress)

Acknowledgments

- Ernesto Gutiérrez Topete (UC Berkeley)
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Send me comments and questions!

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