BILINGUAL ACOUSTIC VOICE VARIATION IS SIMILARLY STRUCTURED ACROSS LANGUAGES

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VOICES ARE HIGHLY VARIABLE

- Voice variability seems to be largely idiosyncratic[1]
- To know a voice is to know how it varies across environments, physical states, and emotions
- Is this variation influenced by language?

[1] Lee, Y., Keating, P., & Kreiman, J. (2019). Acoustic voice variation within and between speakers. The Journal of the Acoustical Society of America, 146(3), 1568–1579.

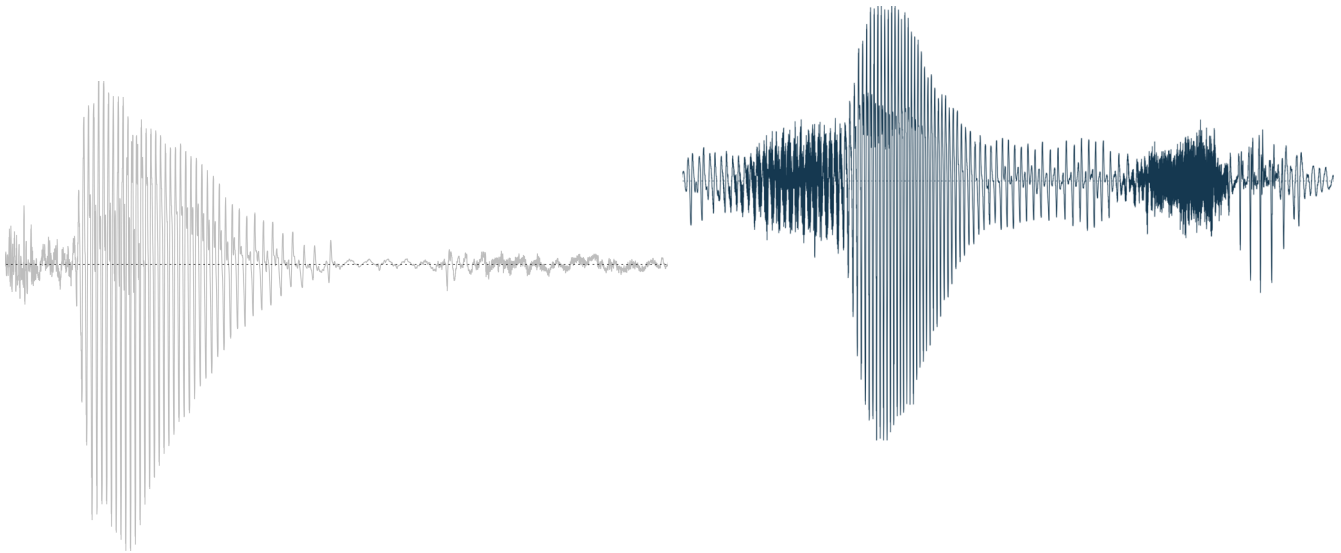
THE ROLE OF LANGUAGE IN VOICE VARIABILITY

- Segmental, suprasegmental, & prosodic aspects of languages vary
- Few Cantonese-English voice quality comparisons[2] :
  - ➞ English tends to be creakier (or less breathy)
  - ➞ Cantonese tends to have lower, more variable pitch
- Perceptual evidence that bilingual talkers can be identified after a language switch, especially by other bilinguals[3]

[2] Ng, M. L., Chen, Y., & Chan, E. Y. K. (2012). Differences in Vocal Characteristics Between Cantonese and English Produced by Proficient Cantonese-English Bilingual Speakers—A Long-Term Average Spectral Analysis. Journal of Voice, 26(4), e171–e176.

[3] Orena, A. J., Polka, L., & Theodore, R. M. (2019). Identifying bilingual talkers after a language switch: Language experience matters. The Journal of the Acoustical Society of America, 145(4), EL303–EL309.

DO BILINGUAL TALKERS HAVE THE SAME VOICE IN EACH OF THEIR LANGUAGES?



DATA

www.spice-corpus.rtfd.io

- SpiCE Corpus[4]
  - 34 high-proficiency, early Cantonese-English bilinguals
  - 30-minute conversational interviews in Cantonese & English
  - High-quality audio
- Pre-processing:
  - Select all voiced participant speech with Praat[5] algorithm
  - Includes vowels, approximants, & some voiced obstruents

[4] Johnson, K. A., Babel, M., Fong, I., & Yiu, N. (2020). SpiCE: A New Open-Access Corpus of Conversational Bilingual Speech in Cantonese and English. Proceedings of The 12th Language Resources and Evaluation Conference, 4089–4095.
[5] Praat

ACOUSTIC MEASUREMENTS

- Drawn from psychoacoustic voice quality model,[6] measurements every 5 ms with VoiceSauce[7]

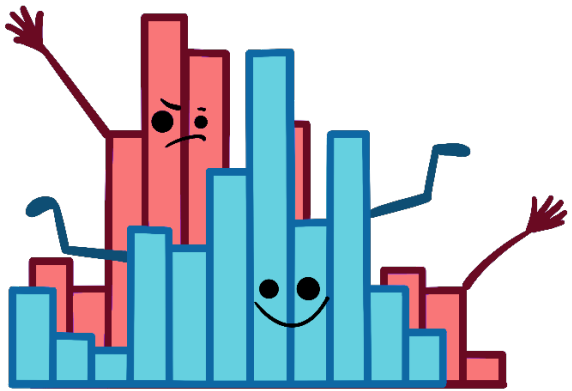
Pitch F0	**Source spectral shape** H1*-H2*, H2*-H4*, H4*-2kHz*, H2kHz*-5kHz*
Formants F1, F2, F3, F4	**Spectral noise** CPP, Energy, SHR

- Post-processing
  - Remove impossible values
  - Calculate moving s.d. for each measure

[6] Kreiman, J., Gerratt, B. R., Garellek, M., Samlan, R., & Zhang, Z. (2014). Toward a unified theory of voice production and perception. Loquens, 1(1), 009.
[7] Shue, Y.-L., Keating, P., Vicenik, C., & Yu, K. (2011). VoiceSauce: A program for voice analysis. Proceedings of the 17th International Congress of Phonetic Sciences, 3, 1846--1849.

METHODS 1/3

- Crosslinguistic comparison of acoustic measurements
  - ➞ Do bilingual talkers have the same mean values for each measure?
- Within- talker Principal components analyses (PCAs)
  - ➞ How is voice variability structured? How much of it is Idiosyncratic?
- Canonical redundancy analysis
  - ➞ How similar are talkers across languages?



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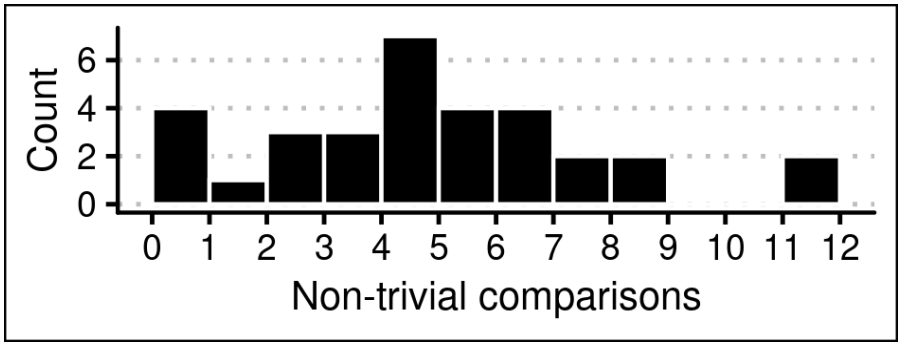
COMPARISON OF ACOUSTIC MEASUREMENTS

- Cohen's *d* for t-tests within-talker, across language
- Most talkers have relatively few non-trivial comparisons



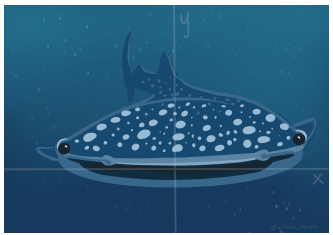
COMPARISON OF ACOUSTIC MEASUREMENTS

- Non-trivial differences tend to…
  - ➞ be small
  - ➞ lack a consistent direction
- When there is a consistent direction, it mirrors prior work
  - ➞ F0 tends to be lower in Cantonese
  - ➞ H1*-H2* consistently puts English on creakier end of spectrum

	Cohen's *d*		
Variable	**Trivial** ***0.0–0.2***	**Small** ***0.2–0.5***	**Medium** ***0.5–0.8***
F0	21	10	3
F0 s.d.	34	0	0
F1	24	9	1
F1 s.d.	29	5	0
F2	26	8	0
F2 s.d.	32	2	0
F3	24	9	1
F3 s.d.	29	5	0
F4	30	3	1
F4 s.d.	28	6	0
H1*–H2*	18	15	1
H1*–H2* s.d.	32	2	0
H2*–H4*	25	9	0
H2*–H4* s.d.	31	3	0
H4*–2kHz*	25	8	1
H4*–2kHz* s.d.	34	0	0
H2kHz*–5kHz*	23	10	1
H2kHz*–5kHz* s.d.	31	3	0
CPP	21	10	3
CPP s.d.	32	2	0
Energy	17	14	3
Energy s.d.	18	16	0
SHR	31	3	0
SHR s.d.	29	5	0

METHODS 2/3

- Crosslinguistic comparison of acoustic measurements
  - → Do bilingual talkers have the same mean values for each measure?
- Principal components analyses (PCAs)
  - → How is voice variability structured? How much of it is idiosyncratic?
- Canonical redundancy analysis
  - → How similar are talkers across languages?



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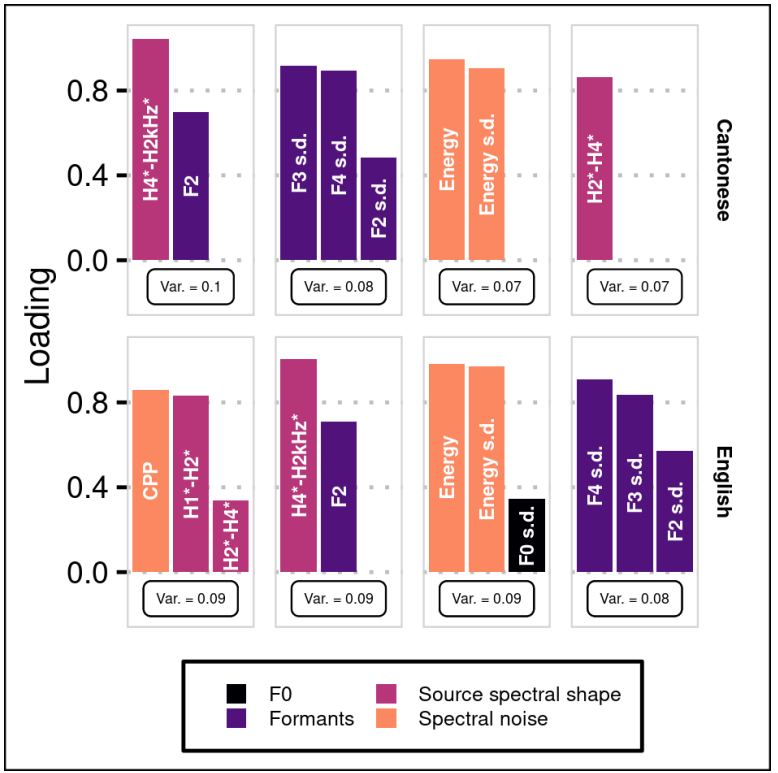
PCA DETAILS

- PCAs by talker and language
- All 24 measures (standardized)
- Oblique promax rotation
- Components retained if eigenvalues were > 0.7x the mean eigenvalue[8]
- Only |loadings| > 0.32 were interpreted

[8] Jolliffe, I. T. Principal Component Analysis, 2nd ed. New York: Springer-Verlag, 2002.

COMPONENT VARIABILITY

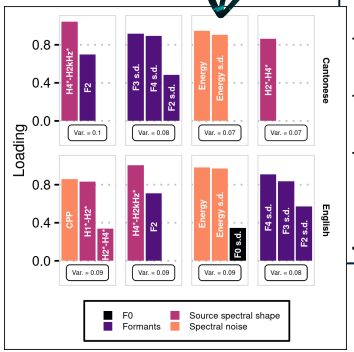
- 10–15 components accounted for 74.6–85.8% of the total variation
- Similar component structure across languages, but variable order



COMPONENT STRUCTURE

- Similar component composition across talkers and languages
- F0 is a less consistent variable
- Plenty of idiosyncratic variation

Variables	Cantonese N	Cantonese Var. %	English N	English Var. %
H4*–H2kHz*, H2kHz*–H5kHz*, F2, *F3*, *F4*	34	9.3–15.5	32	9.2–16.7
H4*–H2kHz* s.d., H2kHz*–H5kHz* s.d.	32	6.3–8.3	34	4.1–5.0
Energy, Energy s.d, *F0*	31	5.8–9.4	33	6.3–9.1
CPP s.d.	29	4.1–5.0	31	4.1–4.9
SHR, SHR s.d.	30	3.8–7.5	29	5.4–7.3
F3, F4, *F2*	26	6.0–8.5	29	5.8–8.5
F3 s.d., F4 s.d., *F2 s.d.*	26	5.3–8.6	29	4.7–8.6
H2*–H4* s.d., H1*–H2* s.d.	26	4.2–6.5	28	4.2–6.8



METHODS 3/3

- Crosslinguistic comparison of acoustic measurements
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- Within- talker Principal components analyses (PCAs)
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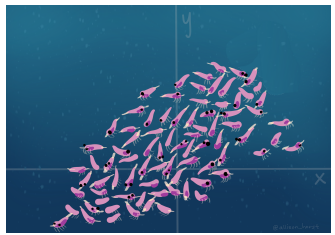

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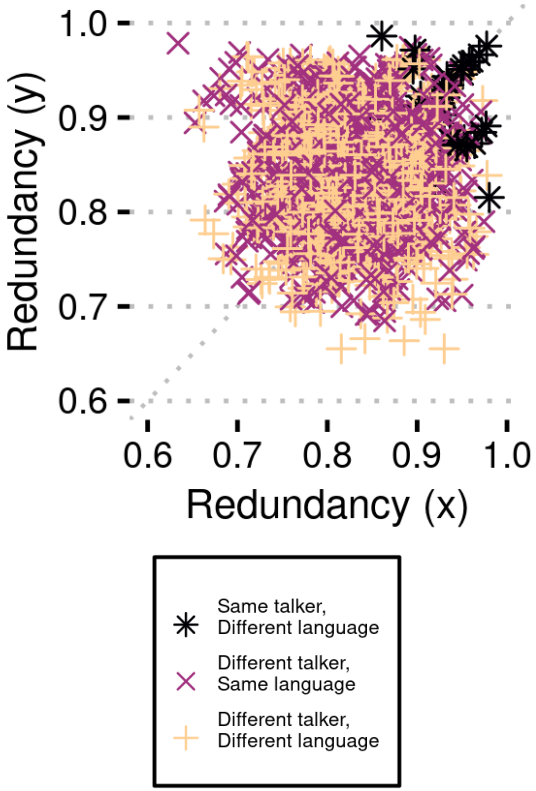
CANONICAL REDUNDANCY ANALYSIS

- Allows for comparison of two PCAs, and accounts for different component orders
- Asymmetrical ➞ variation in A accounted for by B and vice versa
- All loadings retained
- Within-talker comparisons are significantly more redundant: *Welch's t*(71.36) = –17.83, $p < 0.001$, d = 1.76



DISCUSSION

- Methodological differences from prior work[9] led us to find *more similarity across talkers* ➞ longer passages & decision to ignore component order
- Despite substantial segmental & suprasegmental differences across English & Cantonese, bilinguals exhibit similar spectral properties and structure in voice variability ➞ voices are like "auditory faces"
- Generates predictions related to bilingualism and cognitive organization of voices in speech perception

[9] Lee, Y., Keating, P., & Kreiman, J. (2019). Acoustic voice variation within and between speakers. The Journal of the Acoustical Society of America, 146(3), 1568–1579.

THANK YOU!

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The SpiCE corpus will be available soon! Follow for updates: **@khia_johnson**

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