Word class and frequency effects in Hawaiian stressed vowel clusters

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Reduction

- When linguistic units (segments, syllables, words) “are realized with less acoustic-phonetic substance” (Clopper & Turnbull 2018)

Frequency and reduction

- Higher frequency -> shorter acoustic durations
  - English (Gahl 2008)
  - Dutch (Pluymaekers, Ernestus & Baayen 2005)
  - Chinese (Sherr-Ziarko 2015)
- Higher frequency -> centralization in the vowel space
  - English (Munson & Solomon 2004)
  - French (Meunier & Espesser 2011)
  - (though see Tomaschek et al. 2017 for conflicting observations in German)

Word class and reduction

- Function words and pronouns -> shorter acoustic durations
  - English (Shi et al. 2005)
  - Dutch (van Bergem 1993)
  - French (Meunier & Espesser 2011)
  - Icelandic (Schäfer 2013)
  - Scottish Gaelic (Nance 2015)
  - Vietnamese (Nguyễn 2015)
  - Japanese (Shirai 2005)

Theoretical importance

- Most psycholinguistic theories of speech assume separate processes for function and content word production (e.g. Garrett 1989)

Theoretical importance

- Probabilistic Reduction Hypothesis (Jurafsky et al. 2001)
  - Observation: "Word forms are reduced when they have a higher probability"
  - Theoretical claim: "…probabilistic relations between words must play a role in the mental representation of language"

Theoretical importance

- Smooth Signal Redundancy Hypothesis (Aylett & Turk 2004)
  - Observation: "…inverse relationship between language redundancy and **duration**"
  - Observation: "**vowels show increased centralization** with increased language redundancy" (Aylett & Turk 2006)
  - Theoretical claim: "…the acoustic consequences of differences in redundancy can be explained functionally within an information theoretical framework, by the drive for speakers to achieve robust information transfer in a potentially noisy environment while conserving effort."

Theoretical importance

- Grammatical class and frequency play role in lemma variation
  - Drager (2011): English *like* systematically varies in pronunciation: /ai/ & /k/ reduced in quotative compared to lexical *like*
  - Lohmann (2018): English *cut* (n) and *cut* (v) are not homophones: lemma frequency affects duration

Theoretical importance

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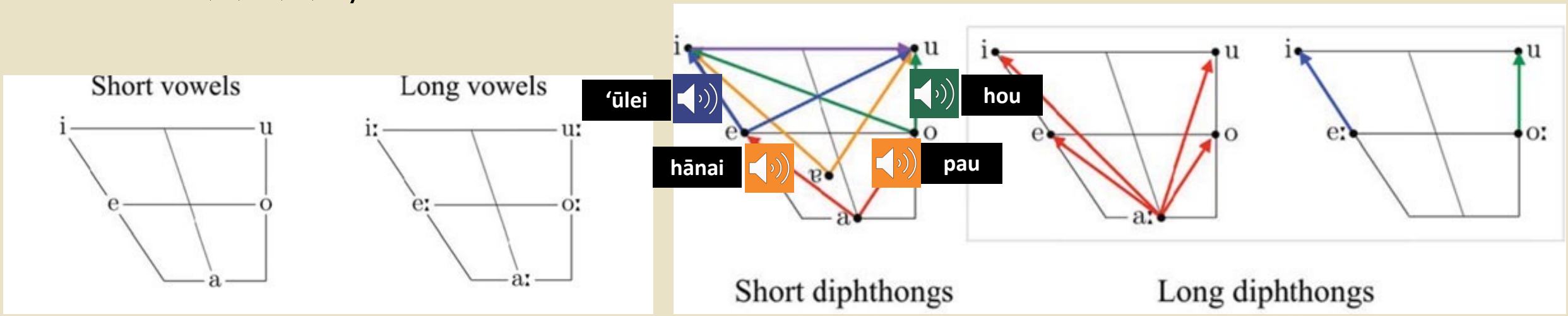
- But! Lack of evidence from wide range of languages
  - Virtually no evidence yet (??) from Austronesian languages

ʻŌlelo Hawaiʻi

- Austronesian > Malayo-Polynesian > Oceanic > Polynesian
  - 7 consonant phonemes
  - 5 short mono, 5 long mono, 25 diphthongs (prob. not phonemic)
  - (C)V(V) syllable structure



Parker Jones (2019)

Speaker: Joseph Makaʻai

ʻŌlelo Hawaiʻi

- Critically endangered but actively revitalizing
- Small literature on Hawaiian sounds (Schütz 1981; Rehg 2007; Parker Jones 2018; Davidson 2021; Davidson & Parker Jones 2023)
  - Few large-scale, multi-speaker descriptions (Newbrand 1951)
  - Little research on inter- and intra-speaker variation (Drager et al. 2017)
  - Little research on inter- and intra-word variation (Kinney 1956; Drager et al. 2017)

Ka Leo Hawai‘i: Present source of data

- Radio show 1972–1988
- 625 hours of tape, mostly interviews with elderly native speakers
- Commonly used in classrooms

Larry Kimura

Current speaker sample

Name	Gender	Native ʻāina	Episode	Recording date
Rachel Mahuiki	female	Wainiha, Kauaʻi	KLH #014	Nov. 9, 1972
Alfred Apaka Sr.	male	Hanalei, Kauaʻi	KLH #057	March 3, 1974
Ida Kapuʻihilani Feary-Milton Nāone	female	Moanalua, Oʻahu	KLH #013	Nov. 1, 1972
Henry Hanalē Machado	male	Kapālama, Oʻahu	KLH #021	Feb. 6, 1973
Lilian Victor	female	Lāhaina, Maui	KLH #032	April 24, 1973
David Kaʻalakea	male	Kīpahulu, Maui	KLH #063	April 21, 1974
Sadie Kaluhiʻōpiopio Beebe	female	Kahaluʻu, Hawaiʻi	KLH #033	May 1, 1973
Joseph Makaʻai	male	Kaʻūpūlehu, Hawaiʻi	KLH #016	Nov. 21, 1972

Each recording ~50-80 minutes, variable amount of target elder speech

Total vowel tokens collected = 35,616

Data preparation

- Forced alignment using MFA (McAuliffe et al. 2018) + manual correction
- Formant extraction with automated LPC selection using FastTrack for Praat and R (Barreda 2021) + manual inspection of outliers facilitated by within-speaker, within-vowel Mahalanobis distances
- Normalization with log-diff method ("ANAE"; cf. Labov, Ash & Boberg 2006; Barreda & Nearey 2018)

Present study: /ai, au, ei, ou/

- Vowel trajectory position
  - Relative location of onset in /ai, au/
- Vowel trajectory length
  - F1/F2 Euclidean distance between point of max F1 and the point of min F1 for each token
- Vowel duration

Present study: /ai, au, ei, ou/

- Considering here:
  - Only word-final primary stressed clusters
- Exclusions:
  - Tokens preceded or followed by a vowel with no intervening consonant
  - Tokens immediately followed by a pause
  - Two tokens greater than 500 ms
- Wordform frequencies measured by Brockway (2021)
  - 4,826 types, 315,785 tokens
  - Taken from transcripts of first 40 episodes of KLH
  - Based on spontaneous speech that matches the genre of corpus

Present study: /ai, au, ei, ou/

- Hypothesis: non-content words and higher frequency words should show centralized onsets, shorter trajectories, shorter durations

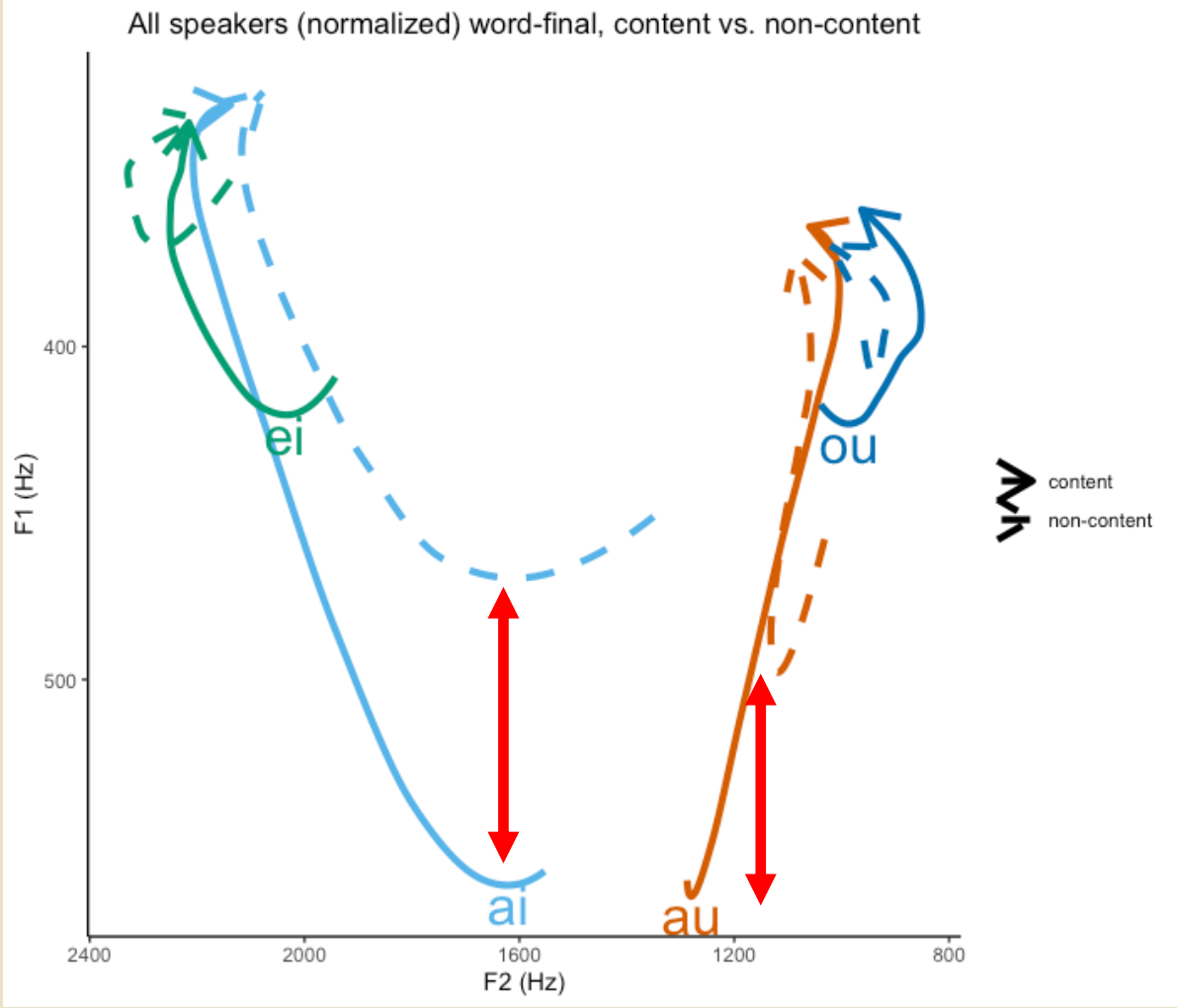
	Content words	Non-content words
/ai/	/ʔai/ eat n=141 (23 types)	/mai/ hither n=237 (2 types)
/au/	/pau/ finished n=175 (25 types)	/vau/ 1SG n=159 (3 types)
/ei/	/lei/ garland n=12 (6 types)	/nei/ PROX n=61 (1 types)
/ou/	/hou/ new n=17 (2 types)	/ˌkaːˈkou/ 1PL.IN n=244 (5 types)

Trajectory position and word class

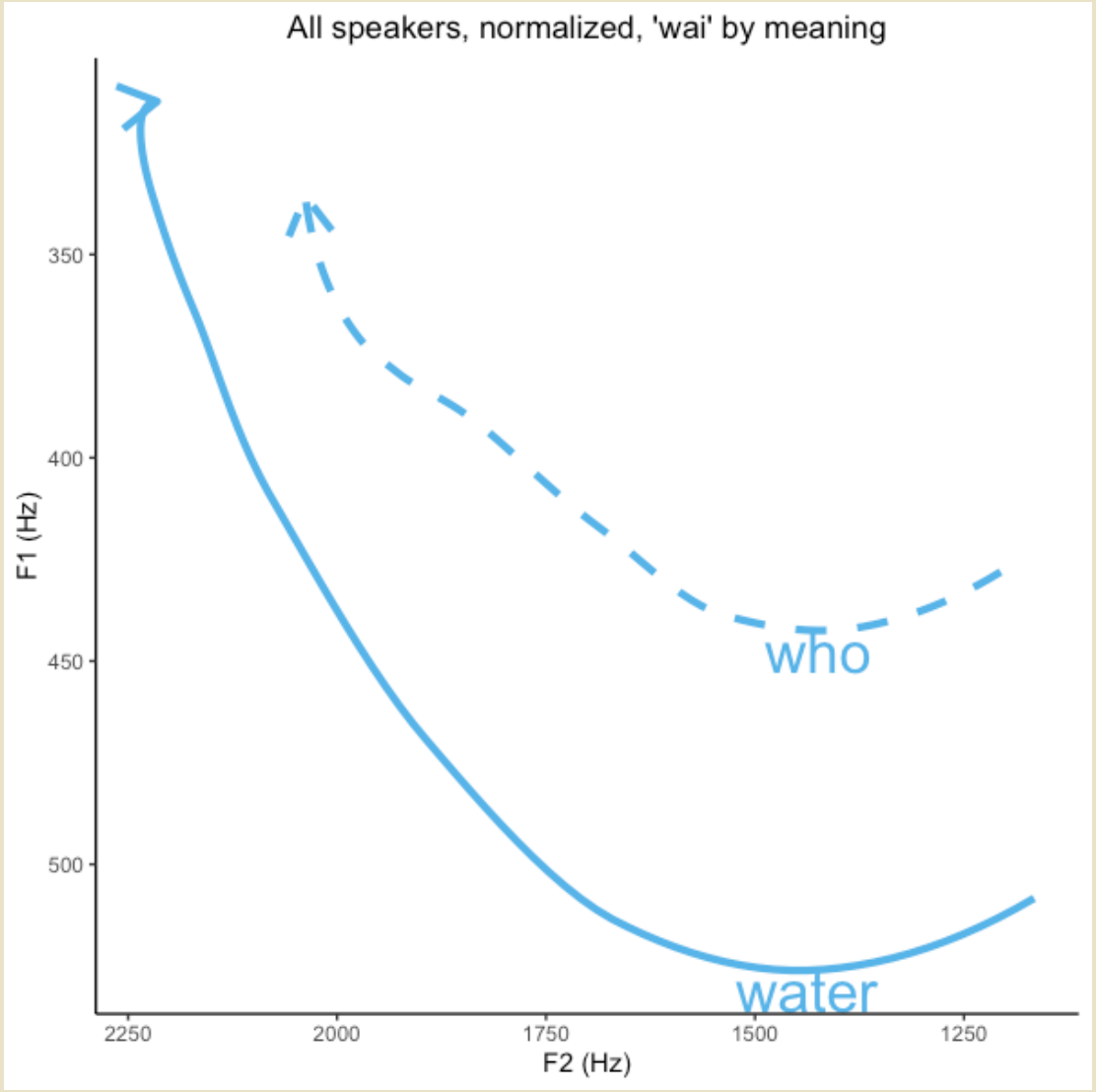
Linear mixed effects model:

MaxF1 ~ LogFrequency + Class + (1|Speaker)

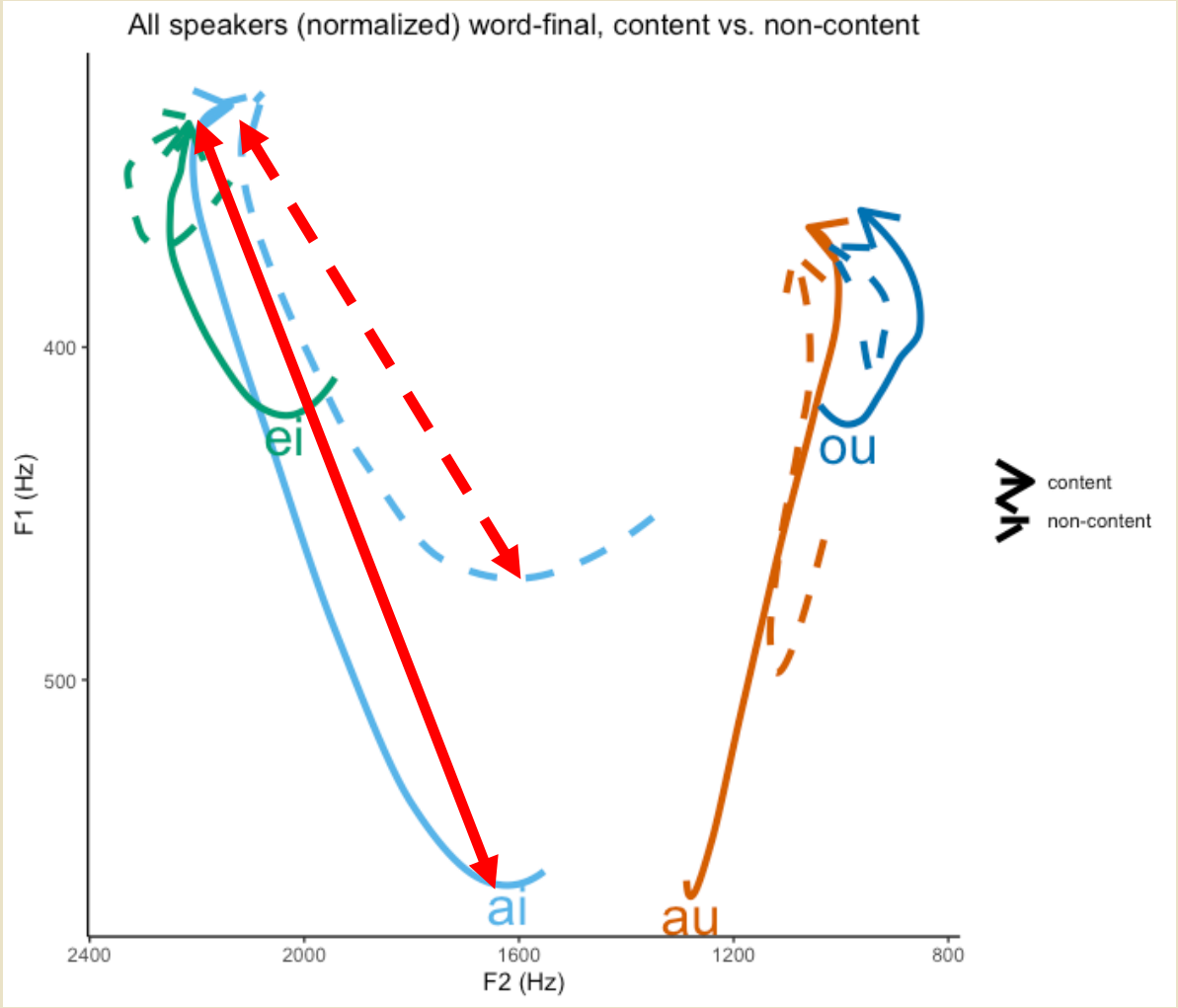
- /ai/: F1 reduced for non-content words (β=-95.8, SE=21.0, t=-4.6, p<.001)
- /au/: F1 reduced for non-content words (β=-103.2, SE=15.2, t=-6.8, p<.001)
- /ei/ or /ou/ not tested



Can also be observed within wordform *wai*



Trajectory length

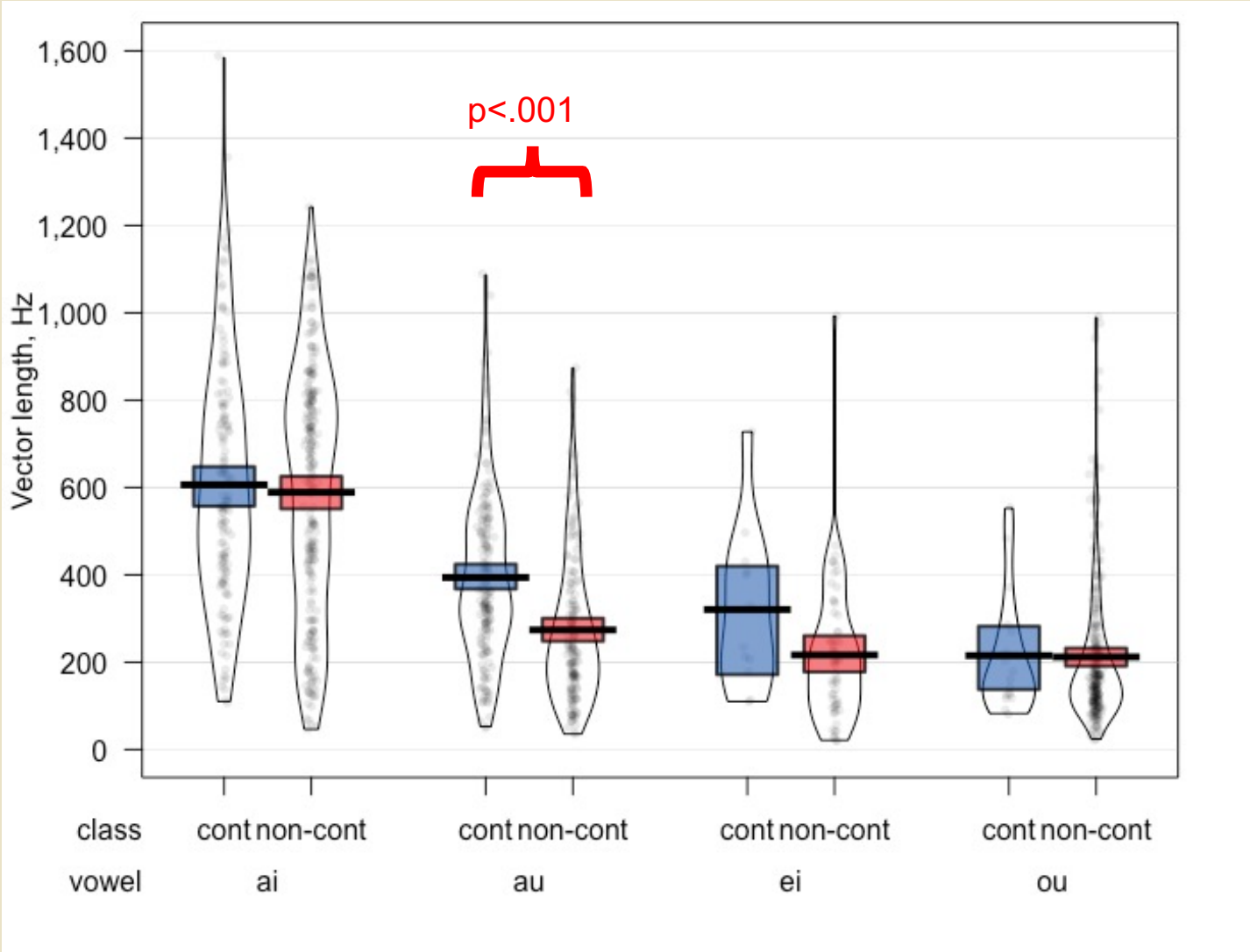


Trajectory length and word class

Linear mixed effects model:

traj_length ~ LogFrequency + Class + (1|Speaker)

- Only /au/ shows significant difference in trajectory length (β=-132.9, SE=25.8, t=-5.2, p<.001)

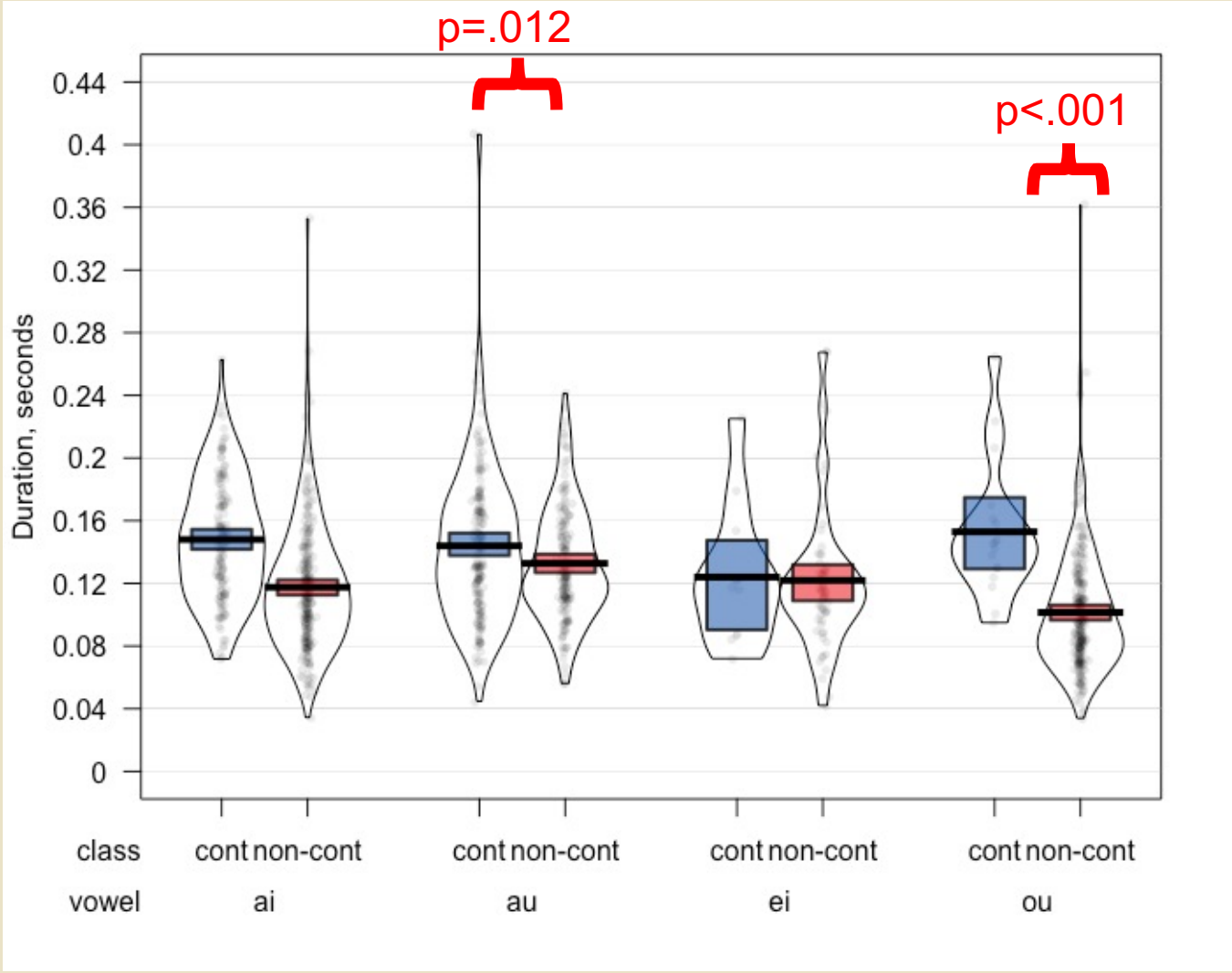


Duration and word class

Linear mixed effects model:

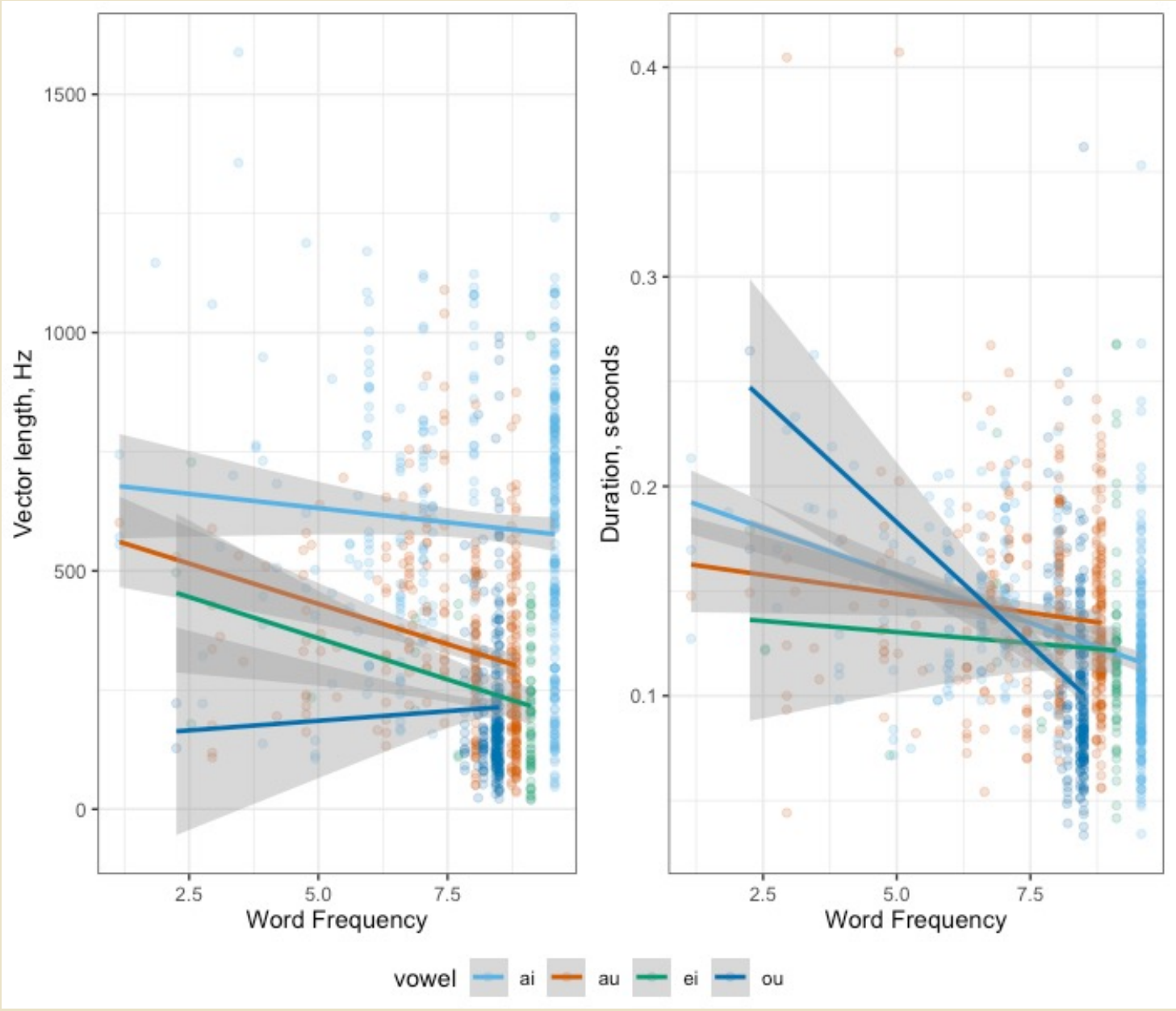
duration ~ LogFrequency + Class + (1|Speaker)

- Sig diff for /au/ (β=-0.016, SE=0.006, t=-2.5, p=.012)
- Sig diff for /ou/ (β=-0.036, SE=0.010, t=-3.6, p<.001)
- No sig diff for /ai/ or /ei/



Frequency effects

- No sig frequency effects for trajectory position
- Sig effect of frequency on trajectory length only for /ai/ (β=-31.9, SE=15.1, t=-2.1, p=.03)
- Sig effect of frequency on duration for /ai/ (β=-0.008, SE=0.002, t=-3.9, p<.001) and /ou/ (β=-0.013, SE=0.002, t=-2.9, p=.004)



Summary of significant effects

	Centralization		Trajectory length		Duration	
	Class	Freq	Class	Freq	Class	Freq
/ai/	✓			✓		✓
/au/	✓		✓		✓	
/ei/						
/ou/					✓	✓

+ bonus: non-content lemma of diphthong in *wai* (who) centralized compared to lexical lemma *wai* (water)

Discussion

- Significant effects observed are all in hypothesized direction
  - Initial evidence of these effects in an Austronesian language
- /ei/ still has too few tokens (73) and word types (1 non-content) to have statistical power
- Unfortunately too few tokens per person/cluster/class to look at interactions using linear mixed effects modelling
  - But! Bayesian methods could help
- Ask me about…
  - Interspeaker variation

Mahalo i ko ʻoukou hoʻolohe ʻana mai!

Thank you for your attention!

Variation between and within speakers

Name	Gender	ʻĀina hānau	Episode	Recording date
Rachel Mahuiki	female	Wainiha, Kauaʻi	KLH #014	Nov. 9, 1972
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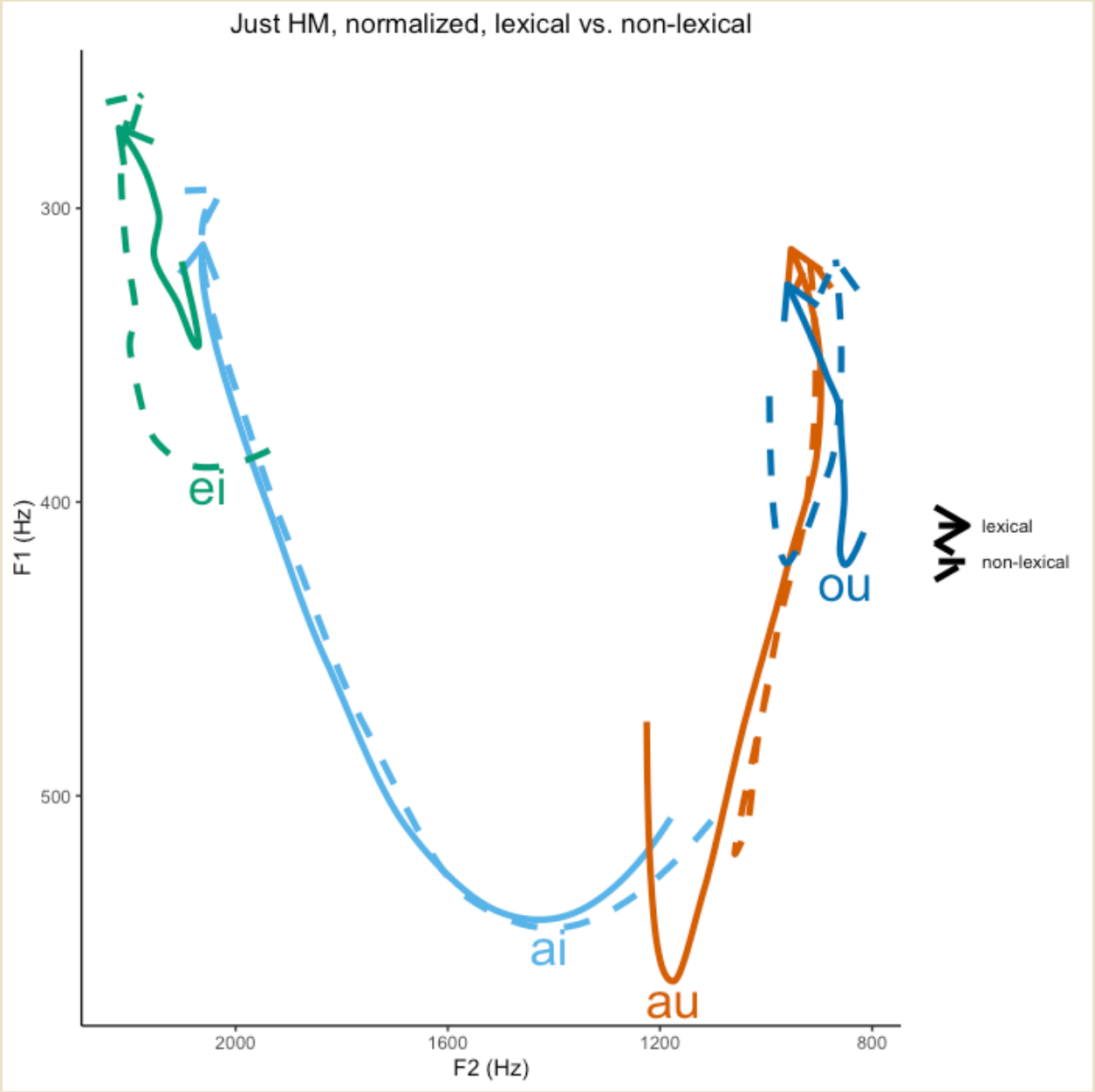
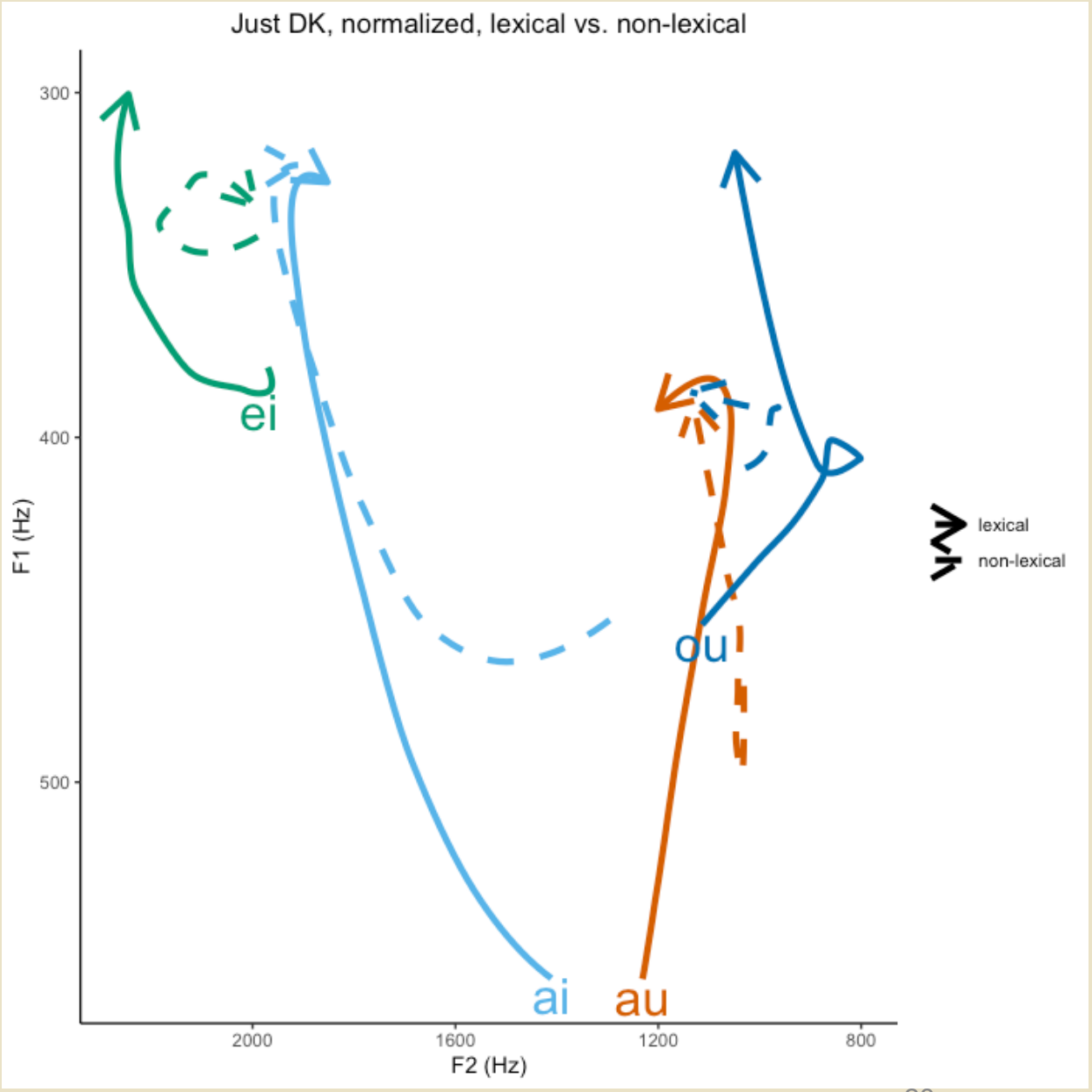
Not all speakers reduce at the same rate


Just HM, normalized, lexical vs. non-lexical
F1 (Hz)
300
400
500
2000
1600
1200
800
F2 (Hz)
ei
ai
au
ou
lexical
non-lexical


Just DK, normalized, lexical vs. non-lexical
F1 (Hz)
300
400
500
2000
1600
1200
800
F2 (Hz)
ei
ai
au
ou
lexical
non-lexical