Prominence effects in vowel perception: Testing sonority expansion and hyperarticulation

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Introduction

Prosodic prominence:

1. highlights important parts of an utterance[1]
2. benefits listeners in discrimination and processing[2]

[1] e.g., Baumann and Schumacher 2020; Ladd 2008
[2] e.g., Connaghan and Patel 2017; Cutler 1976

Introduction

Additionally, prominence shapes how speakers articulate segmental contrasts in various ways

- beyond duration, pitch, intensity
- "strengthening" distinctiveness of cues, e.g. vowel formants

Perceptual consequences for these *prominence strengthening* effects are not well understood

This talk

is about how listeners perceive vowel formants as cue to vowel category, based on prosodic prominence.

- a test case in which two prominence strengthening effects compete

Prominence strengthening

Conception of prominence

- marked by placement of accent
- perceived as a function of context, various phonetic cues (among other things...)

Prominence strengthening in segments:

- e.g., in stops: increased differentiation of VOT and closure duration for voiced/voiceless stops under prominence[1]
- enhancing cues to the contrast

This represents enhancement of intrinsic segmental features/paradigmatic contrast enhancement

- localized hyperarticulation[3]

[1] Cole et al. 2007; Kim et al. 2018

Prominence strengthening in vowels

An additional consideration with vowels: Sonority expansion

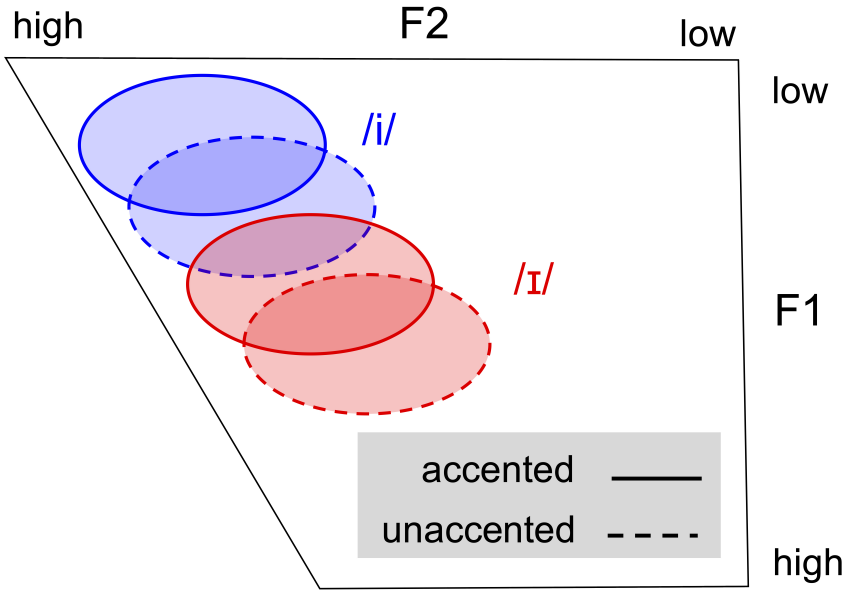
- sonority : openness of the vocal tract, "impedance looking forward from the glottis"[1]

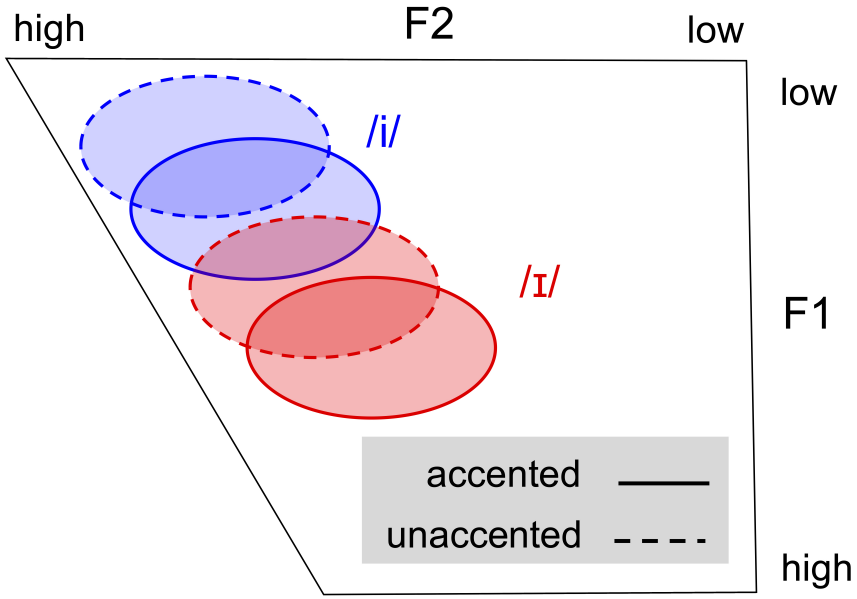
Prominent vowels are produced with "expanded" sonority:

- increased amplitude of jaw lowering[2], independent tongue body lowering[3]
- acoustic correlate: raised F1[2,3] - for some vowels, lowered F2[4]

[1] Beckman et al. 1992; Silverman and Pierrehumbert 1990
[2] van Summers 1987
[3] Cho 2005
[4] Erickson 2002

High front vowels: competing prominence strengthening effects





Hyperarticulation

Lowered F1, raised F2 when prominent (accented)
More impact on F2[1]

Sonority expansion

Raised F1, Lowered F2 when prominent (accented)
More impact on F1[1]

[1] Cho 2005

High front vowels: competing constraints

Various patterns for /i/ and /ɪ/ in English and other languages

- both sonority expansion[1] and hyperarticulation[2] attested across studies
- some intermediate patterns[3]

Evident inter-speaker variation within a given study

[1] Houde (1967); Garellek (2015)
[2] Kent and Netsell (1971); Nadeu (2014)
[3] Cho (2005); Kim et al. (2016); Mooshammer and Geng (2008)

Research questions

1. Will listeners adjust their perceptual categorization of a vowel contrast, /i/-/ɪ/, cued by F1 and F2, on the basis of prominence?
2. If yes, which (acoustic) pattern of prominence strengthening will they favor? Are they variable?

Method

Two alternative forced choice task

- continuum varying in F1/F2 categorized as /i/ or /ɪ/
  - "seat" or "sit"
- contextual prominence manipulation
- 38 native American English speaking participants (remote participation)

Statistical assessment: log-link Bayesian multilevel regression[1]

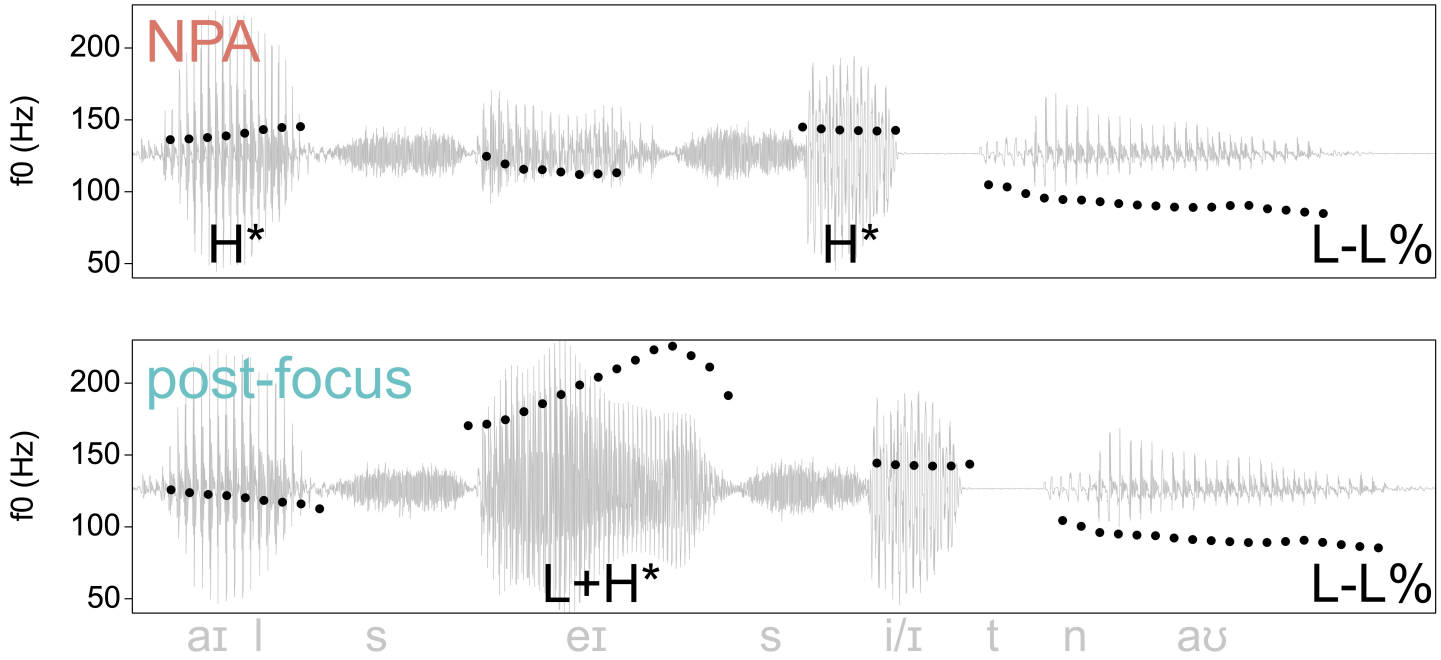
- uninformative priors
- `resp.~F1*F2*prominence+(1+F1*F2*prominence|participant)`

[1] brms: Bürkner 2017

Prominence manipulation

Two conditions cuing a contrast in accentuation

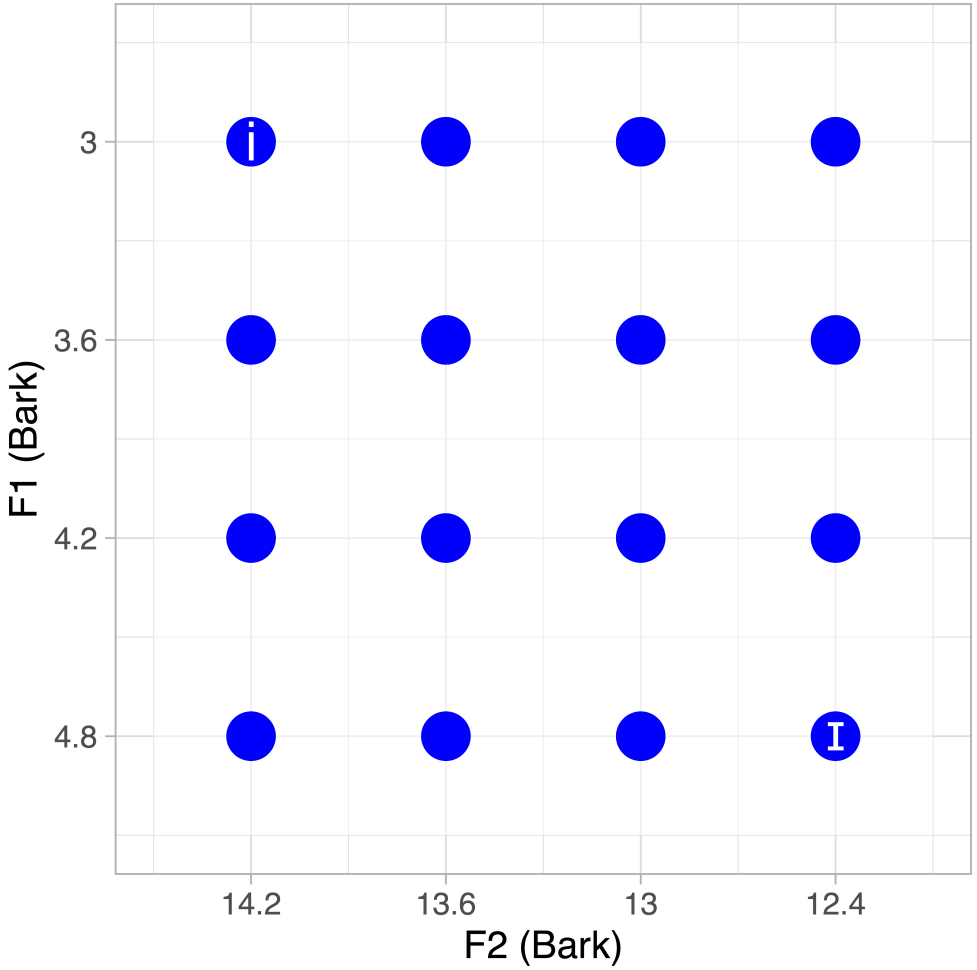
1. I'll say *x* now — *nuclear pitch accent (NPA)*
   H* H* L-L%
2. I'll SAY *x* now — *post-focus*
   L+H* L-L%



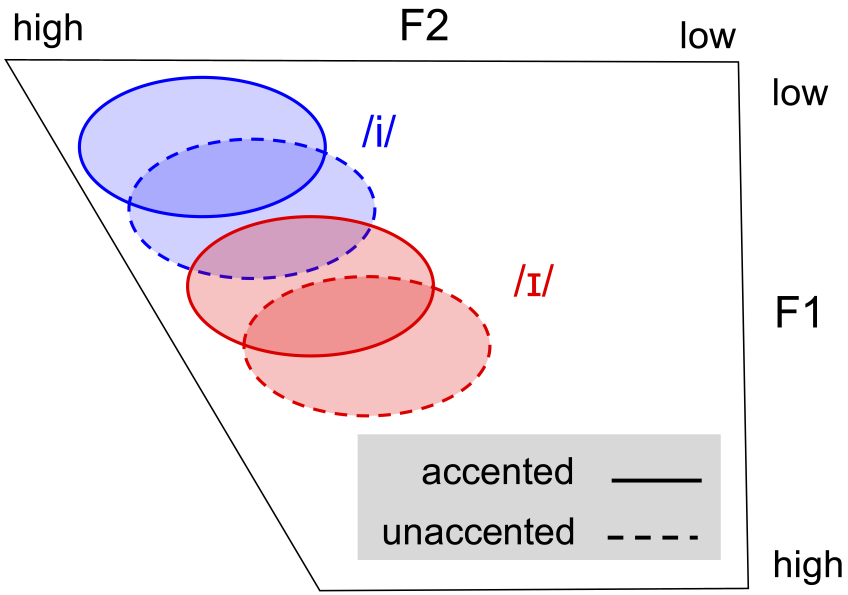
Two dimensional continuum

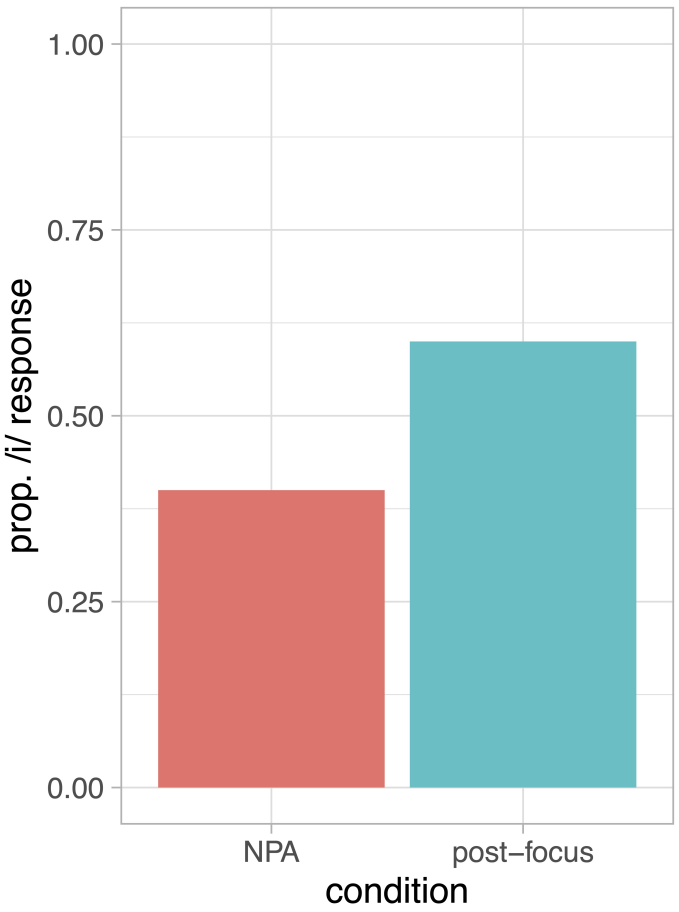
Orthogonal variation in F1 and F2

- n.b. duration held constant



Predictions: hyperarticulation



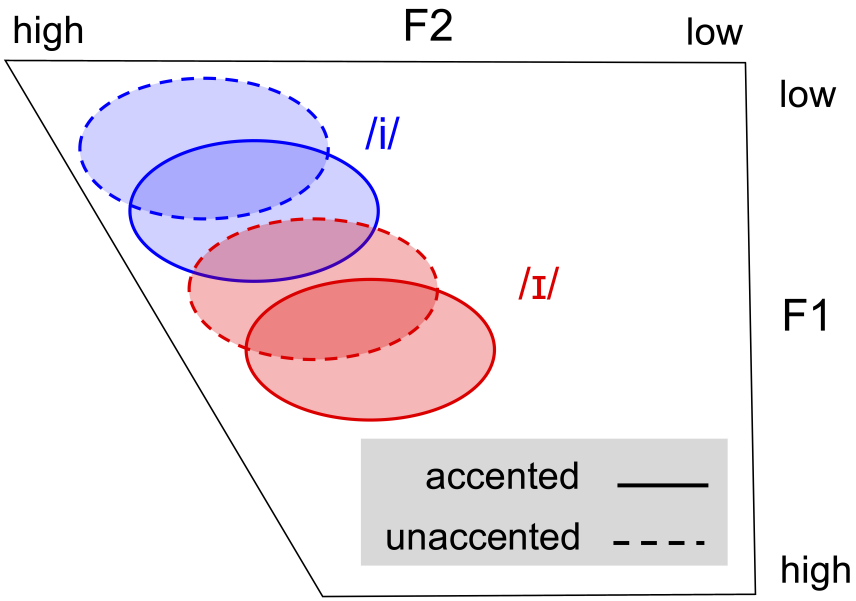


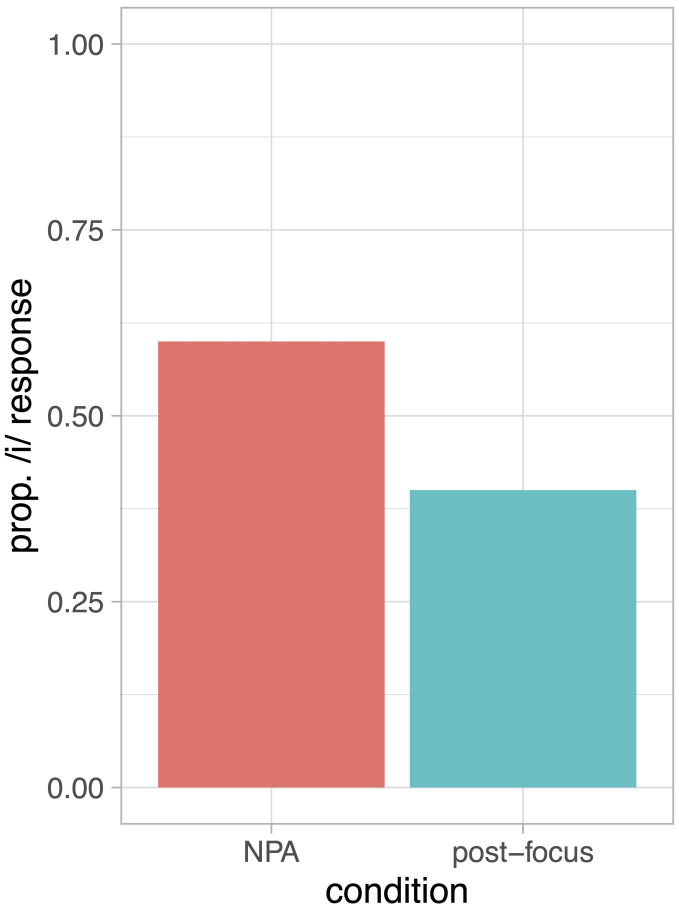
decreased /i/ when prom

Hyperarticulation

Expected raised F2, lowered F1 when prominent (accented)

Predictions: sonority expansion



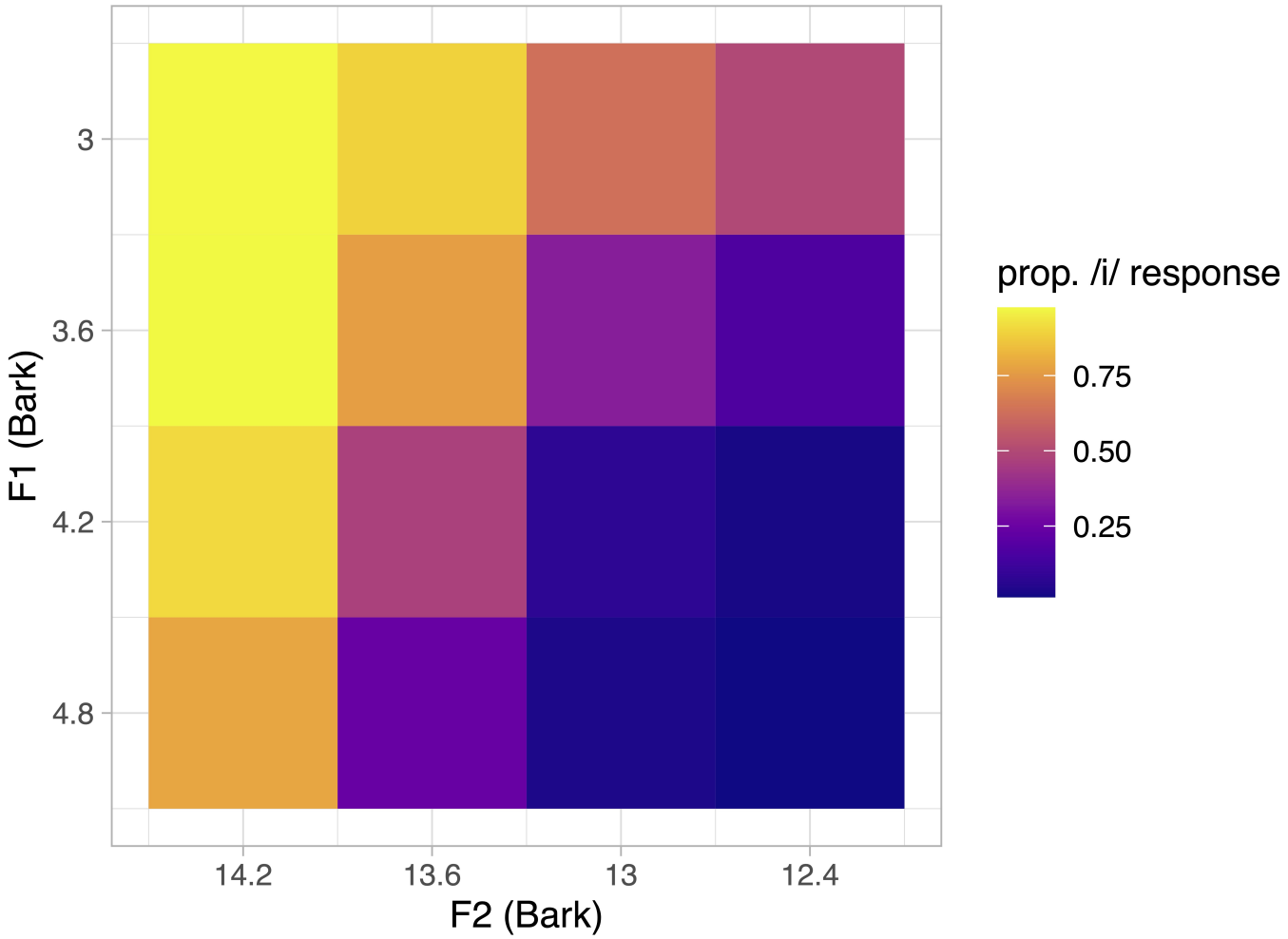


increased /i/ when prom

Sonority Expansion

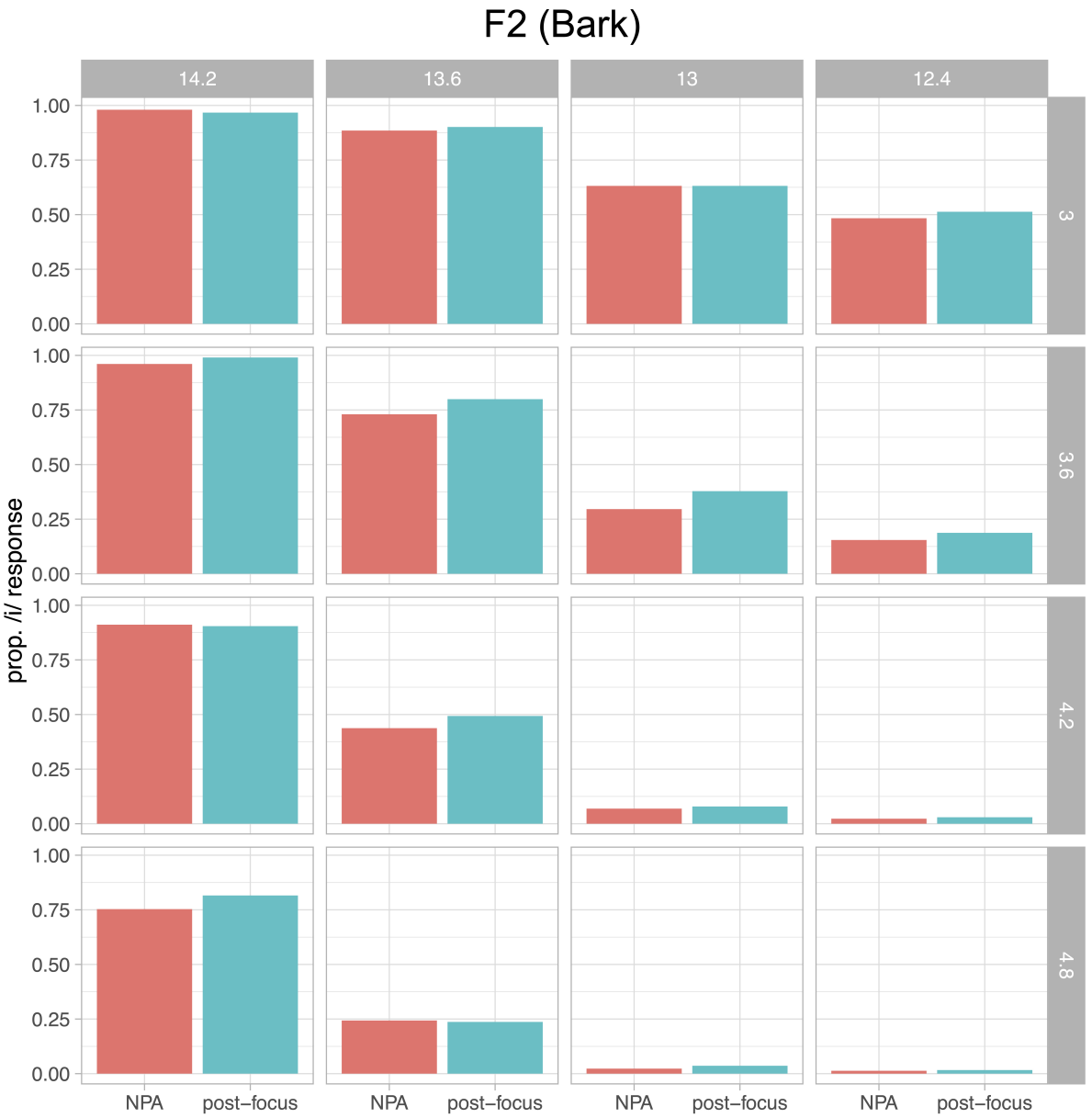
Expected lowered F2, raised F1 when prominent (accented)

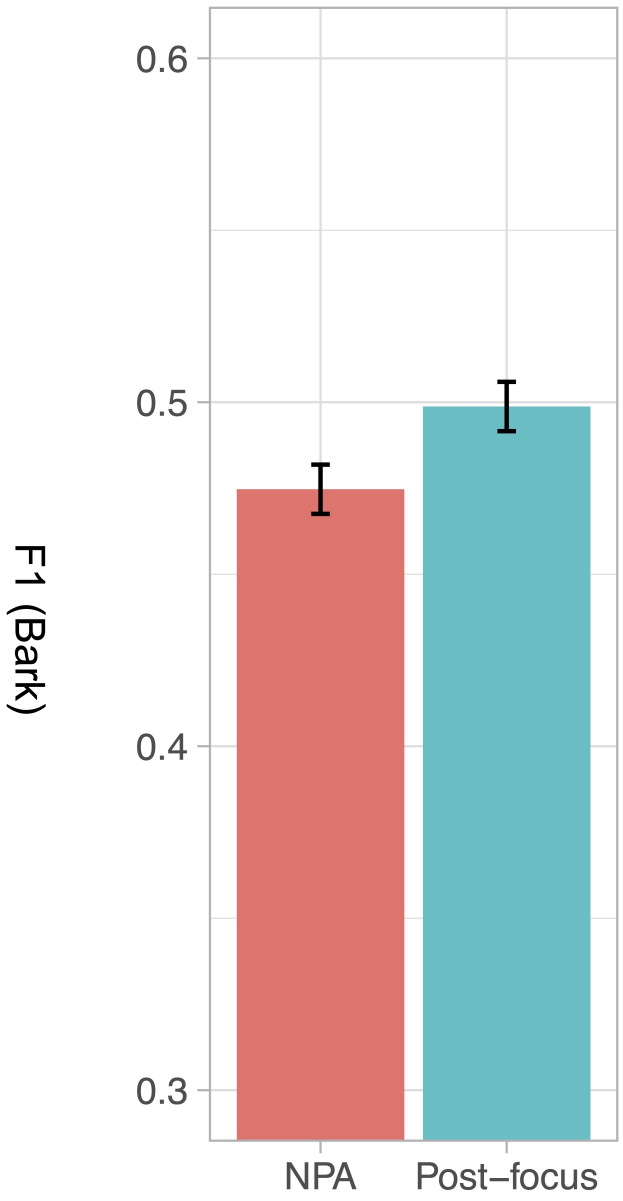
Results: continuum[1]



[1] F1: β= -1.80, 95%CI=[-2.10,-1.52]
F2: β= 2.63, 95%CI=[2.28,2.99]

Results: prominence[1]





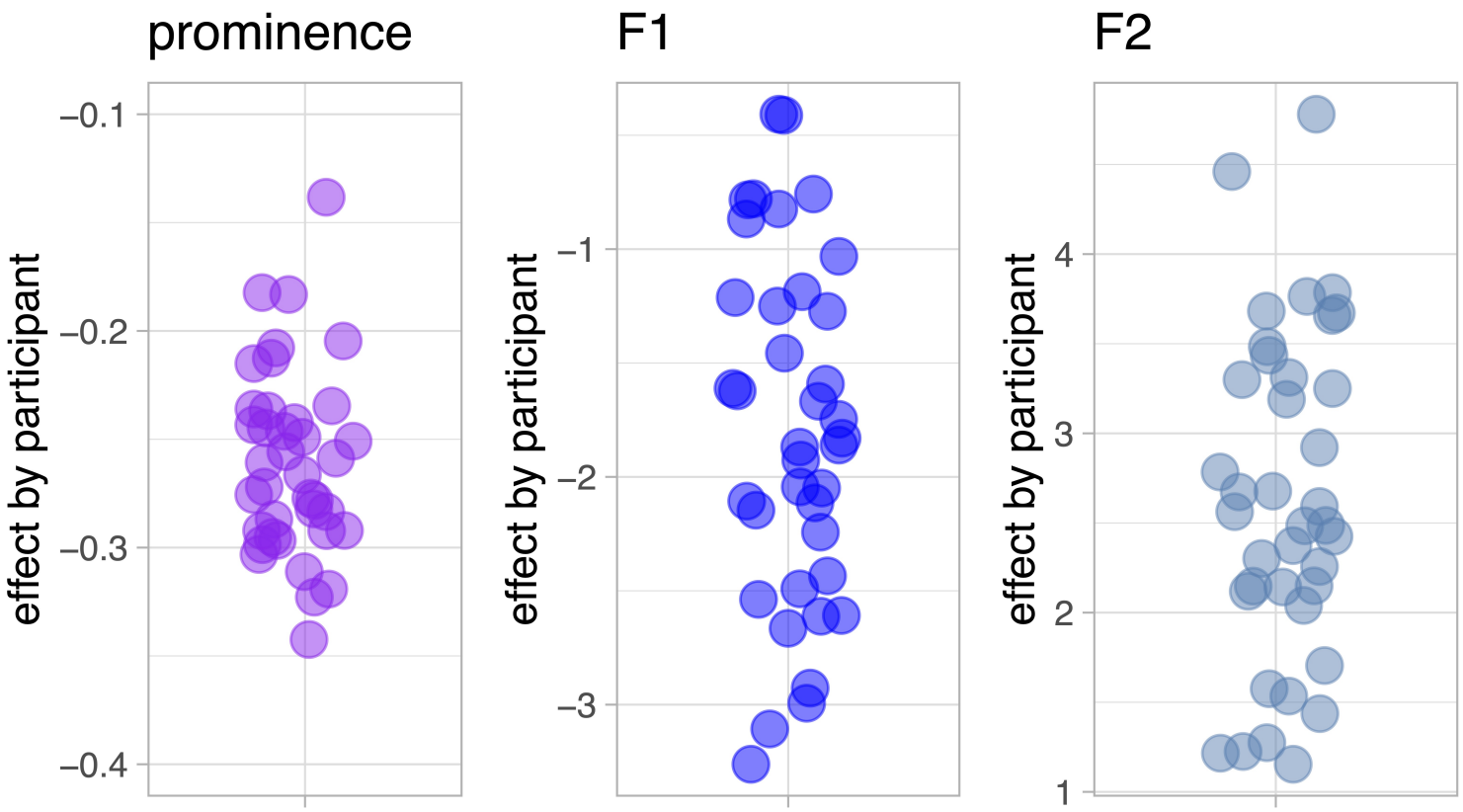
[1] β= -0.25, 95%CI=[-0.42,-0.10]

Results: participants' use of cues

One point of interest, how variable are participants?

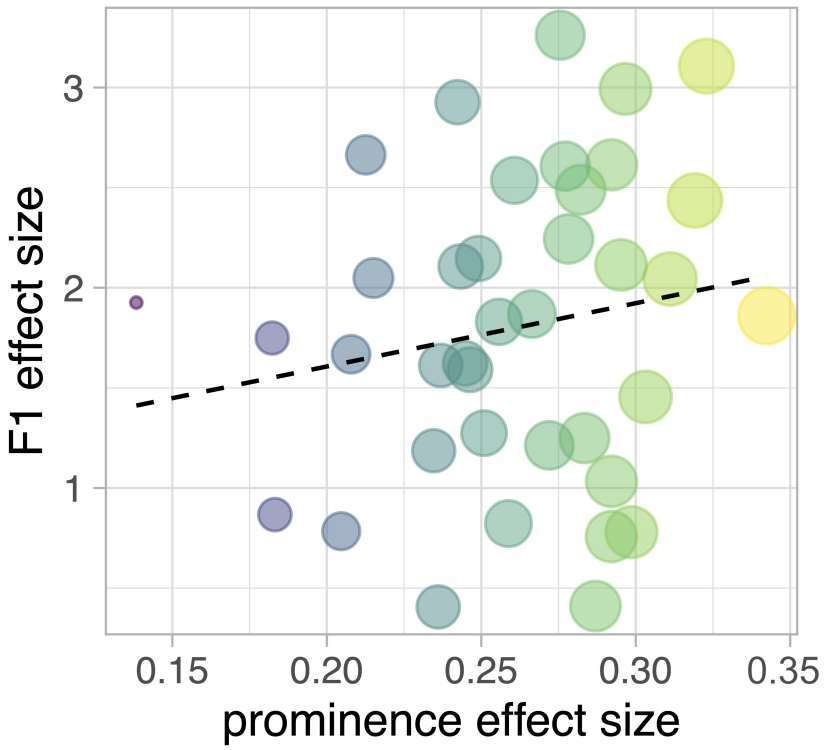
- especially for the prominence effect

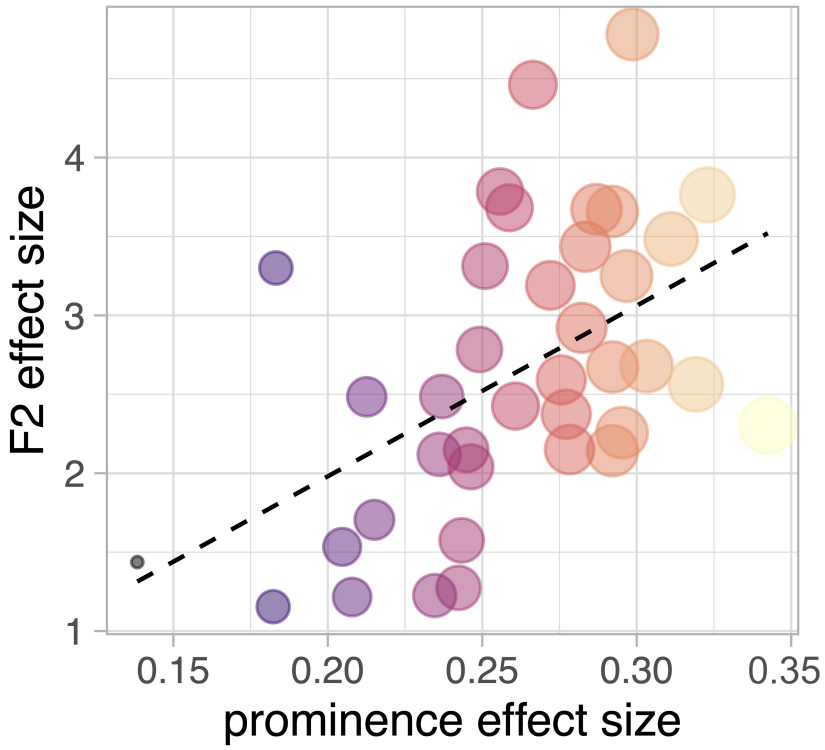
To inspect: effect estimates for each participant[1]



[1] Politzer-Ahles and Piccinini 2018

Results: participants' use of cues





F1: weak positive correlation between F1 and prominence ($\tau = 0.12$, p=0.30)

F2: robust positive correlation between F2 and prominence ($\tau = 0.39$, p<0.001)

Take home messages

1. Listeners shift their perception of formant cues on the basis of contextual prominence
2. Listeners expect (acoustically) hyperarticulated variants of high/front vowels in prominent contexts

Some questions

Why perceptual compensation for hyperarticulation?

- **Production**: variation in which forms of prominence strengthening are prioritized across speakers[1]
- **Perception**: uniform expectation of acoustically hyper-articulated variants of vowels

[1] Cho 2005; Houde 1967; Kent and Netsell 1971

Further directions

Explore further variability and relation to cue weighting/shifting

- attempt to reverse effect via exposure
- stimuli with multiple voices evidencing different patterns

Relationship to the segmental inventory of the language ?

- c.f. Tongan with /i,e,a,o,u/, where /i/ shows uniform sonority expansion in terms of F1[1]

[1] Garellek and White 2015

Thank you!

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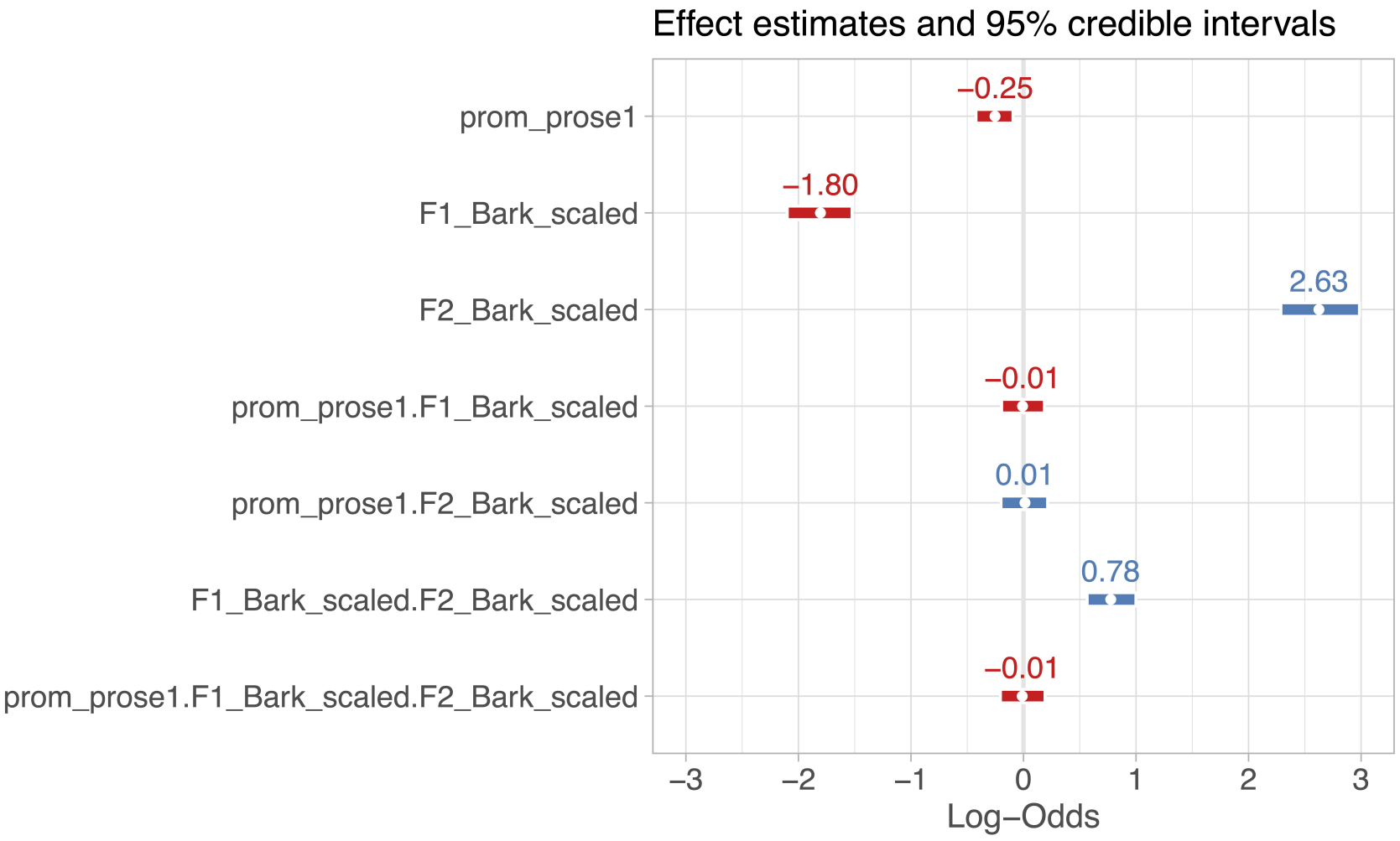
Appendix slides

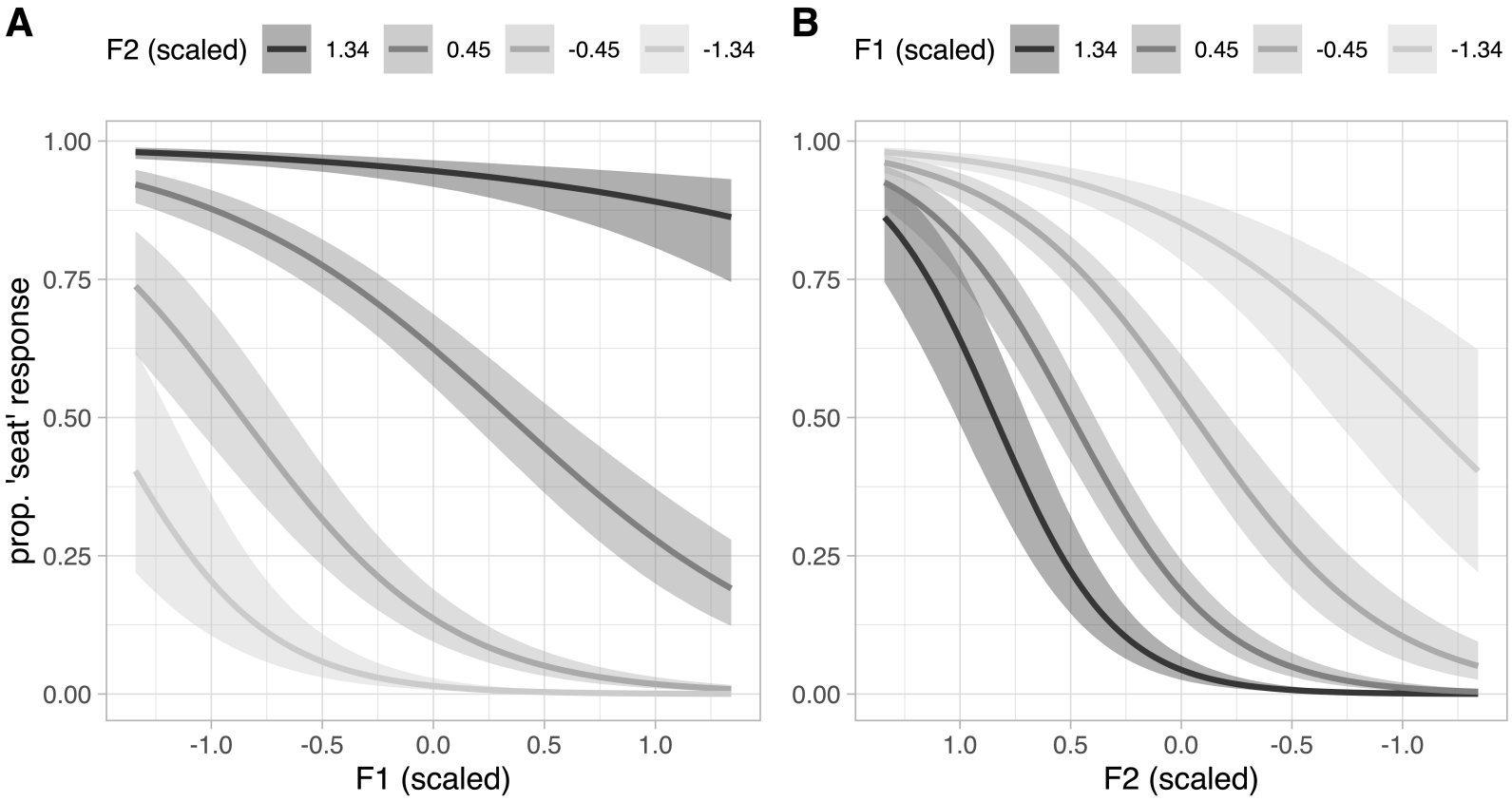
Model summary



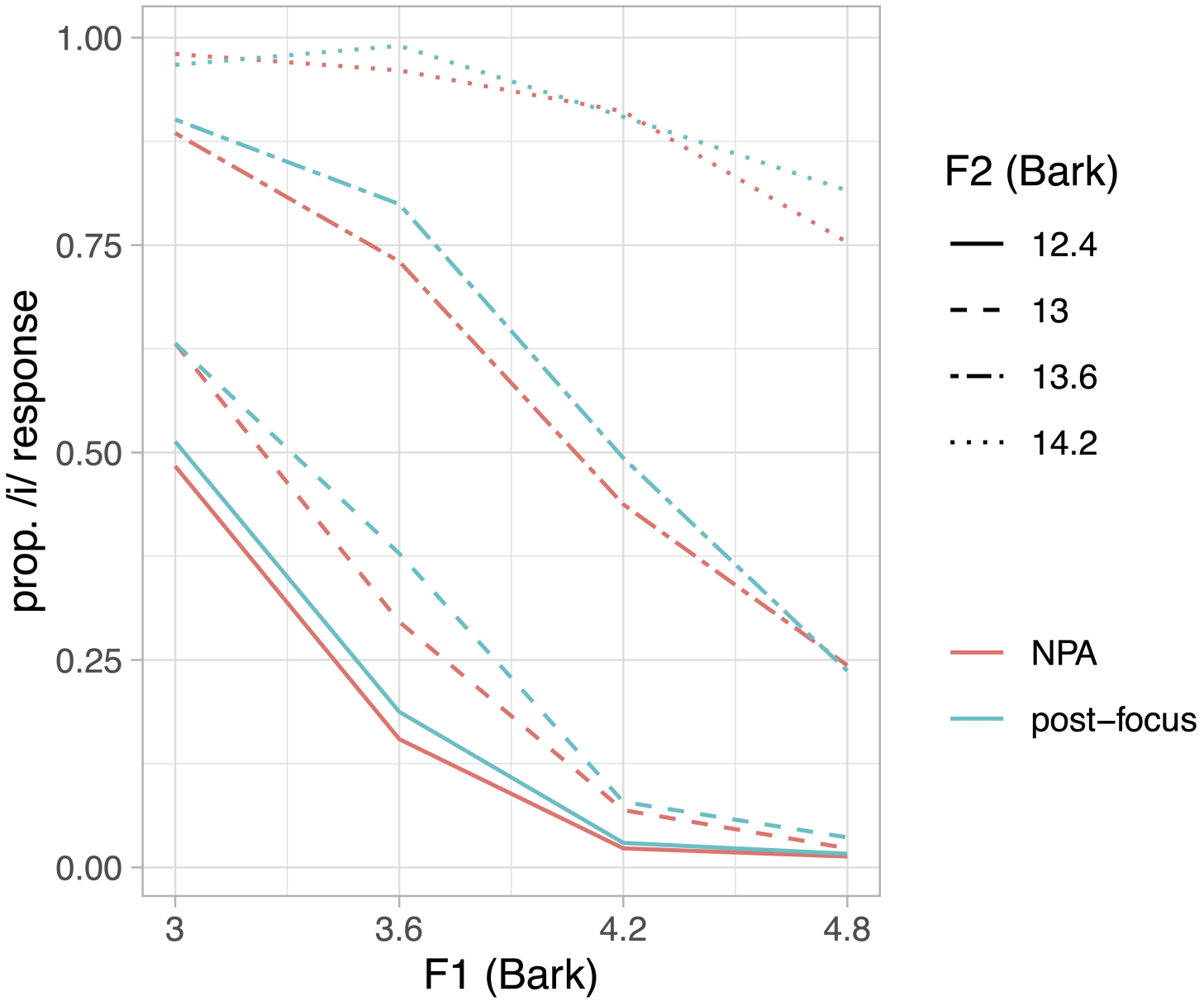
Model output

	Estimate	Est. Error	L-95% CI	U-95%CI	cred.?
intercept	-0.54	0.15	-0.84	-0.25	✓
prominence	-0.26	0.08	-0.42	-0.10	✓
F1	-1.80	0.15	-2.10	-1.52	✓
F2	2.63	0.18	2.28	2.99	✓
F1:F2	0.78	0.11	0.57	1.00	✓
F1:prominence	-0.01	0.10	-0.19	0.19	
F2:prominence	0.01	0.11	-0.20	0.22	
F1:F2:prominence	-0.01	0.10	-0.20	0.19	

F1/F2 interaction



Results: split by F2



Relation to the vowel system of the language?

American English has a relatively crowded vowel space[1]

- perceptually favoring hyperarticulation could relate to the perceptual expectation of dispersion in prominent contexts

In Tongan, with a five vowel system /i,e,a,u,o/ - all vowels incl. /i/ show uniform raising of F1 when prominent (= son. expansion)[2]

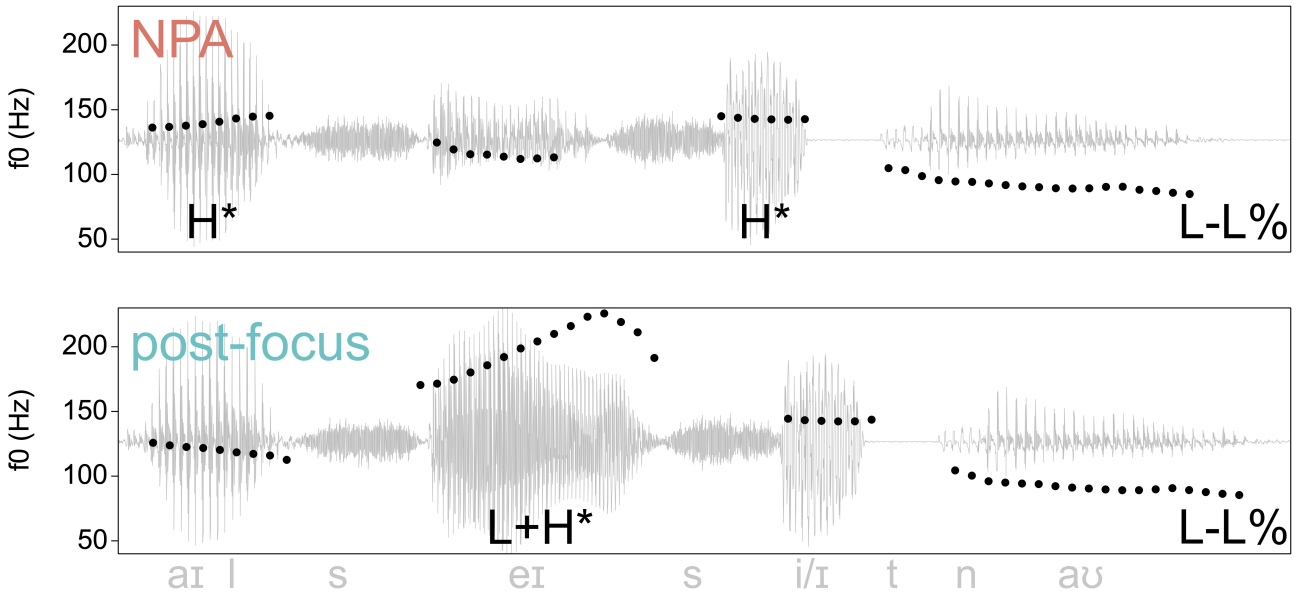
- unlike variability seen in American English /i/

Testing how perceptual prominence strengthening operates cross-linguistically and relation to segmental inventory will help explore these ideas

[1] Becker-Kristal 2010

[2] Garellek and White 2015

Considering durational contrast effects



A longer vowel precedes the target in the post focus condition

- By durational contrast the target should be perceived as shorter in the post focus condition
- If vowel duration used as a cue, decreased /i/ responses in the post focus condition (/i/ longer than /ɪ/)
- This is the opposite of the effect that was found

F1/F2 cue use by participant