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., Connagahan and Patel 2017; Cutler 1976
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
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

- localized hyperarticulation\(^3\)
Prominence strengthening in vowels

An additional consideration with vowels: **Sonority expansion**

- sonority: openness of the vocal tract, “impedance looking forward from the glottis”

Prominent vowels are produced with “expanded” sonority:

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

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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

Sonority expansion
Raised F1, lowered F2 when prominent (accented)
More impact on F1

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

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\(^1\) 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
- \(\text{resp.} \sim \text{F1*F2*prominence+}(1+\text{F1*F2*prominence}|\text{participant})\)

\(^1\) brms: Bürkner 2017
Prominence manipulation

Two conditions cuing a contrast in accentuation

1. I’ll say x now
   \[ H^* \quad H^* \quad L-L\%
   \]
   nuclear pitch accent (NPA)

2. I’ll SAY x now
   \[ L+H^* \quad L-L\%
   \]
   post-focus

![Graphs showing accentuation patterns](https://via.placeholder.com/150)

- **NPA**
  - `H*` followed by `H*` and then `L-L%`
- **post-focus**
  - `L+H*` followed by `L-L%`
Two dimensional continuum

Orthogonal variation in F1 and F2

• n.b. duration held constant
Predictions: hyperarticulation

Hyperarticulation

Expected raised F2, lowered F1 when prominent (accented)

decreased /i/ when prom
Predictions: sonority expansion

Sonority Expansion

Expected lowered F2, raised F1 when prominent (accented)

increased /i/ when prom
Results: continuum

$F1: \beta = -1.80, \; 95\%CI=[-2.10,-1.52]$  
$F2: \beta = 2.63, \; 95\%CI=[2.28,2.99]$
Results: prominence

\[ \beta = -0.25, \ 95\% \text{CI} = [-0.42, -0.10] \]
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\(^1\)

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\(^1\)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

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1Garellek and White 2015
Thank you!

Many thanks are due to: Adam Royer, Sun-Ah Jun, Pat Keating, Megha Sundara & Taehong Cho
References I


Appendix slides
## Model output

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<th>L-95% CI</th>
<th>U-95% CI</th>
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</table>
F1/F2 interaction

- **A:** F2 (scaled) with values ranging from 1.34 to -1.34. The graph shows the proportion 'seat' response against F1 (scaled) values from -1.0 to 1.0.

- **B:** F1 (scaled) with values ranging from 1.34 to -1.34. The graph shows the proportion 'seat' response against F2 (scaled) values from 1.0 to -1.0.
Results: split by F2

![Graph showing results split by F2](image)

- F2 (Bark)
  - 12.4
  - 13
  - 13.6
  - 14.2

- NPA
- post-focus
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

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\(^1\) 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