Deriving sibilant-vowel phonotactics from a **soft bias** in perception

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Overview

- Background
  - *Soft* bias?
  - Fricative context impacts vowel perception
    - Coarticulation?
    - Sensitivity to interactions in the acoustics?
- Modeling prior work
- Our experiment
- Preliminary results

Background

Soft biases on phonotactics

- *Absolute (hard) biases*
  - *FRICATIVES
    (Barlow, 1997; Barlow & Gierut, 1999)

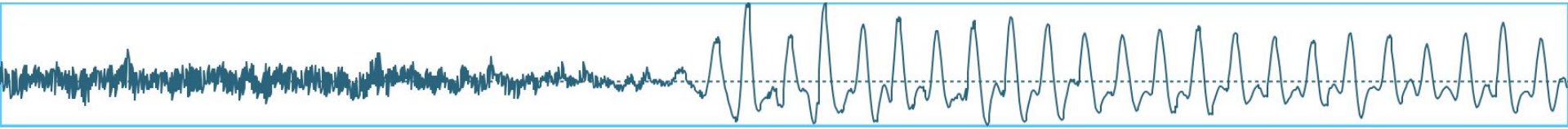
- "Soft" biases → gradient phenomena
  - Phonological markedness as ease of learnability
  - Preferences that can be overridden

Soft biases on *fricative-vowel* phonotactics

- Several comparable phonotactic constraints on fricative-vowel combinations
  - sibilant place contrasts in the context of [i] in …
    - Japanese (Vance, 2008)
      - /ʃu/, /ʃi/, /su/, */si/
    - Chinese “dialects” (Li, 2021)
    - Chakobo (Panoan); Telugu (Dravidian) (Lee-Kim, 2014)

- **Do such contrasts arise, at least in part, from perceptual biases?**

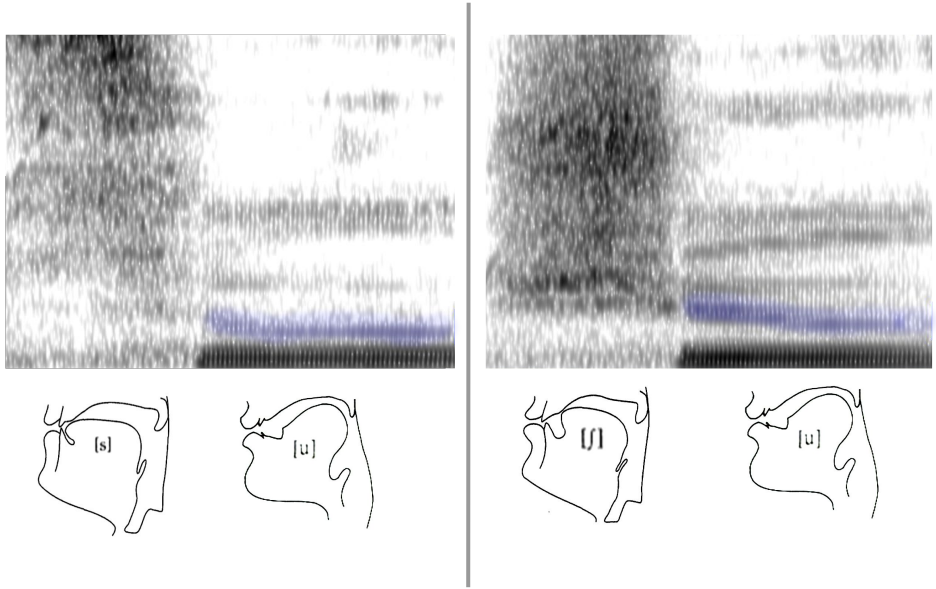
Anticipatory effects in perception (/sV/, /ʃV/)



- Listeners can anticipate the **category** of the vowel during **aperiodic energy of the fricative**, even before hearing the **periodic energy of the vowel**
  (Yeni-Komshian & Soli, 1981; Galle et al., 2019)
- Fricative noise ***influences*** vowel categorization
  (Whalen, 1989)
- Vowel F2 also influences fricative categorization
  (Kunisaki & Fujisaki, 1977; Mann & Repp, 1980; Whalen, 1981)
- Probably due to **coarticulation**

Coarticulation

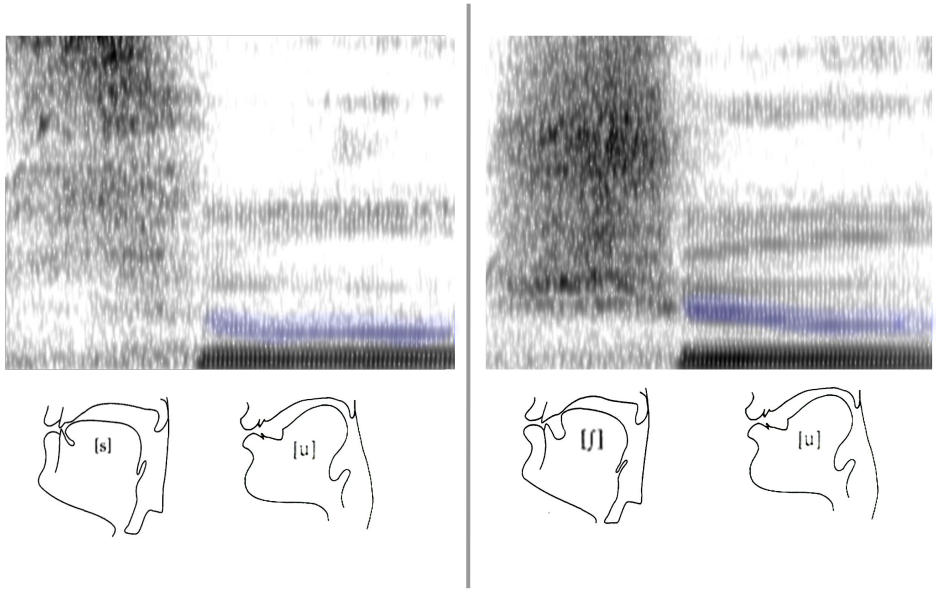
- Articulation of vowel begins during the fricative
  - at some point, fricative and vowel are articulated simultaneously
- Can be observed in the acoustics
- Cues listeners to both the fricative and vowel simultaneously



Coarticulation

- /s/:
  - more **anterior** constriction
  - **SHORTER** front cavity
    HIGHER frication noise
  - **LONGER** back cavity
    LOWER F2

- /ʃ/:
  - more **posterior** constriction
  - **LONGER** front cavity
    LOWER frication noise
  - **SHORTER** back cavity
    HIGHER F2



Is coarticulation *all we need?*

- Anticipation is a **domain-general** cognitive ability
- Perceptual informativity of coarticulation is well established
- Still not clear whether it accounts for the totality of the anticipation effects
- Listeners might have processing biases that contribute to anticipation,
  independent of what is present in the speech signal

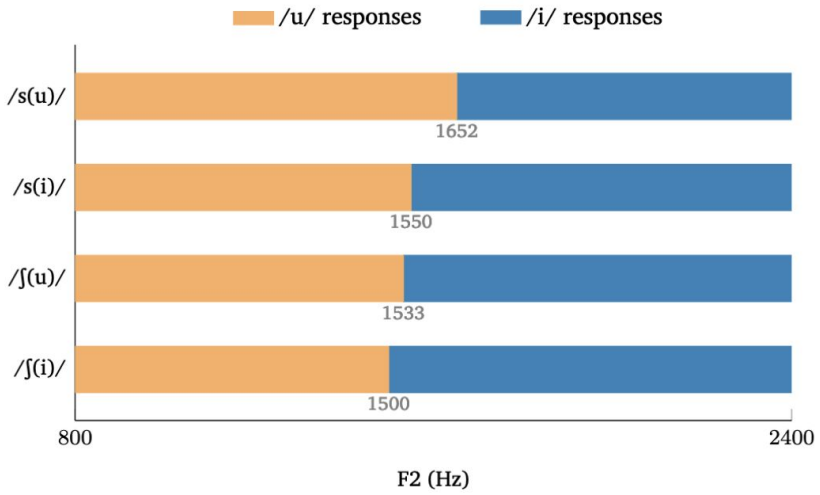
Whalen (1989): Experiment 2

- “Fricative noise can ***influence*** vowel categorization”
- Naturally produced fricative (/s/, /ʃ/) noise
- Vowels synthesized along a continuum between /u/ & /i/.
- Fricatives were excised from /si/, /su/, /ʃi/ and /ʃu/ recordings
  - Fricative acoustics contained coarticulation for the vowel context
  - Participants had to judge category of ambiguous vowel as /i/ or /u/

Whalen (1989): Key takeaways

- fricatives excised from /u/ contexts condition more /u/ responses than those excised from /i/ contexts

- The **higher frequencies associated with /s/** condition more /u/ responses (lower F2) than the **lower frequencies associated with /ʃ/**



Questions left open

- Can we observe the effect of fricative context on vowel perception *without* coarticulation?

- Can we observe similar patterns of discrimination along a continuum, rather than discrete categories?

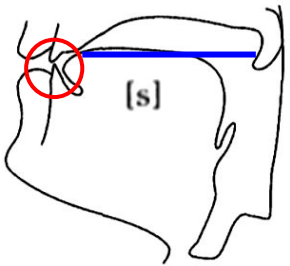
Model

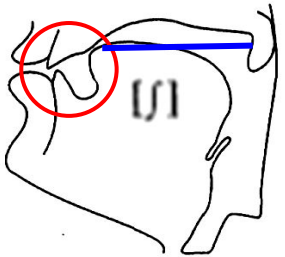
Deriving Whalen (1989) results in DFT

Remember:

- Fricative spectral peak frequencies ← size of the cavity in front of the constriction during generation of **aperiodic energy**

- F2 at the onset of voicing ← resonance of the back cavity;
  - **periodic energy** might correspond with spectral peak in **preceding fricative turbulence**





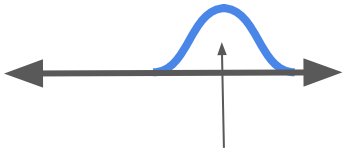
Deriving Whalen (1989) results in DFT

- Distinct neural populations process **aperiodic** and **periodic** energy in speech sounds
  (Yrttiaho et al., 2011)

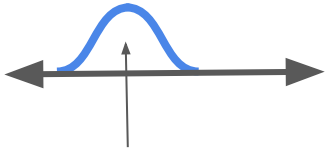
- Our model:
  coupled DNFs independently detecting aperiodic and periodic energy

Proposal: coupled fields

aperiodic energy field



/s/ frication peak frequency

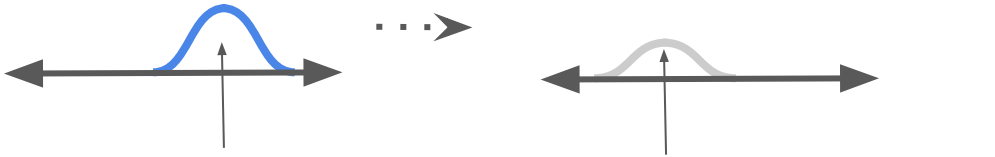


/ʃ/ frication peak frequency

Proposal: coupled fields

aperiodic energy field

periodic energy (F2) field



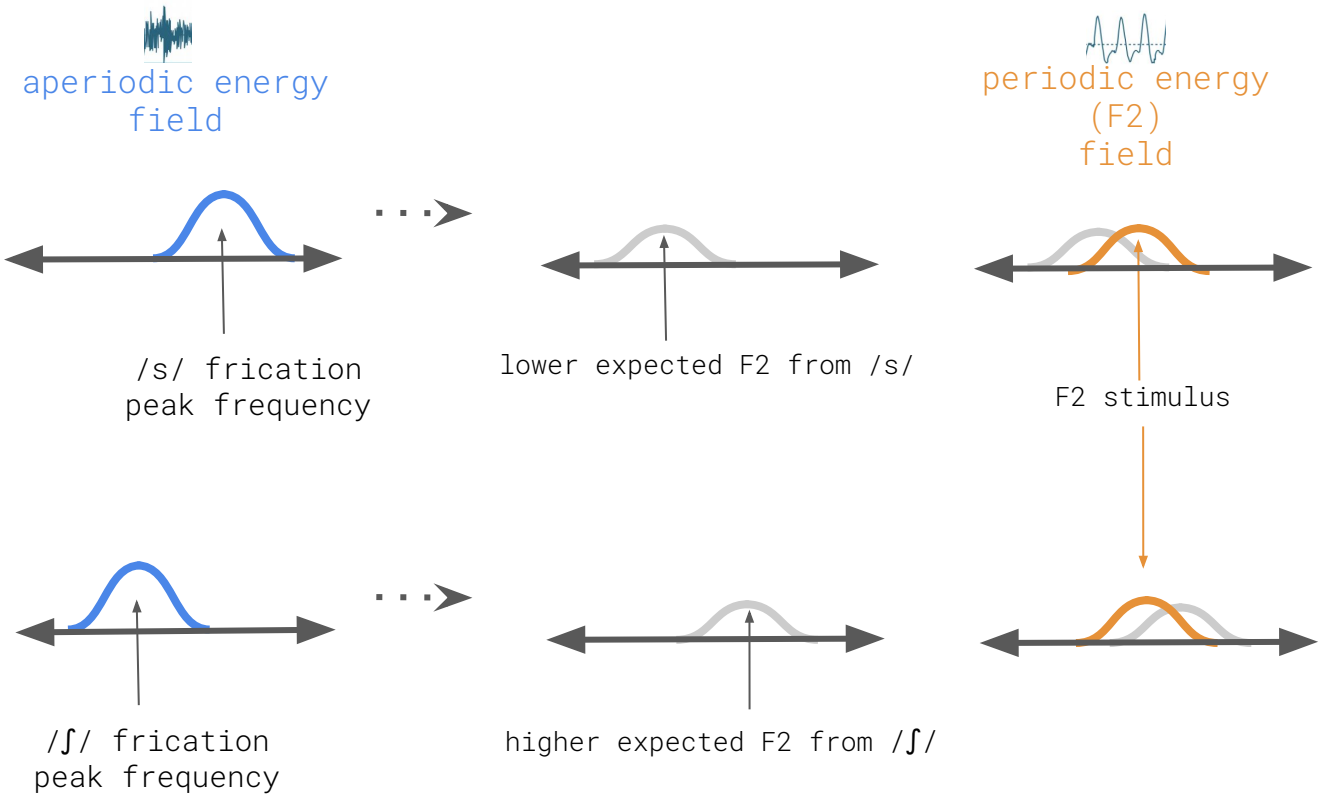
/s/ frication peak frequency

lower expected F2 from /s/

/ʃ/ frication peak frequency

higher expected F2 from /ʃ/

Proposal: coupled fields



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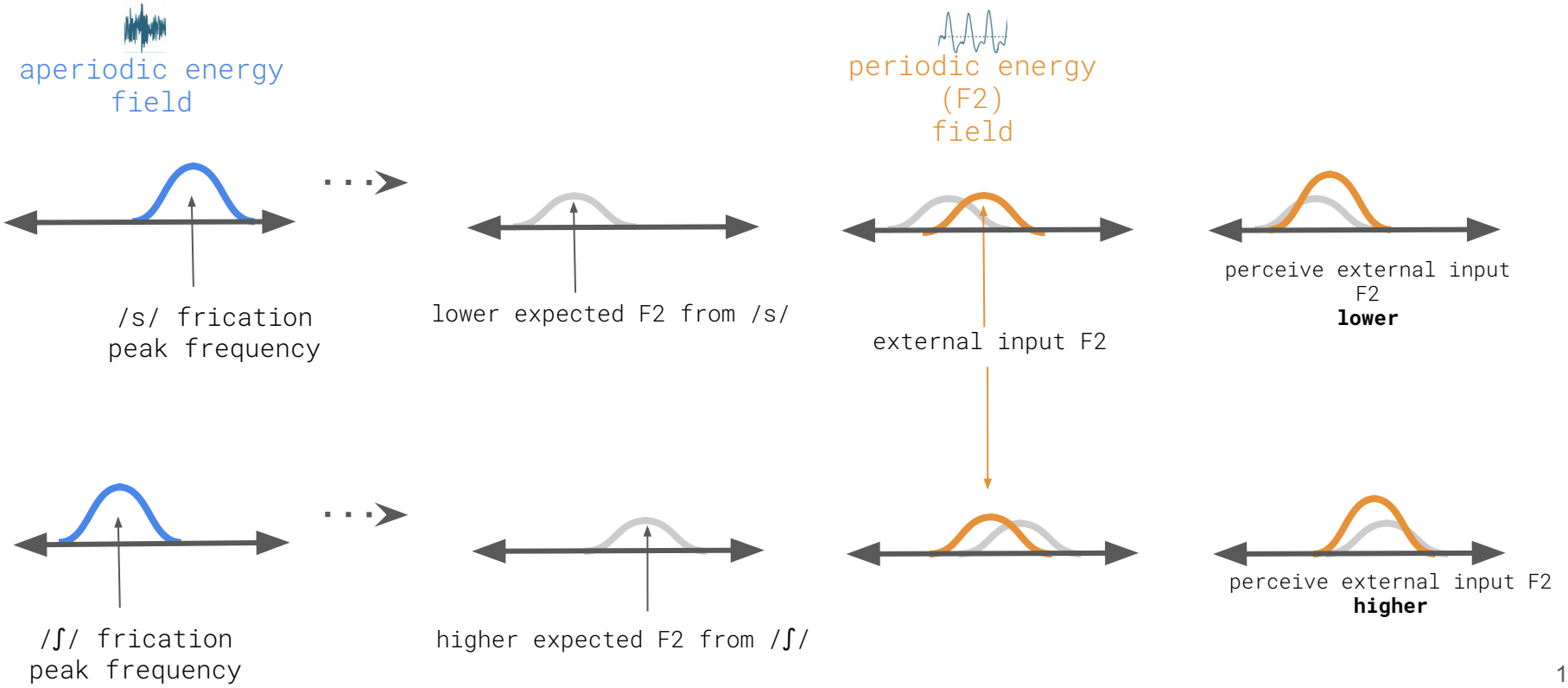
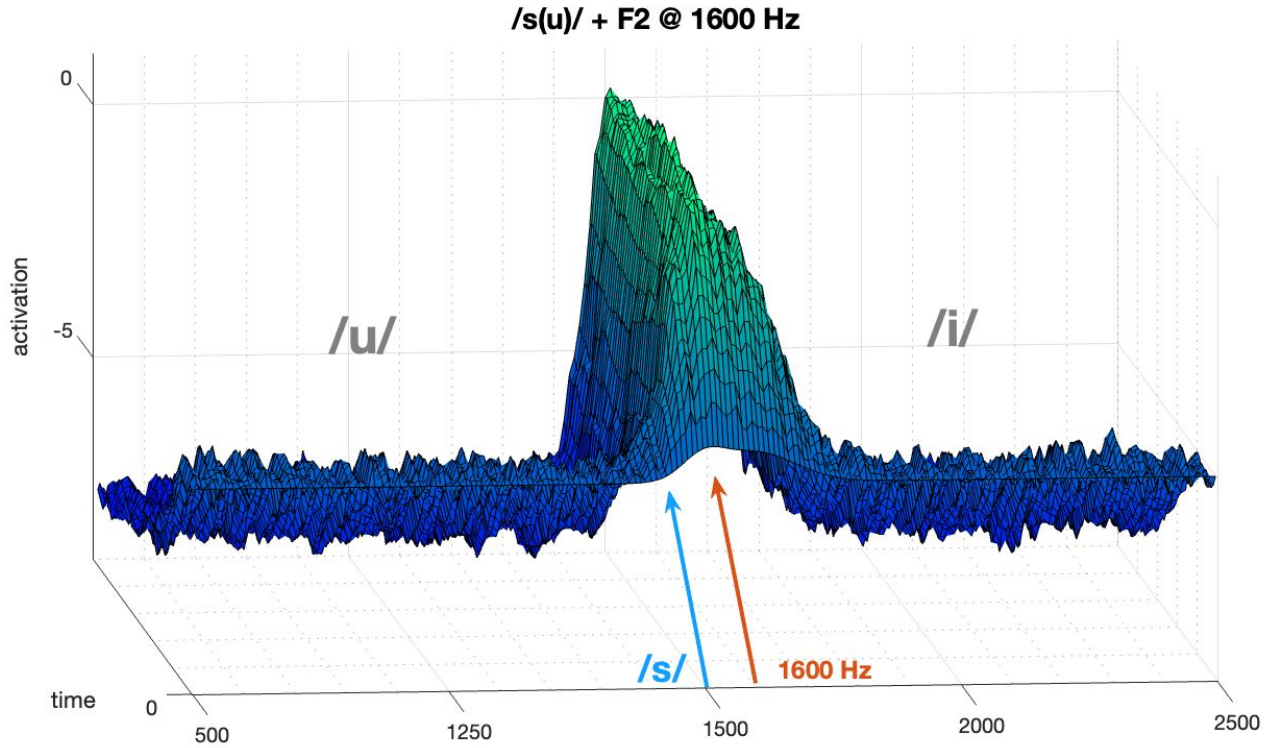


Whalen (1989): Model



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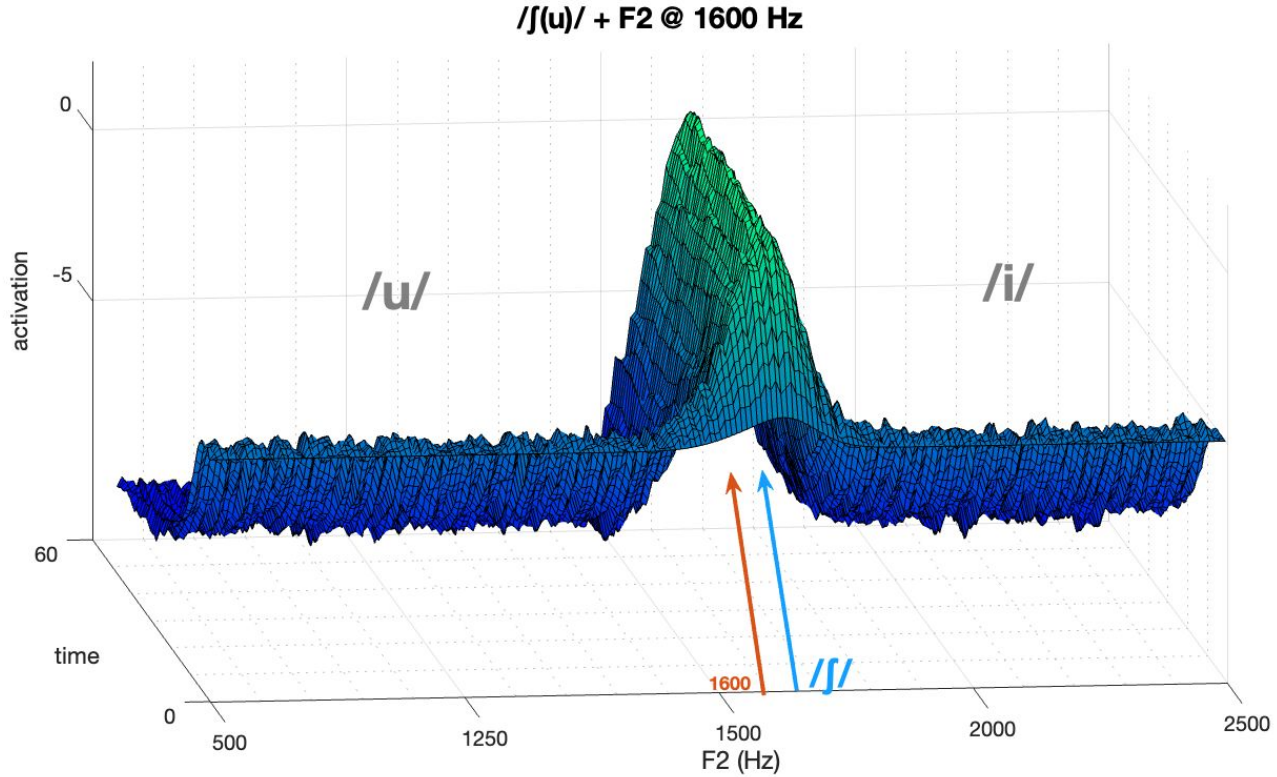
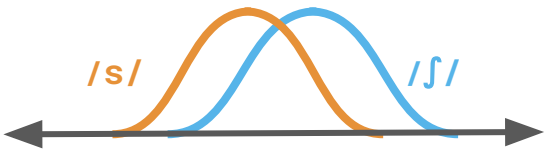


Model predictions

"Attraction effect":

- Listeners are more likely to perceive **lower F2s** as "same" for **/s/** stimuli than /ʃ/ stimuli
- Listeners are more likely to perceive **higher F2s** as "same" for **/ʃ/** stimuli than /s/ stimuli

H_0: no difference between proportion of same responses across fricatives



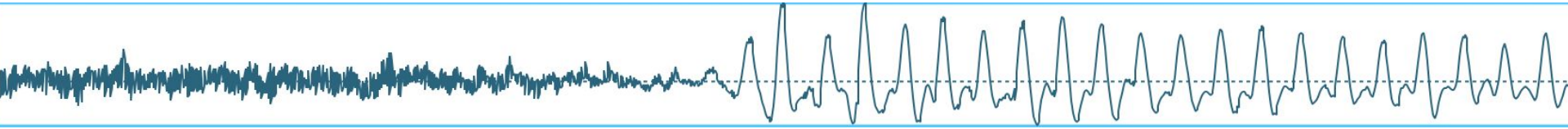
Effect of coarticulation:

- We expect any observed effect of fricative category on vowel perception to be stronger when coarticulation is present in the signal

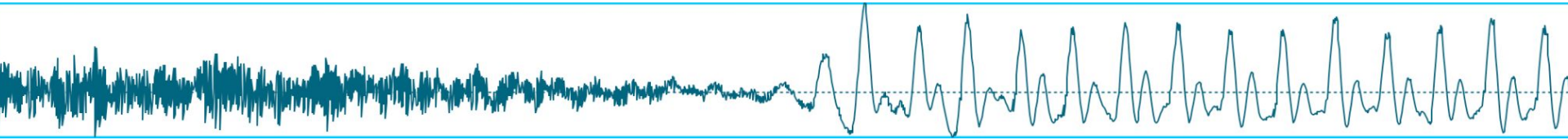
H_0: the presence or absence of coarticulation makes no difference

Summary

- Prior work has demonstrated contextual effects on fricative-vowel perception
- We used a DFT model to make predictions about this phenomenon on a continuous scale
- We extended prior work by modulating the presence of coarticulation
- Future work may expand to speakers of other languages
  - How much do the responses to coarticulated vs. non-coarticulated change?
  - Can we separate innate biases from statistical learning?



Thank you



Appendix: Model parameters

	/$s_{(u)}$/	/$s_{(i)}$/	/$ʃ_{(u)}$/	/$ʃ_{(i)}$/
preshape_p	100	100	115	115
preshape_w	**4**	**6**	**5**	**6**
preshape_a	4	4	4	4

Across simulations:
- F2_w = 8
- F2_a = 6

field size = 200
τ = 10
h = -5
β = 4

sigmaExc = 10
ampExc = 10
sigmaInh = 12.5
ampInh = 5