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

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Overview

- Background
  - *Soft* bias?
  - Fricative context impacts vowel perception; **source?**
    - Coarticulation?
    - Listener sensitivity to interactions in the acoustics?

- Modeling prior work
  - Consequent predictions

- Future directions

Background

Soft biases on phonotactics

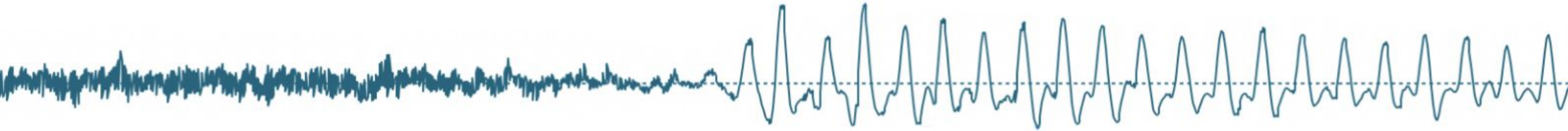
- *Absolute (hard) biases*
  - *FRICATIVES
    (Barlow, 1997; Barlow & Gierut, 1999)

- *“Soft” biases*
  (White, 2013, 2014; White & Sundara, 2014)
  - Phonological markedness as ease of learnability
  - Initial dispreference for a phonological pattern which can be overcome with more exposure

Soft biases on ***fricative-vowel*** phonotactics

- Sibilant place contrasts in [_i] context:
  - Japanese (Vance, 2008)
    - [ʃu-su] vs. [ʃi-*si]
  - Mandarin Chinese (Li, 2021)
    - Avoidance of 3-way contrast:
      - [sa-ɕa-ʂa] vs. [*si-ɕi-*ʂi]
  - Acoma (Kersan); Chakobo (Panoan); Telugu (Dravidian) (Lee-Kim, 2014)
    - 3-way place distinction reduced to 2-way:
      - [s-ɕ-ʂ] or [s-ʃ-ʂ] → [si-ɕi], [si-ʃi], or [ɕi-ʂi]
- **Do such contrasts arise, at least in part, from perceptual biases?**

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



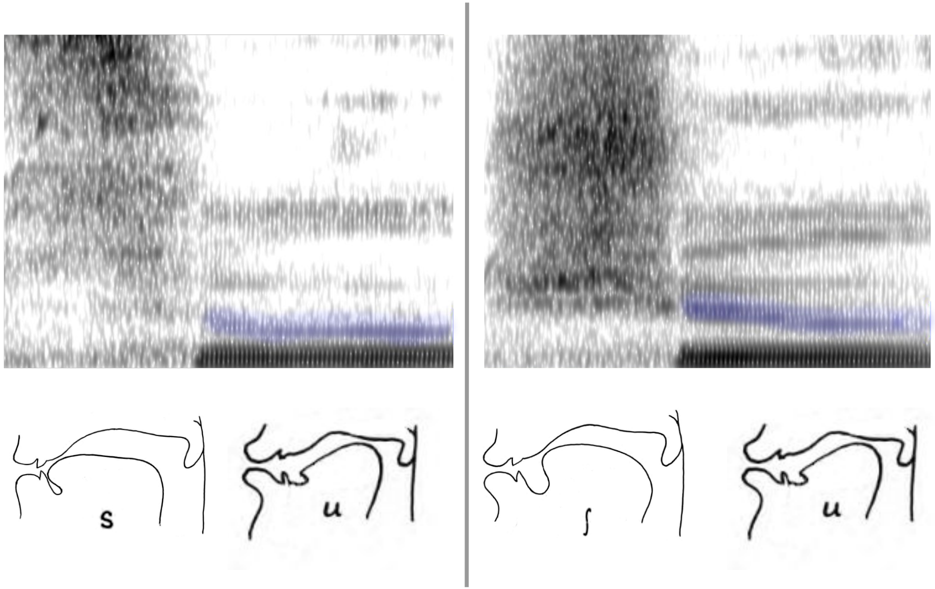
- Listeners can anticipate the **category** of the vowel during **aperiodic energy of the fricative**, even before hearing the **periodic energy of the vowel**
  (Yeni-Komshian & Soli, 1981; Galle et al., 2019)
- Fricative noise ***influences*** vowel categorization
  (Whalen, 1989)
- Vowel F2 also influences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

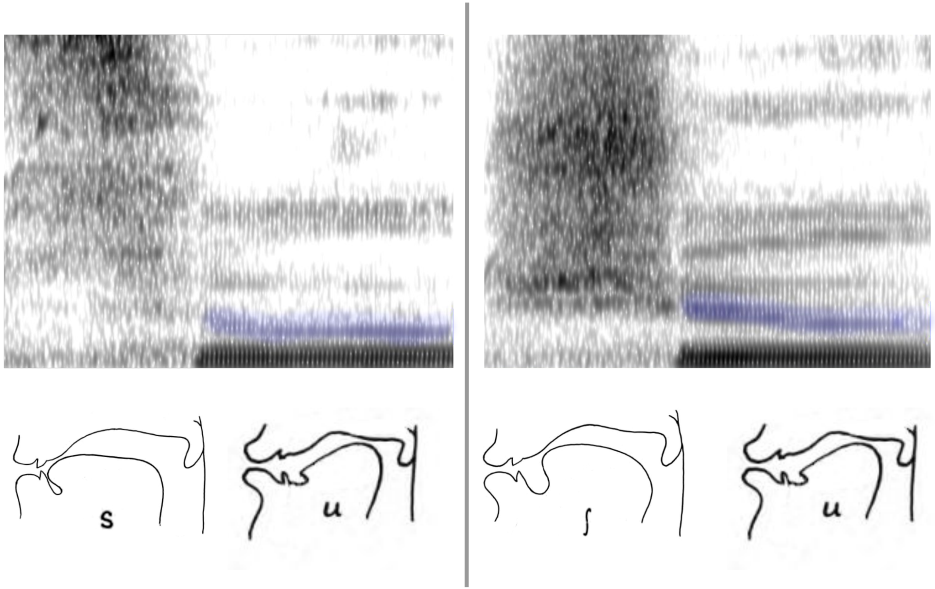


*X-ray tracings adapted from Straka, 1965, p. 38, 59

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



*X-ray tracings adapted from Straka, 1965, p. 38, 59

But 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

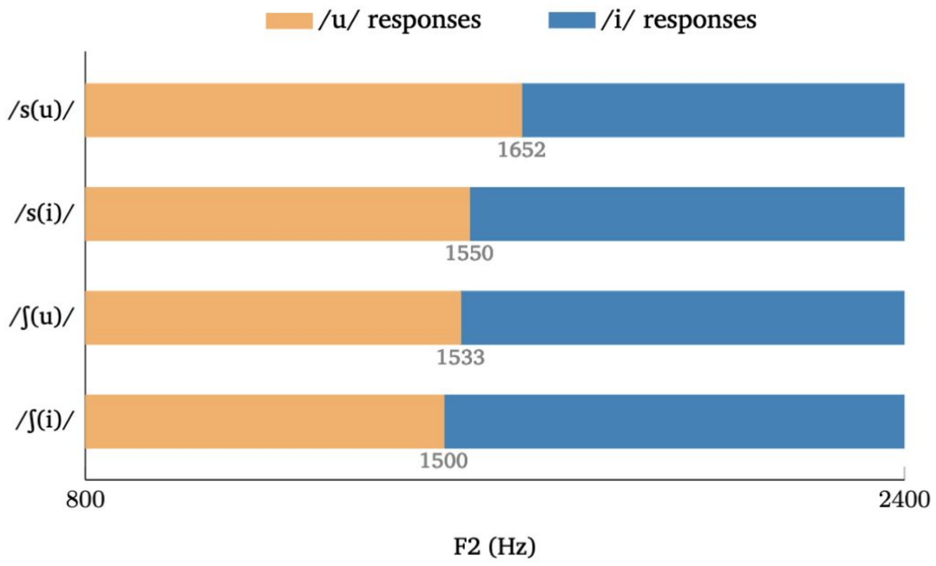
- Vowels synthesized along a continuum between /u/ & /i/.

- 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 <u>more /u/ responses</u> (lower F2) than the **lower frequencies associated with /ʃ/**



And what can DFT do for us now?

- What might we expect to see if we could observe similar patterns of discrimination **along a continuum**, rather than discrete categories?

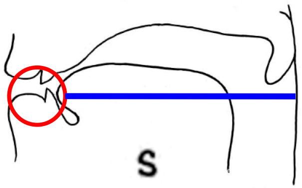
- Modeling these results with DFT can give us some ideas

Our model

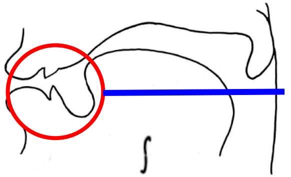
Deriving Whalen (1989) results in DFT

Remember:

- Fricative spectral peak frequencies ← size of 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

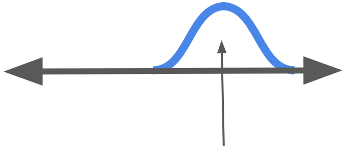
- Evidence that distinct neural populations process **`aperiodic`** and **`periodic`** energy in speech sounds
  (Yrttiaho et al., 2011)

- Suppose this is the case…*

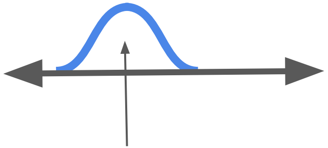
- Our model:
  coupled DNFs independently detecting aperiodic and periodic energy

Proposal: coupled fields

aperiodic energy
field



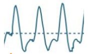
/s/ frication
peak frequency



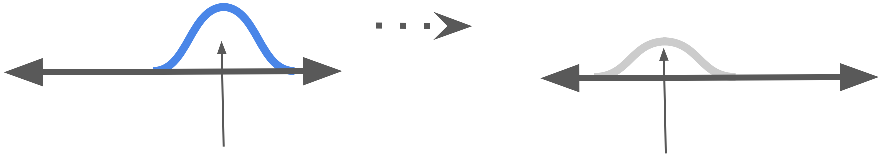
/ʃ/ frication
peak frequency

Proposal: coupled fields

aperiodic energy field



periodic energy (F2) field



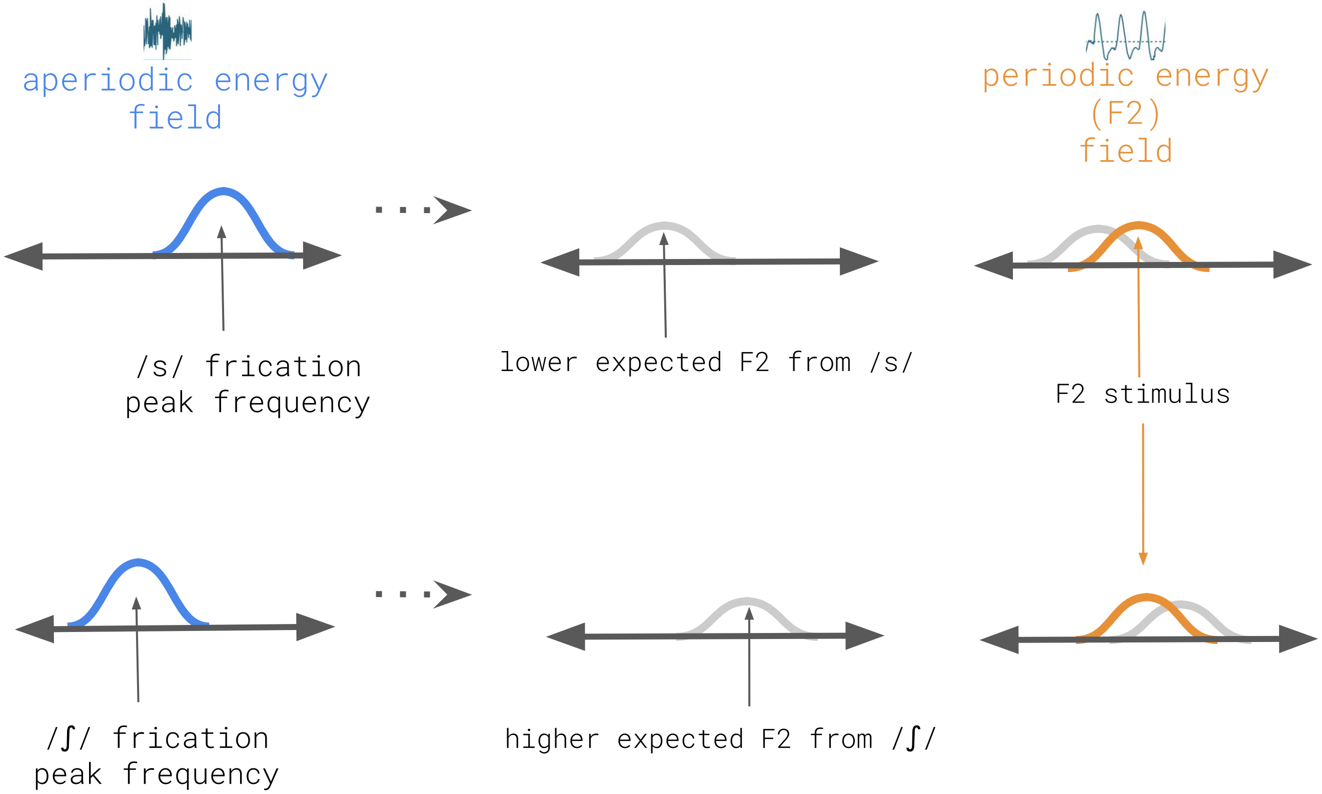
/s/ frication peak frequency

lower expected F2 from /s/

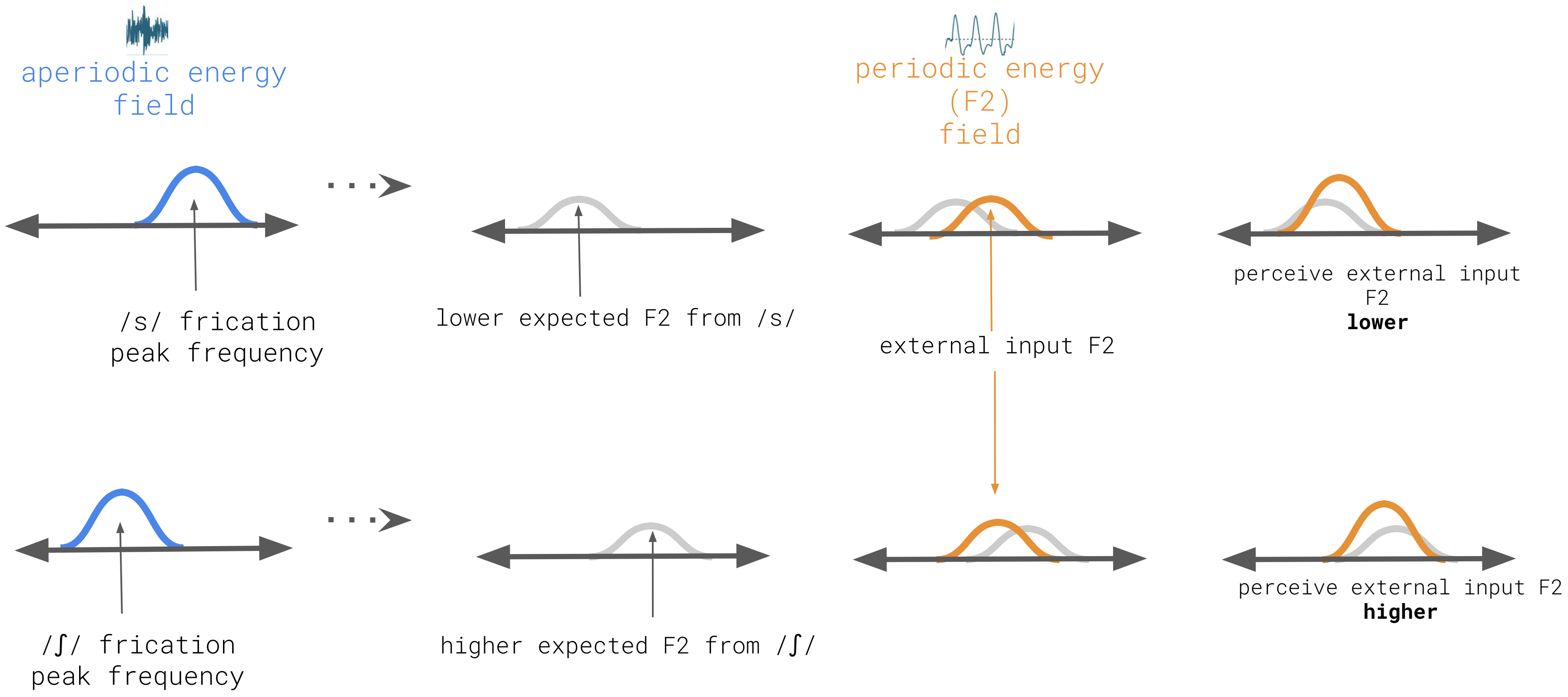
/ʃ/ frication peak frequency

higher expected F2 from /ʃ/

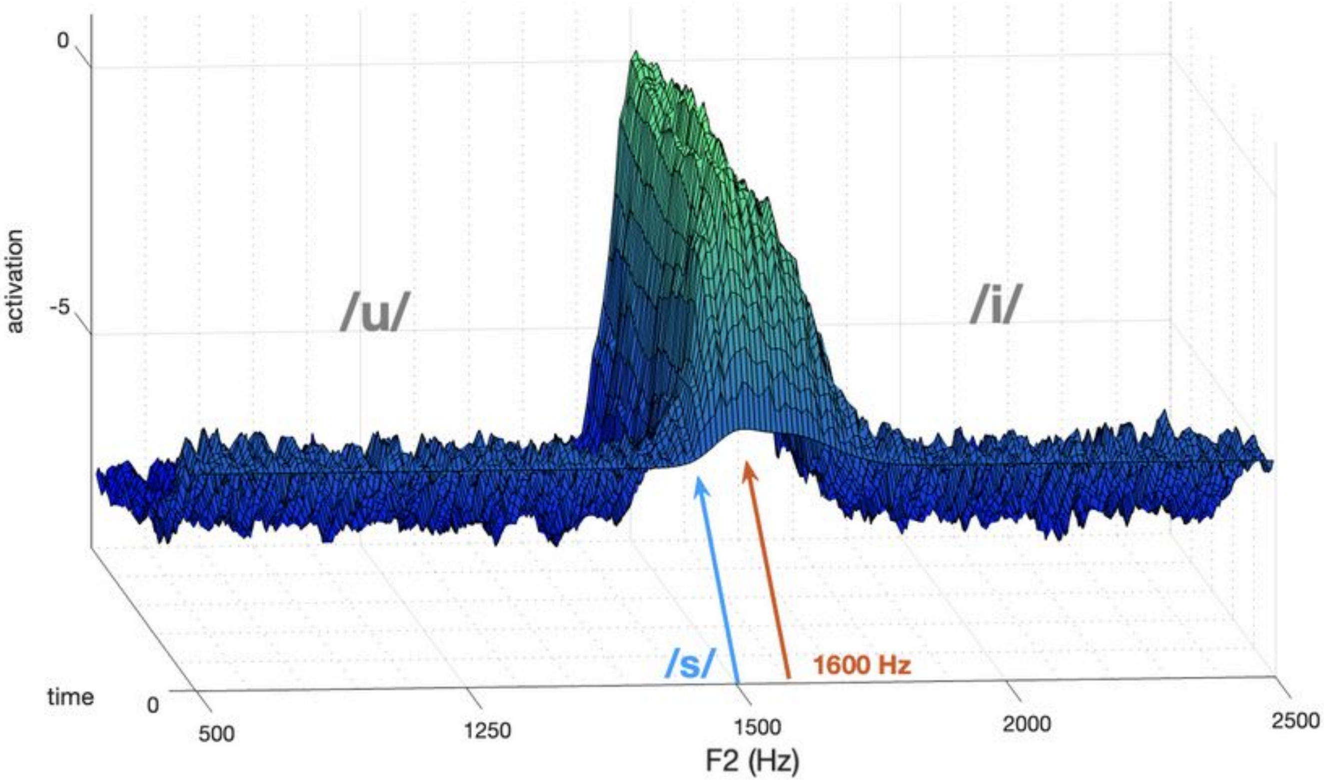
Proposal: coupled fields



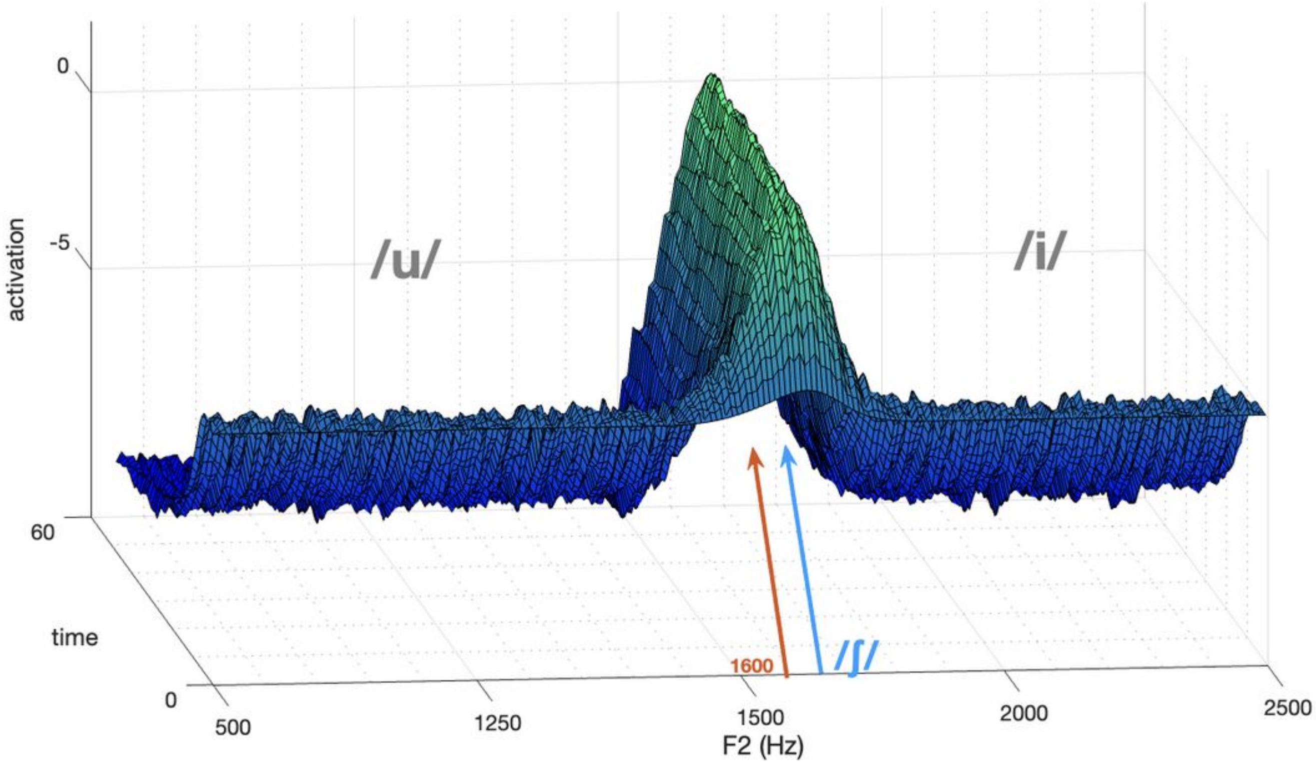
Proposal: coupled fields



Simulation results: F2 peak following /s/



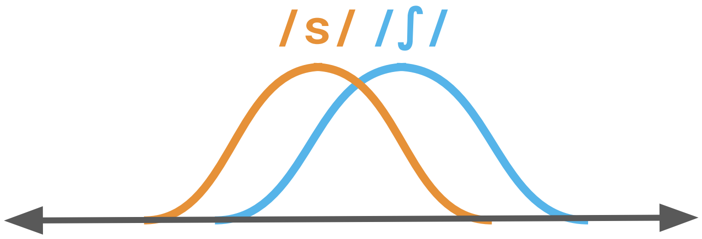
Simulation results: F2 peak following /ʃ/



Model prediction: “Attraction effect”

- A preceding **/s/** conditions **lowered** perception of **F2**

- A preceding **/ʃ/** conditions **higher** perception of **F2**

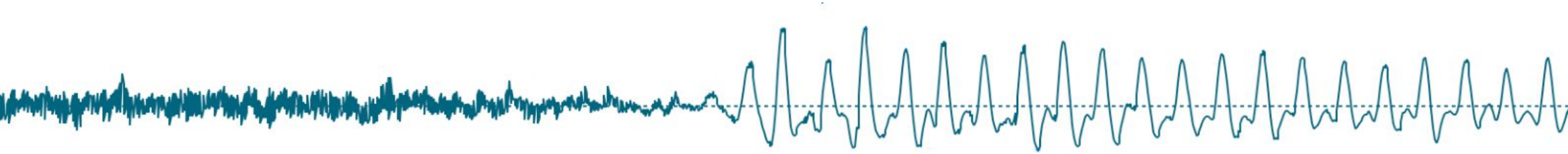


Summary

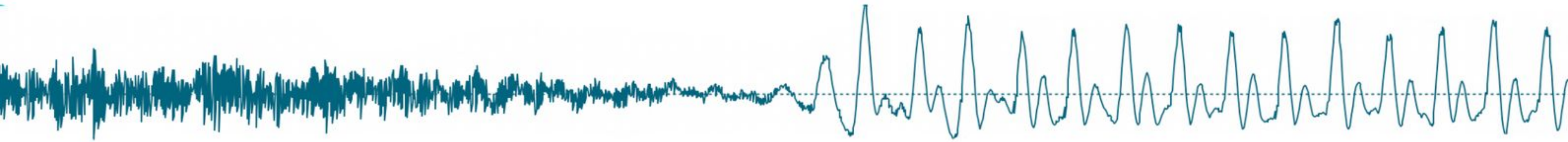
- Prior work has demonstrated contextual effects
  on fricative-vowel perception

- We used a DFT model to **derive** these attested contextual effects
  & make new predictions

- Future work can empirically test these predictions
  - Which is underway! :)



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