



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
- Model predictions
- Future directions

# Background

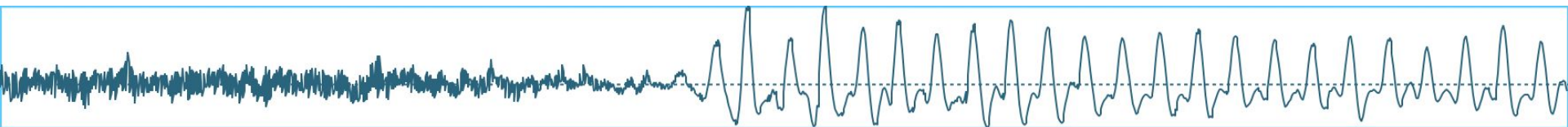
# Soft biases on phonotactics

- *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)

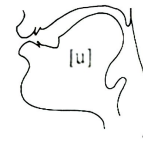
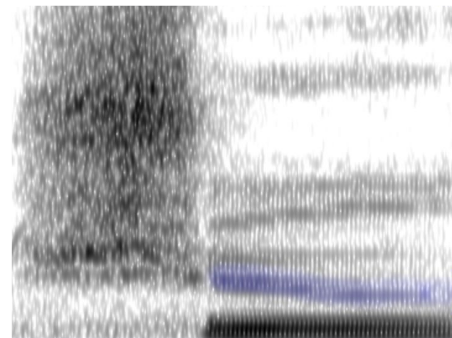
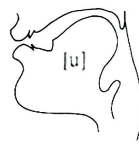
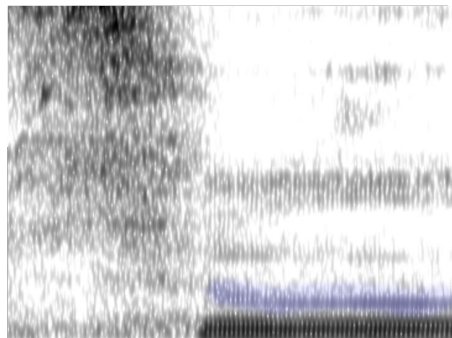
- Vowel F2 also influences fricative categorization

(Kunisaki & Fujisaki, 1977; Mann & Repp, 1980; Whalen, 1981)

- Probably due to coarticulation

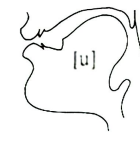
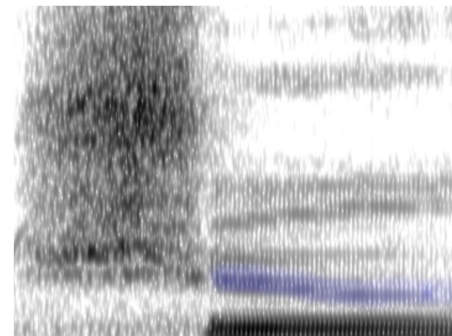
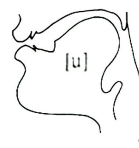
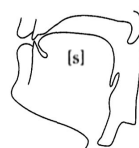
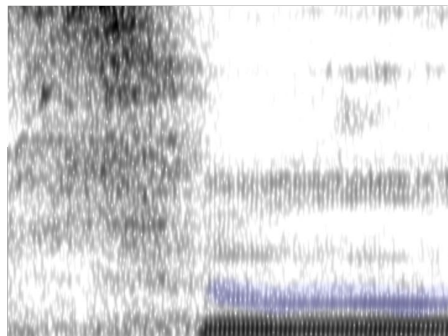
# Coarticulation

- 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*?

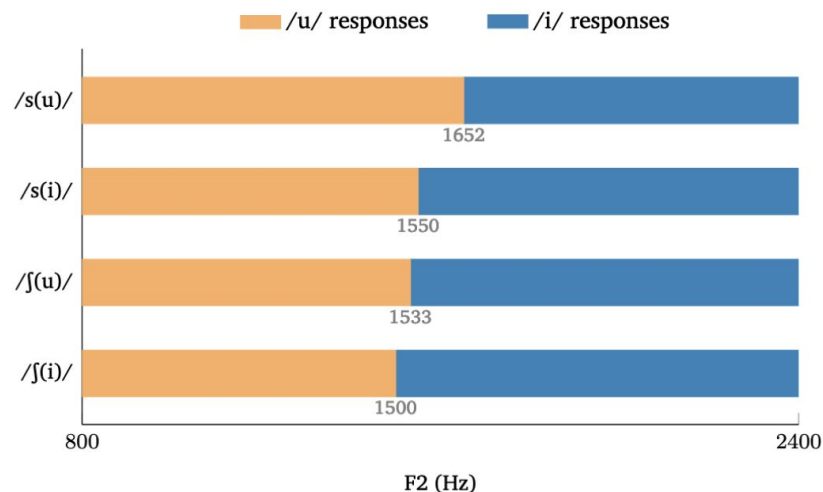
- Anticipation is a **domain-general** cognitive ability
- Perceptual informativity of coarticulation is well established
- Still not clear whether it accounts for the totality of the anticipation effects
- Listeners might have processing biases that contribute to anticipation,  
independent of what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

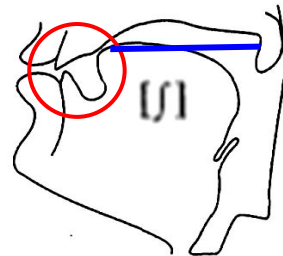
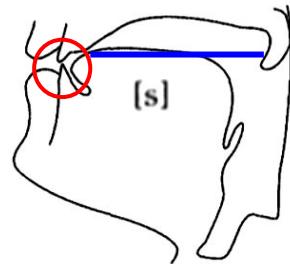
- Can we observe the effect of fricative context on vowel perception *without* coarticulation?
- Can we observe similar patterns of discrimination along a continuum, rather than discrete categories?

# Model

# Deriving Whalen (1989) results in DFT

Remember:

- Fricative spectral peak frequencies  $\leftarrow$  size of the cavity in front of the constriction during generation of **aperiodic energy**
- F2 at the onset of voicing  $\leftarrow$  resonance of the back cavity;
  - **periodic energy** might correspond with spectral peak in **preceding fricative turbulence**

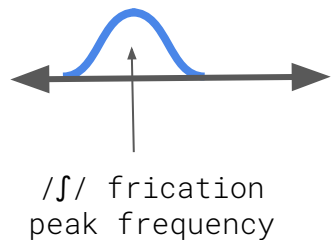
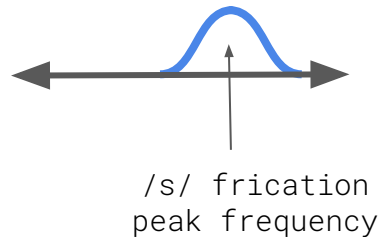


## Deriving Whalen (1989) results in DFT

- 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

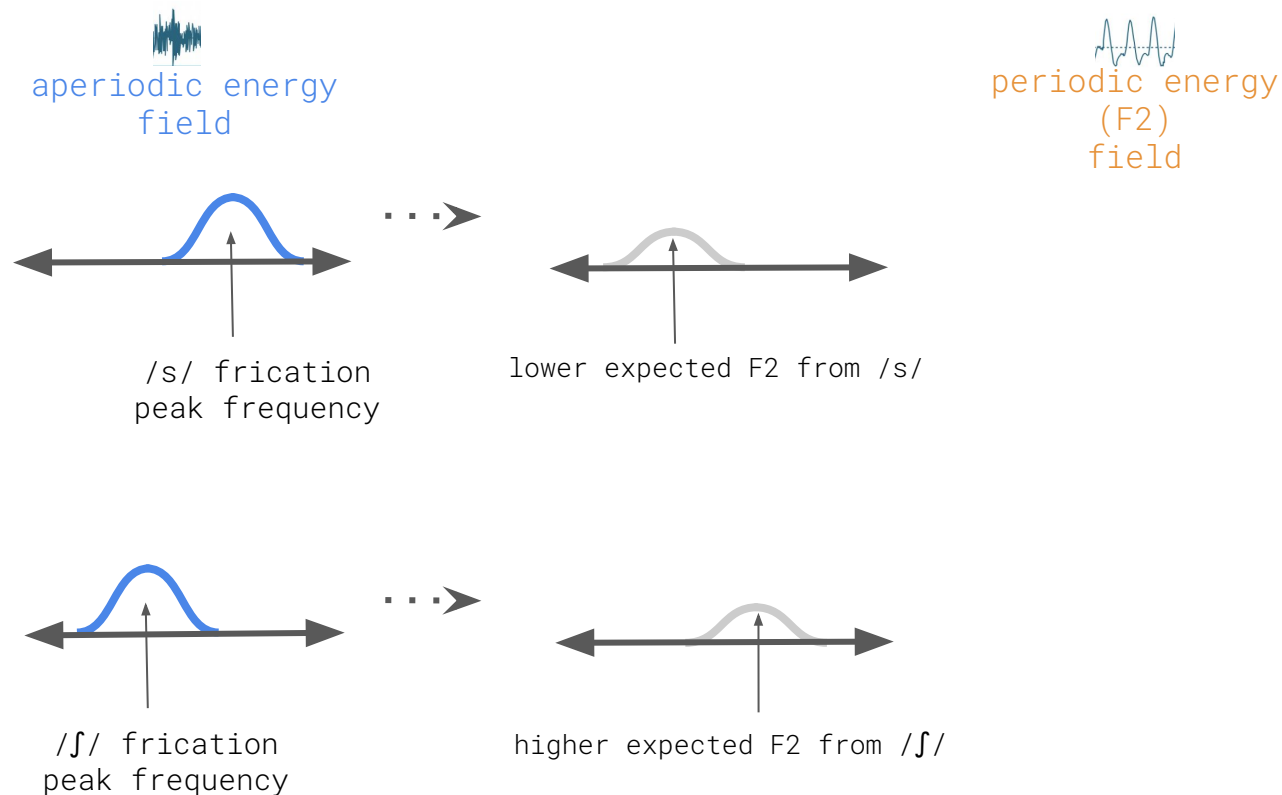
# Proposal: coupled fields

  
aperiodic energy  
field

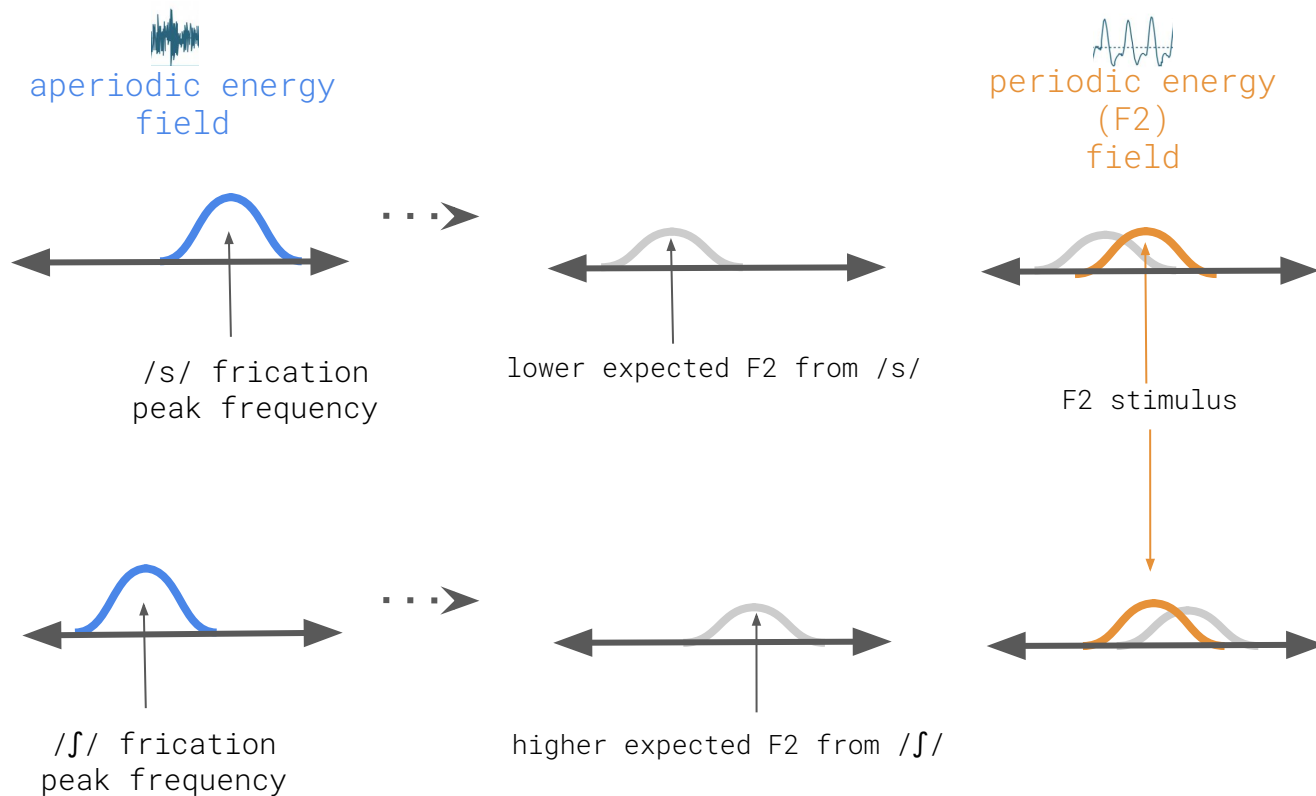




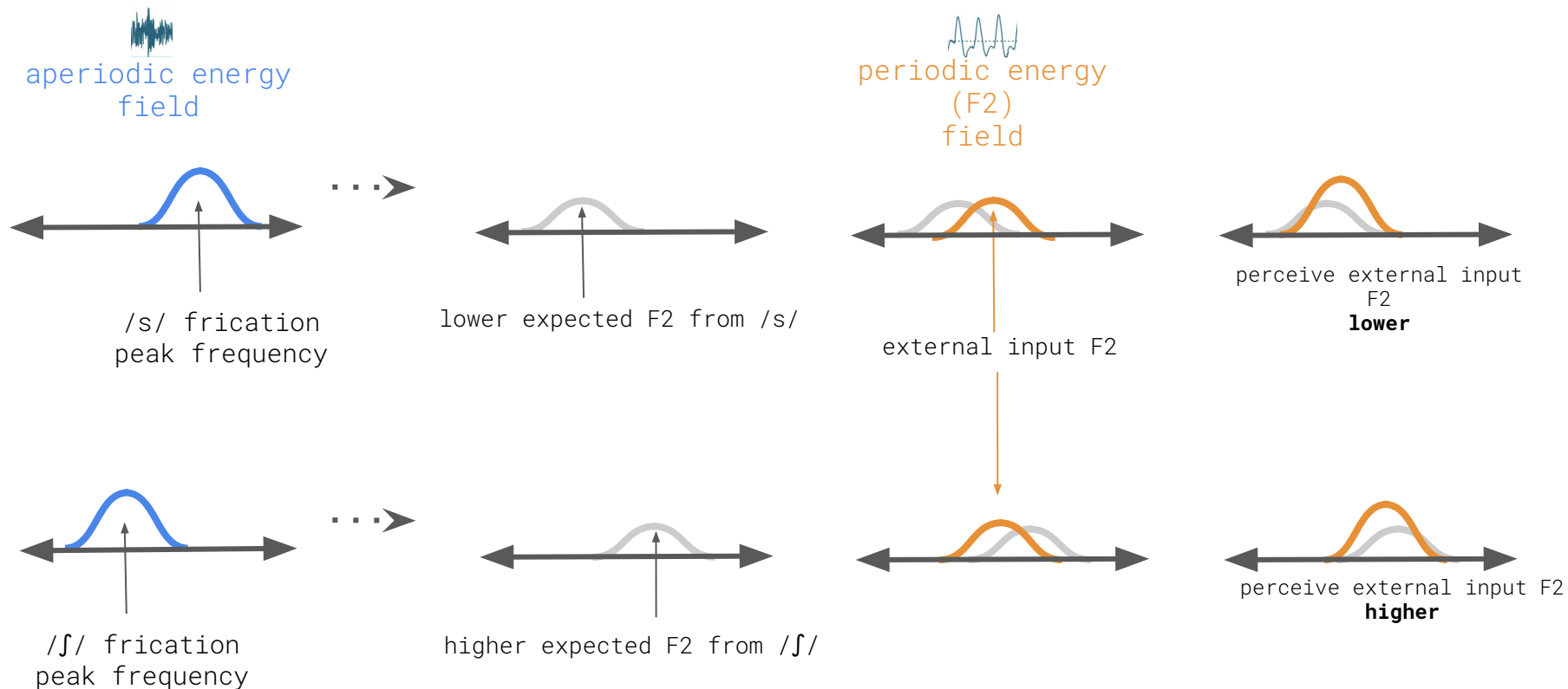
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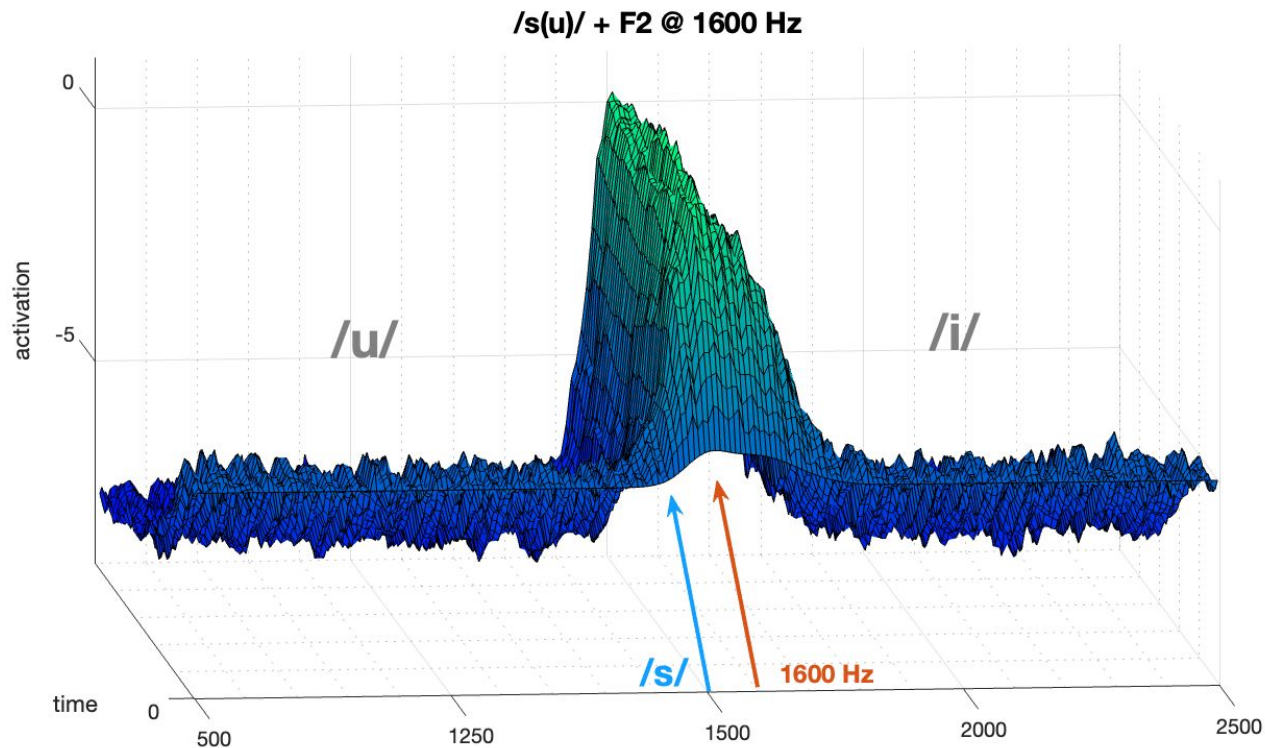
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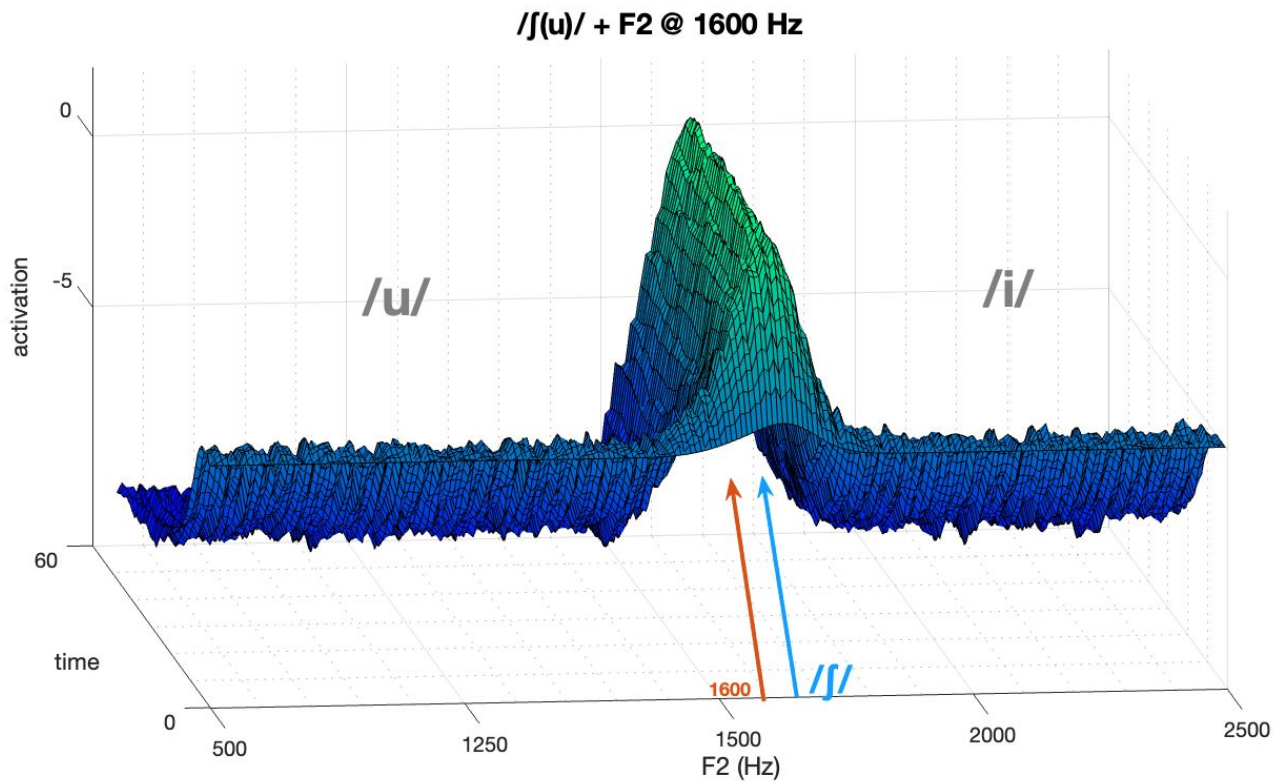
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# Whalen (1989): Model



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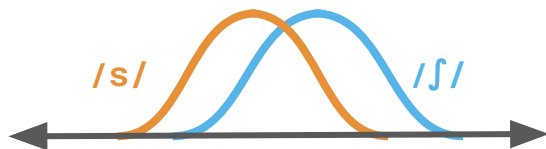


# Model predictions

## "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



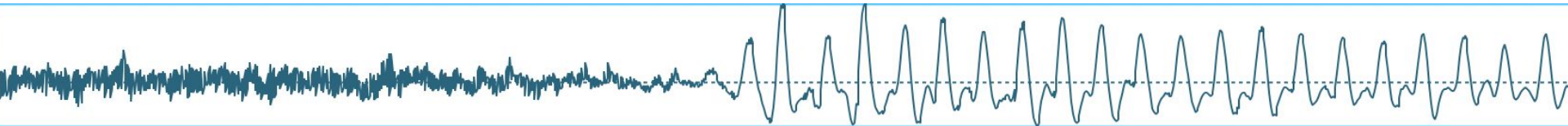
## Effect of coarticulation:

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

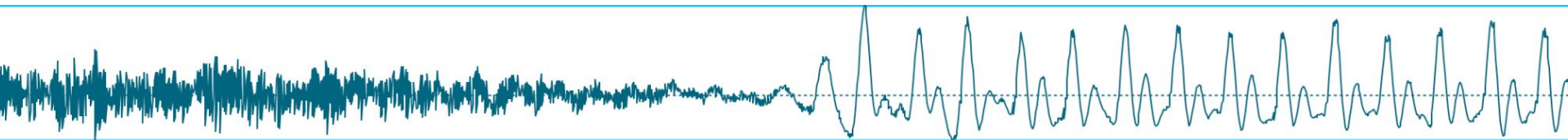
$H_0$ : the presence or absence of coarticulation makes no difference

# 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
- Future work can empirically test these predictions
  - Which we have done! :)



Thank you





## Appendix: Model parameters

	$/s_{(u)}/$	$/s_{(i)}/$	$/J_{(u)}/$	$/J_{(i)}/$
preshape_p	100	100	115	115
<b>preshape_w</b>	<b>4</b>	<b>6</b>	<b>5</b>	<b>6</b>
preshape_a	4	4	4	4

Across simulations:

- $F2\_w = 8$
- $F2\_a = 6$

field size = 200

$\tau = 10$

$h = -5$

$\beta = 4$

$\sigma_{Exc} = 10$

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$\sigma_{Inh} = 12.5$

$\sigma_{Inh} = 5$