Covert /ʌ/ allophony in English: variation in a socially uninhibited sound pattern

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American English /ʌ/:  
- a variety perceptually indistinct production strategies (Delattre and Freeman 1968, Tiede et al. 2004).  
  - bunched  
  - retroflex  
  - etc.
The Delattre and Freeman taxonomy:

- Types 2-7 reported for American English (Delattre and Freeman 1968, Tiede et al. 2004).
- Delattre and Freeman found Types 1 and 8 in British English.
The r-less /ʌ/ types (bunched)

British

Northeast American

Type 1

Type 2
The dorsal /ʌ/ types (bunched)

- Velar
- Classic bunched

Type 3

Type 4
The blade /ɹ/ types (bunched)

Posterior blade

Anterior blade

Type 5

Type 6
The retroflex /ɾ/ types

Apical retroflex

Type 7

Classic retroflex

Type 8

Covert /ɾ/ allophony
Multiple strategies

- Individual speakers employ multiple strategies (e.g., Delattre and Freeman 1968, Ong and Stone 1998, Guenther et al. 1999, Campbell et al. 2004).
Multiple strategies

- Individual speakers employ multiple strategies (e.g., Delattre and Freeman 1968, Ong and Stone 1998, Guenther et al. 1999, Campbell et al. 2004).
- We present results from an ultrasound experiment showing that speakers with more than one distinct /a/ production strategy often:
  - use each “allophone” consistently in different contexts
  - do so in the interest of articulatory ease, and
  - differ quite a bit from one another.
Phonetic and social factors

▶ /ʌ/ allophony is subject to phonetic factors but cannot be subject to social factors.
Phonetic and social factors

- /ɹ/ allophony is subject to phonetic factors but cannot be subject to social factors.
- Strange properties:
Phonetic and social factors

- /ɔ/ allophony is subject to phonetic factors but cannot be subject to social factors.
- Strange properties:
  - Speaker-specific allophony patterns.
Phonetic and social factors

▶ /ʌ/ allophony is subject to phonetic factors but cannot be subject to social factors.
▶ Strange properties:
  ▶ Speaker-specific allophony patterns.
  ▶ Complex allophony patterns:
Phonetic and social factors

- /r/ allophony is subject to phonetic factors but cannot be subject to social factors.
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  - Complex allophony patterns:
    - Different conditioning segments for different syllable positions.
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  - Complex allophony patterns:
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    - Different conditioning consonants for different vowel contexts
    - Sets of conditioning environments that are not easily defined.
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  - Complex allophony patterns:
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    - Different conditioning consonants for different vowel contexts
    - Sets of conditioning environments that are not easily defined.
  - Allophones can induce different coarticulatory effects on nearby sounds, which are perceptible.
Introduction

We argue that these facts show that:

▶ multiple sound patterns can emerge in response to the same phonetic motivation,
▶ speakers can control complex allophonic rules,
▶ the simplification characteristic of many familiar sound patterns appears to be the result of social convergence on a single conventionalized pattern, and
▶ this convergence cannot occur here because the difference between allophones is imperceptible.

But perceptually indistinct allophones can induce perceptible effects on nearby sounds.
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Introduction

/s/ retraction


Expectation: different /ô/ sounds cause different coarticulation.

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Covert /ô/ allophony
/s/ retraction

▶ /[strɪŋ]/ → [ʃtrɪŋ]

▶ /strιŋ/ → [ʃtriŋ]
▶ Expectation: different [ɜ]s cause different coarticulation.
Experiments

We present the results of two experiments:
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▶ Experiment #1 investigates within-speaker variation in /ɪ/ production strategy.
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▶ Experiment #1 investigates within-speaker variation in /ʌ/ production strategy.

▶ Experiment #2 investigates the role of /ʌ/ production strategy in /s/ retraction.
Methods overview

- Subjects were recorded producing English words containing /α/ (audio, video, and ultrasound video)
Subjects were recorded producing English words containing /ɒ/ (audio, video, and ultrasound video)

Stimuli were monosyllabic words with /ɒ/ in different syllabic and segmental contexts.
Methods overview

- Subjects were recorded producing English words containing /ɒ/ (audio, video, and ultrasound video).
- Stimuli were monosyllabic words with /ɒ/ in different syllabic and segmental contexts.
- Produced in the carrier phrase “Please say X again.”
Stimuli

Segments:

- Vowels in stimuli were /a o i/.
- Preceding /a/ were /p t k fʃ θ/ and #.
- Following /a/ were /p t k f tʃ θ l/ and #.
Stimuli

Segments:

- Vowels in stimuli were /a o i/.
- Preceding /\x/ were /p t k f θ/ and #.
- Following /\x/ were /p t k f t θ l/ and #.

Words (subject to the existence of words):

- 3 words for each C__V & V__C context (92)
- 5 words for each initial & final context (30)
- 1 word for each C__C context (25) (many gaps)
Stimuli

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- Vowels in stimuli were /a o i/.
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Words (subject to the existence of words):

- 3 words for each C__V & V__C context (92)
- 5 words for each initial & final context (30)
- 1 word for each C__C context (25) (many gaps)

All words repeated 3 times.
Subjects

- 32 University of Arizona undergraduates
- 5 subjects excluded from analysis (4 non-native speakers of American English and 1 who imaged very poorly)
- 27 subjects analyzed
Analysis of tokens

- 441 tokens (3 × 147) per subject analyzed:
  - visual inspection of ultrasound images
  - visual inspection of ultrasound video
  - with and without Palatron tongue-palate alignment (Mielke et al. 2004).
- Each token labeled according to Delattre and Freeman’s (1968) taxonomy.
An ultrasound image of the tongue
An ultrasound image of the tongue
An ultrasound image of the tongue
An ultrasound image of the tongue
An ultrasound image of the tongue
Retroflex: r08’s ‘frog’
Bunched: r08’s ‘Shriek’
Bunched: r15’s ‘morph’
Coarticulated bunched: r15’s ‘torch’
/ɻ/ production strategies:

- Type 3 only
- Type 4 only
- Type 7 only
- Type 8 only
- Types 4/5/6
- Types 3-7
- 3-6 vs. 7-8

Total 27 subjects
/ɔ/ production strategies:

Type 3 only

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Total 27 subjects
/ɹ/ production strategies:

- Type 3 only
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\( / \text{ɪ}/ \) production strategies:

- Type 3 only
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- Type 7 only

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- 3-6 vs. 7-8
- Total

27 subjects
Average retroflexion rates for prevocalic /ɹ/ (11 subjects)
Generalizations: prevocalic /ɹ/

Prevocalic /ɹ/ retroflexion rates:
- (C)ra, (C)ro > (C)ri
Generalizations: prevocalic /ɨ/

Prevocalic /ɨ/ retroflexion rates:
- (C)ra, (C)ro > (C)ri
- #rV, prV, frV > krV, frV, trV, θrV
Prevocalic /ɾ/ retroflexion rates:

- (C)ra, (C)ro > (C)ri
- #rV, prV, frV > krV, frV, trV, θrV
- fri, tri, θri = zero
Generalizations: prevocalic /ʌ/ 

Prevocalic /ʌ/ retroflexion rates:
- (C)ra, (C)ro > (C)ri
- #rV, prV, frV > krV, frV, trV, θrV
- ʃri, tri, θri = zero

Discourage retroflexion:
- high front vowel
- lingual consonants, especially coronals
Average retroflexion rates for postvocalic /u/ (11 subjects)
Generalizations: postvocalic /ʌ/

Postvocalic /ʌ/ retroflexion rates:

- low overall
Generalizations: postvocalic /ᵻ/

Postvocalic /ᵻ/ retroflexion rates:

- low overall
- highest Vrl
Generalizations: postvocalic /ʌ/

Postvocalic /ʌ/ retroflexion rates:
- low overall
- highest Vrl
- ar(C), or(C) > ir(C)
Average retroflexion rates for syllabic /ɹ/ (11 subjects)
Generalizations: syllabic /ɹ/

Syllabic /ɹ/ retroflexion rates:
- low overall
Generalizations: syllabic /ʌ/

Syllabic /ʌ/ retroflexion rates:
- low overall
- highest (C)rl
Generalizations: syllabic /ɜ/

Syllabic /ɜ/ retroflexion rates:

- low overall
- highest (C)rl
- higher prV, frV
Summary of results so far

- Average retroflexion rates are highest before vowels and /l/.
Summary of results so far

- Average retroflexion rates are highest before vowels and /l/.
- Average retroflexion rates next to different segments are phonetically sensible:
Summary of results so far

- Average retroflexion rates are highest before vowels and /l/.
- Average retroflexion rates next to different segments are phonetically sensible:
  - Less retroflexion next to segments that place demands on the tongue that are antagonistic with retroflexion.
Average retroflexion rates are highest before vowels and /l/.

Average retroflexion rates next to different segments are phonetically sensible:

- Less retroflexion next to segments that place demands on the tongue that are antagonistic with retroflexion
- More retroflexion where segments do not interfere or where tongue body position is compatible with retroflexion
Nine speakers have some environments with 100% retroflexion.
Categorical retroflexion (Subject r19)

- Nine speakers have some environments with 100% retroflexion.
- r19 retroflexes everywhere but ʃri, tri, θri
Categorical retroflexion (Subject r19)

- Nine speakers have some environments with 100% retroflexion.
- r19 retroflexes everywhere but šri, tri, ůri
- often bunches šro, tro, ůro
Systematic gaps (Subject r08)

- Some speakers have systematic gaps.

Some speakers have systematic gaps. ▶ r08 doesn’t retroflex in SrV ▶ almost never retroflexes in Cri
Some speakers have systematic gaps.

r08 doesn’t retroflex in frV
Systematic gaps (Subject r08)

- Some speakers have systematic gaps.
- r08 doesn’t retroflex in $\text{frV}$
- almost never retroflexes in Cri
Other speakers have other gaps.
Systematic gaps (Subject r17)

- Other speakers have *other* gaps.
- r17 doesn’t retroflex in krV or θrV
Other speakers have *other* gaps.

r17 doesn’t retroflex in krV or θrV

but *does* retroflex in ſrV
Three speakers have only sporadic retroflexion.
Sporadic retroflexion (Subject r01)

- Three speakers have only sporadic retroflexion.
- r01 has some retroflexion in #ra
Sporadic retroflexion (Subject r01)

- Three speakers have only sporadic retroflexion.
- r01 has some retroflexion in #ra
- and occasional retroflexion in #ro, fra, fro
Retroflexion before liquids (Subject r19)

- Eight subjects retroflex postvocalic or syllabic /ʃ/.

![Graph showing retroflexion patterns](image-url)
Eight subjects retroflex postvocalic or syllabic /ʊ/.

Four of these retroflex only before /l/.
Retroflexion before liquids (Subject r19)

- Eight subjects retroflex postvocalic or syllabic /ʌ/.
- Four of these retroflex only before /l/.
- r19 retroflexes in all pre-liquid contexts.
Four subjects regularly retroflex before any other consonants.
Four subjects regularly retroflex before any other consonants.

r22 retroflexes in most nonprevocalic contexts.
Retroflexion before other consonants (Subject r22)

- Four subjects regularly retroflex before any other consonants.
- r22 retroflexes in most nonprevocalic contexts.
- but never in krk, ŋrk, trk, or ŋrt
/\_\_ allophony rules are... 

- phonetically natural
- speaker-specific
- complex
/ɾ/ allophony rules are **phonetically natural**

- Bunched /ɾ/ typically occurs next to “bunched” consonants and vowels.
/μ/ allophony rules are **phonetically natural**

- Bunched /μ/ typically occurs next to “bunched” consonants and vowels.
- Retroflex /μ/ typically occurs in contexts without antagonistic tongue shapes.
More bunching next to linguals and [i]

- [ʃ], [k], and [i] all involve essentially a “bunched” tongue body.
More bunching next to linguals and [i]

- [ʃ], [k], and [i] all involve essentially a “bunched” tongue body.
- Retroflexion is rare in these contexts: e.g., r08’s “shriek”
More bunching next to linguals and [i]

- [ʃ], [k], and [i] all involve essentially a “bunched” tongue body.
- Retroflexion is rare in these contexts: e.g., r08’s “shriek”
- ... but not impossible: r30’s “shriek”.
Retroflexion next to labials, word boundary back vowels
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- Labials do not interfere with retroflexion or provide free bunching.
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For retroflex /u/, the tongue body is back, as for a back vowel.
Retroflexion next to labials, word boundary back vowels

- Labials do not interfere with retroflexion or provide free bunching.
- For retroflex /\u00e4/, the tongue body is back, as for a back vowel.
- Retroflexion is more common here: r08’s “frog”.

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Covert /\u00e4/ allophony
Retroflexion before /l/

- More retroflexion before /l/ than before any other consonant.
Retroflexion before /l/:

- More retroflexion before /l/ than before any other consonant.
- The syllable structure of words with Vrl is ambiguous (e.g., ‘Carl’, ‘curl’, ‘whorl’).
Retroflexion before /l/

- More retroflexion before /l/ than before any other consonant.
- The syllable structure of words with Vrl is ambiguous (e.g., ‘Carl’, ‘curl’, ‘whorl’).
- Mixed results: 8 of 13 subjects who retroflex before vowels also retroflex before /l/. 
Retroflexion before /l/:

- More retroflexion before /l/ than before any other consonant.
- The syllable structure of words with Vrl is ambiguous (e.g., ‘Carl’, ‘curl’, ‘whorl’).
- Mixed results: 8 of 13 subjects who retroflex before vowels also retroflex before /l/.
- Consistent with other findings relating /l/’s phonetic ambiguity to mixed phonological behavior (e.g. Mielke 2005).
/ʌ/ allophony rules are **speaker-specific**: 

- Different reactions to the same phonetic motivations
/ᵻ/ allophony rules are **speaker-specific**: 

- Different reactions to the same phonetic motivations
- Responses to different speaker-specific phonetic motivations
Different reactions to the same motivations

<table>
<thead>
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<th>Context</th>
<th>Avg. rate</th>
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Different conditioning consonants

Subjects differ in what lingual Cs condition retroflexion.
Different conditioning consonants

Subjects differ in what lingual Cs condition retroflexion.

- Some differences may be attributed to speaker-specific articulatory motivations.
Subjects differ in what lingual Cs condition retroflexion.

- Some differences may be attributed to speaker-specific articulatory motivations.
- Some differences are not obviously rooted in different articulatory motivations.
Different conditioning consonants. Why?

r08 retroflexes after /k/ and /θ/, but not after /ʃ/.
Different conditioning consonants. Why?

r08 retroflexes after /k/ and /θ/, but not after /ʃ/.

r17 retroflexes after /ʃ/, but not after /k/ or /θ/.
Speaker-specific motivations: \[ \∫ \]

‘Shrop’

r08 (bunched): r17 (retroflex):
Speaker-specific motivations?: [k]

‘Crop’

r08 (retroflex):  r17 (bunched):
Speaker-specific motivations?: $\emptyset$

‘throb’

$\text{r08 (retroflex):}$

$\text{r17 (bunched):}$
/ɾ/ allophony rules are complex

- Different conditioning segments for different syllable positions
/u/ allophony rules are complex

- Different conditioning segments for different syllable positions
- Different conditioning consonants for different vowel contexts
/ɹ/ allophony rules are complex

- Different conditioning segments for different syllable positions
- Different conditioning consonants for different vowel contexts
- Sets of conditioning environments are not easily defined.

E.g. r04 has:
\[
/ɹ/ \rightarrow \text{retroflex} \ / \ \{\# p f k\} \_\_\{a o\} \ \vee \ p\_i \ \vee \ \theta\_a
\]
Retroflexion before and after consonants

Consonants that allow retroflexion of a following /ʌ/.

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Retroflexion before /a o/ and /i/

Consonants that allow retroflexion of a following /ʌ/ before /a o/.

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Consonants that allow retroflexion of a following /ɹ/ before /a o/.

Consonants that allow retroflexion of a following /ɹ/ before /i/.

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These are different from typical sound patterns.
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We do not typically see:

- such a wide range of speaker-specific interpretations of a phonetically-motivated sound pattern.
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We do not typically see:

- such a wide range of speaker-specific interpretations of a phonetically-motivated sound pattern.
- such complex conditioning environments.
- sound patterns that respect each speaker’s idiosyncratic articulatory needs.

But apparently these types of patterns are possible.
Phonological constraints are coarse-grained because complex constraints are less stable across speakers with different vocabularies.
Pierrehumbert (2001)

- Phonological constraints are coarse-grained because complex constraints are less stable across speakers with different vocabularies.
- We might add that different speakers have different phonetic motivations too.
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Typical sound patterns are simpler than would be necessary to satisfy a particular speaker’s articulatory needs.
Phonological constraints are coarse-grained because complex constraints are less stable across speakers with different vocabularies.

We might add that different speakers have different phonetic motivations too.

Typical sound patterns are simpler than would be necessary to satisfy a particular speaker’s articulatory needs.

/ɔ/ allophony can have fine-grained conditioning environments because no allophony pattern ever has to be learned by more than one speaker.
Why is /ɪ/ allophony different?

- The difference between allophones is inaudible.
Why is /ɹ/ allophony different?

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- Speakers cannot converge on a common rule because no one knows what anyone else is doing.
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- Speakers cannot converge on a common rule because no one knows what anyone else is doing.
- Social convergence has been linked to the simplification of sound patterns (e.g., Trudgill 2002)
- Social convergence on an /ɪ/ allophony pattern (if possible) might:
  - iron out speaker-specific articulatory differences,
  - tend to favor an easily learned variant.
/ʌ/ allophony and /s/ retraction
/ɒ/ allophony and /s/ retraction

▶ /s/ retraction has been treated as exaggerated coarticulation to /ɒ/ (e.g., Joseph and Janda 2001, Durian 2006)
/ɔ/ allophony and /s/ retraction

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- Not all speakers exhibit categorical /s/ retraction
/ʊ/ allophony and /s/ retraction

- /s/ retraction has been treated as exaggerated coarticulation to /ʊ/ (e.g., Joseph and Janda 2001, Durian 2006)
- Not all speakers exhibit categorical /s/ retraction
- Modern non-retractors should exhibit the kind of coarticulation that led to modern /s/ retraction.
/ʌ/ allophony and /s/ retraction

- /s/ retraction has been treated as exaggerated coarticulation to /ʌ/ (e.g., Joseph and Janda 2001, Durian 2006)
- Not all speakers exhibit categorical /s/ retraction
- Modern non-retractors should exhibit the kind of coarticulation that led to modern /s/ retraction.
- Different /ʌ/s should cause different coarticulation.
/ʌ/ allophony and /s/ retraction

A reasonable hypothesis: bunched /ʌ/ causes more retraction.

Problem: The /st/ environment strongly encourages bunching of /ʌ/.

Another hypothesis: more retraction for speakers whose /s/ and /ʌ/ production strategies are more different. (Greater postural change requires more gestural overlap.)

Jeff Mielke, Adam Baker, and Diana Archangeli
A reasonable hypothesis: bunched /ɜ/ causes more retraction
A reasonable hypothesis: bunched /ʌ/ causes more retraction

Problem: The /st...V/ environment strongly encourages bunching of /ʌ/.
/ʌ/ allophony and /s/ retraction

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▶ Problem: The /st__V/ environment strongly encourages bunching of /ʌ/.

Another hypothesis: more retraction for speakers whose /s/ and /ʌ/ production strategies are more different.

▶ (Greater postural change requires more gestural overlap.)
Methods

- Data collection identical to /ʌ/ experiment
- Subjects were another 32 University of Arizona undergraduates.
  - 6 excluded from analysis for poor imaging or other technical problems.
  - 26 subjects analyzed: 10 retractors and 16 non-retractors
Stimuli

- Word-initial clusters: /sV/, /ʃV/, /ɻV/, /ʃɻV/, /s{p t k}ɻ/, /s{p t k}/, /{b d g}ɻ/
- Vowels in stimuli were /æ i u ɹ/.
- 2 words per context: 108 target words.
- Words repeated 4 times.
Acoustic measurements

- Centroid frequency: [s] has higher centroid frequency than [ʃ]
  - Weighted average over 1-10 kHz
  - 5 ms analysis window
- Average of centroids of spectra from the middle half of the sibilant
  - 2 ms time step
  - Tokens were averaged across item.
Impressionistic judgments

- Experimenters listened to subjects and categorized each as an /s/ retractor or non-retractor.
Impressionistic judgments

- Experimenters listened to subjects and categorized each as an /s/ retractor or non-retractor.
- (Not a difficult task)
Articulatory analysis

- Visual inspection of overlaid images
Subject s15 is an /s/ retractor.

/s/ from /st/ clusters
Subject s15 is an /s/ retractor.

/s/ from /stə/ clusters
Subject s15 is an /s/ retractor.
Subject s15 is an /s/ retractor.

/s/ from /stʌ/ clusters and /ʃ/
Articulatory analysis

- Visual inspection of overlaid images
- Specifically:
  - /ɒ/ from /stɒ/ clusters vs. /s/ from /st/ clusters
  - Similar or different?
Dissimilar /s/ and /ʌ/ (Subject s24)

/ʌ/ from /stʌ/ clusters
Dissimilar /s/ and /ɹ/ (Subject s24)

/s/ from /st/ clusters
Similar /s/ and /ɾ/ (Subject s05)

/ɾ/ from /stɾ/ clusters
Similar /s/ and /ɹ/ (Subject s05)

/s/ from /st/ clusters

Jeff Mielke, Adam Baker, and Diana Archangeli
Covert /ɹ/ allophony
/s/ retraction and /ɻ/-/s/ similarity

- two factor between-subjects ANOVA (dependant variable is /s/ centroid frequency)
  - /ɻ/-/s/ Similarity, (similar, dissimilar)
  - Retractor (retractor, non-retractor)
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Both main effects significant
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  - Retractor \( F(1, 1793915) = 12.84, \ p < 0.0001 \)
- No significant interaction
  - \( F(1, 286009) = 2.05, \ p < 0.155 \)
The influence of /ɻ/-/s/ similarity on /s/ retraction

Speakers with more dissimilar pairings produce /s/ with a centroid of 138 Hz lower in the /stɻ/ context than those with more similar pairings.
Covert motivations for /s/ retraction

- Variations in /ʌ/ production introduces covert phonetic motivations for /s/ retraction.
Covert motivations for /s/ retraction

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- Variations in /ɻ/ production introduces covert phonetic motivations for /s/ retraction.
- /ɻ/ is somewhat retracted (coarticulated) even for speakers who do not appear to have [ʃ] as a production target.
- Especially for speakers with /ɻ/ production strategies which are dissimilar from their /s/.
- Speaker-specific phonetic motivation
Overt motivations for /s/ retraction

/s/ retractor[s] as a group do not have greater articulatory motivation for retraction.
Overt motivations for /s/ retraction

/s/ retractors as a group do not have greater articulatory motivation for retraction.

▶ [ʃ] is a target (variationist work on this topic e.g., Labov 1994, Durian 2004).
Overt motivations for /s/ retraction

/s/ retractors as a group do not have greater articulatory motivation for retraction.

- [ʃ] is a target (variationist work on this topic e.g., Labov 1994, Durian 2004).

- Categorical /s/ retraction is socially-motivated in these speakers.
Different motivations

- Consistent with the Big Bang Model of sound change (Joseph & Janda 2001): the phonetic motivation only needs to be present at the inception of a sound change.
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- Speakers can wind up with sound patterns which reflect someone else’s phonetic motivations.
Conclusions

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Different sound patterns can emerge in response to the same phonetic motivation.

Different speakers can have different phonetic motivations.

Speakers can exhibit sound patterns that reflect someone else’s phonetic motivations.

Sound patterns can be both simultaneously phonetically natural and complex.

Phonetic naturalness and simplicity can be byproducts of the development of a sound pattern, and they need not emerge together.
Thank you

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