Forever young:
Inaudible /r/ allophony resists conventionalization

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*
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Introduction

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

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- We present ultrasound data showing that speakers with more than one distinct /ɹ/ 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.

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- Complex allophony patterns:
  - Different conditioning segments for different syllable positions
  - Different conditioning consonants for different vowel contexts
  - Sets of conditioning environments that are not easily defined.

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- 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.

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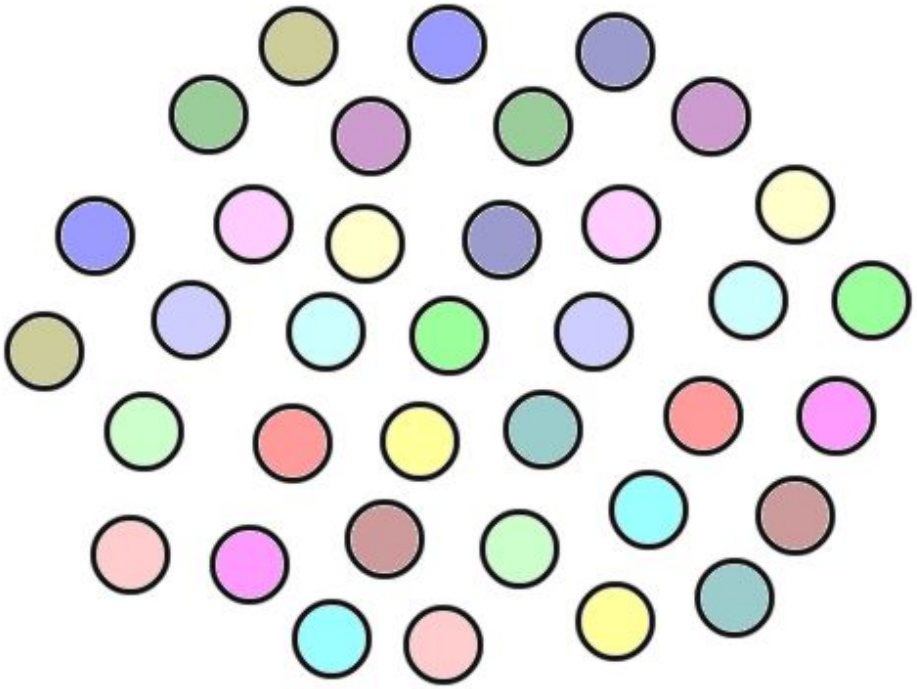
- An illustration:

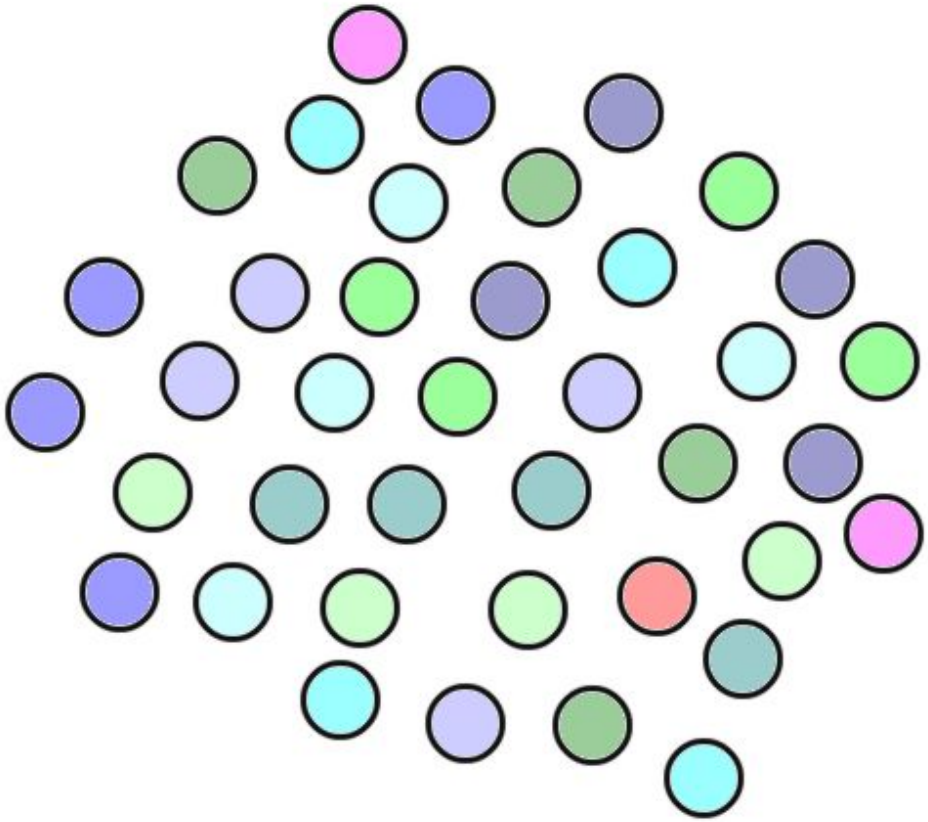
The maturation of a sound pattern...

Many possible variants.



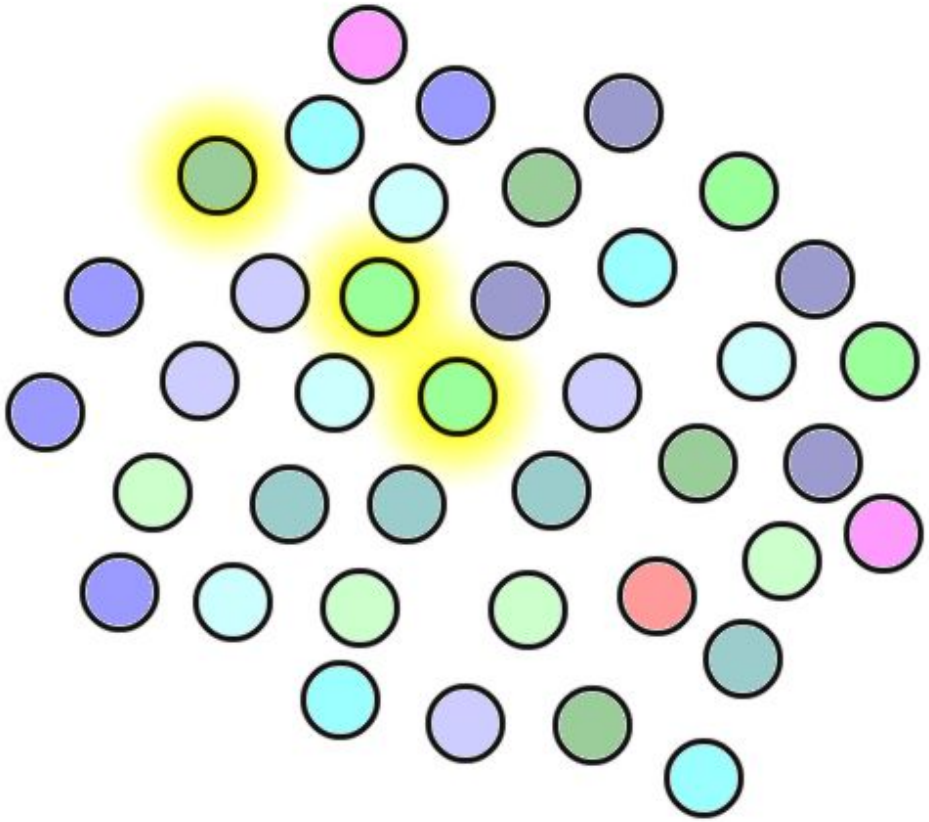
The maturation of a sound pattern...

Biased toward phonetically natural ones.



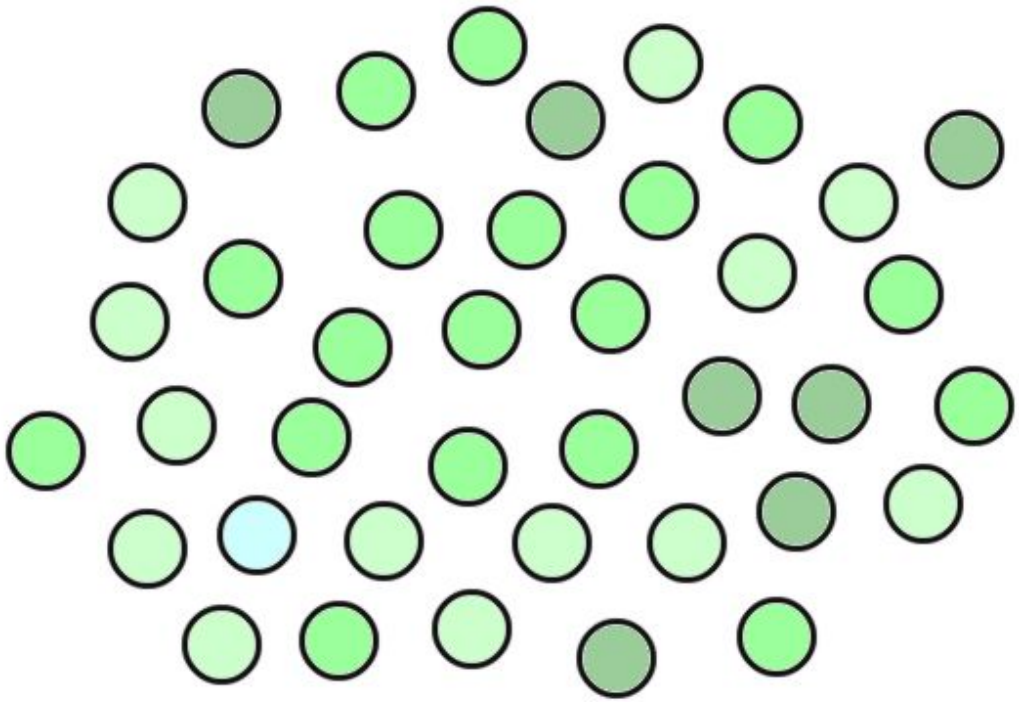
The maturation of a sound pattern...

Something gets social significance.



The maturation of a sound pattern...

Speakers converge and it gets conventionalized.



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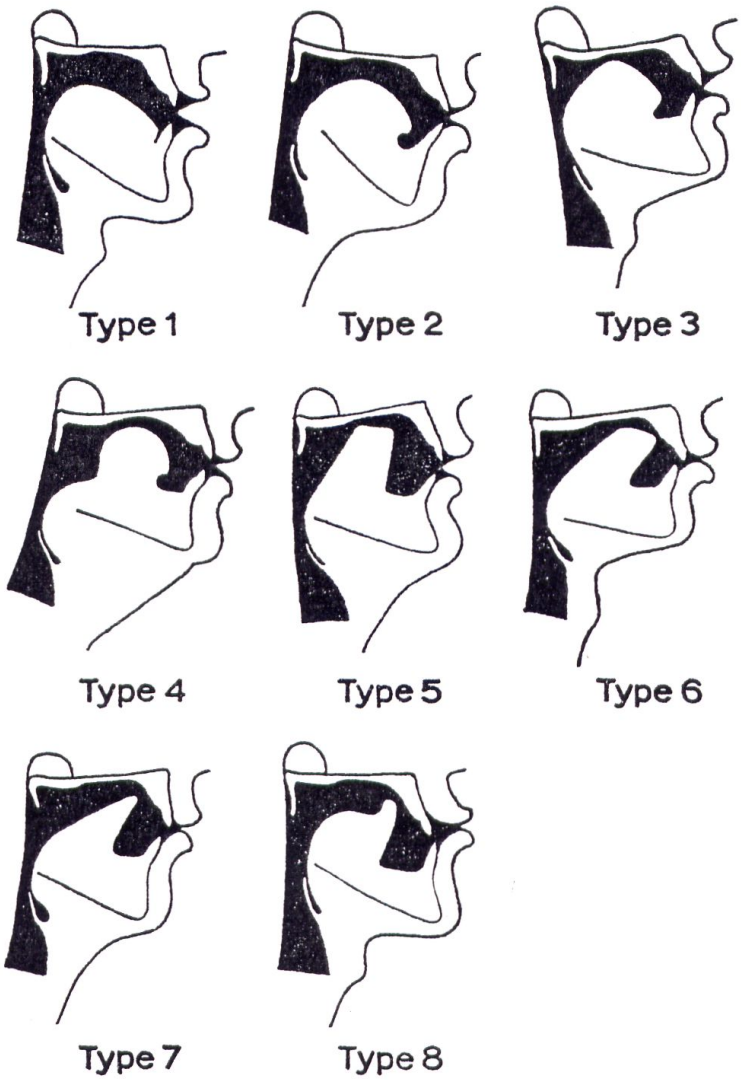
- Articulatory variability helps achieve acoustic stability (Guenther et al 1999, Boyce and Espy-Wilson, 1997).

The Delattre and Freeman taxonomy:

- Types 2-7 reported for American English (Delattre and Freeman 1968, Tiede et al. 200X).
- Delattre and Freeman found Types 1 and 8 in British English.



The r-less /ɹ/ types (bunched)

British

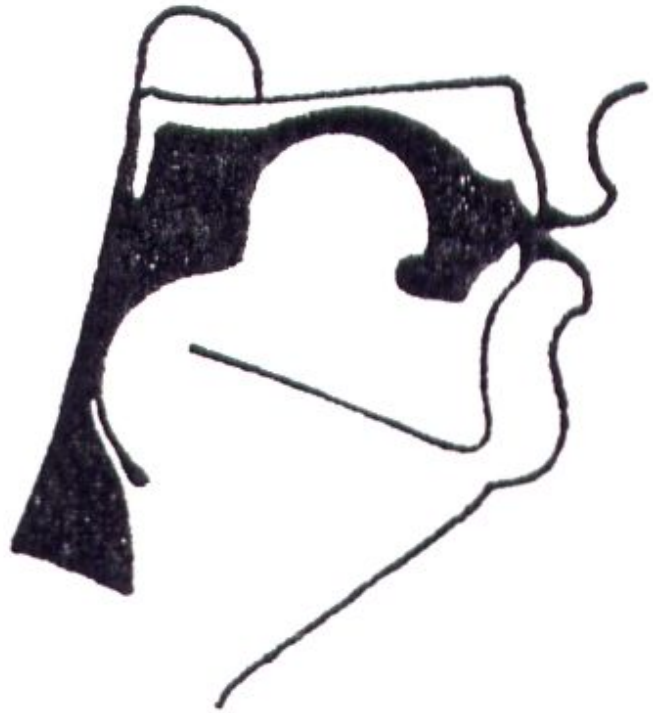
Northeast American

The dorsal /ɹ/ types (bunched)

Velar

Type 3

Classic bunched



Type 4

The blade /ɹ/ types (bunched)

Posterior blade

Type 5

Anterior blade

Type 6

The retroflex /ɹ/ types

Apical retroflex

Type 7

Classic retroflex

Type 8

Methods overview

- Subjects were recorded producing English words containing /ɹ/ (audio, video, and ultrasound video)
- Stimuli were monosyllabic words with /ɹ/ 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 /ɹ/ were /p t k f ʃ θ/ and #.
- Following /ɹ/ were /p t k f tʃ 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)

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

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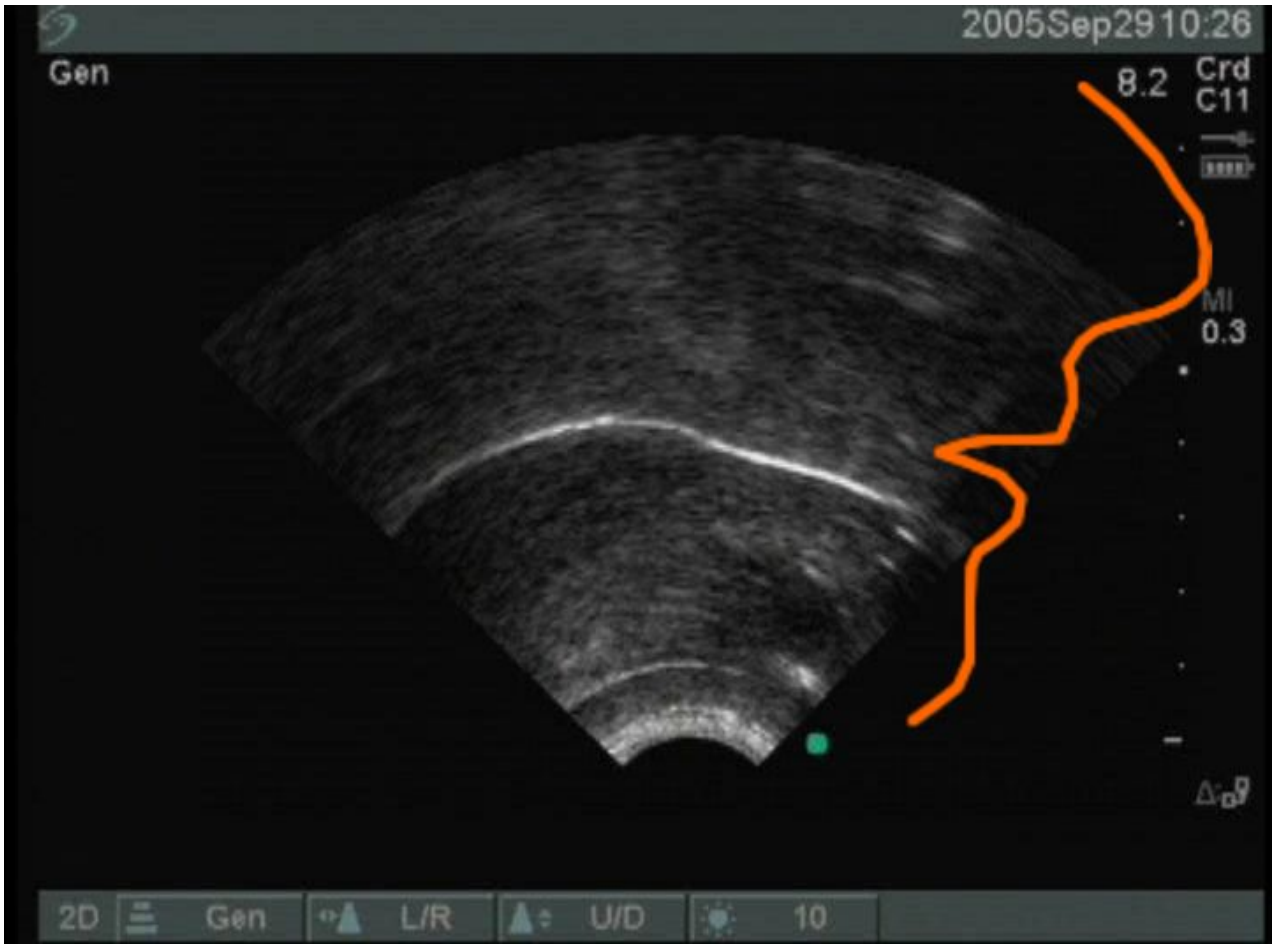

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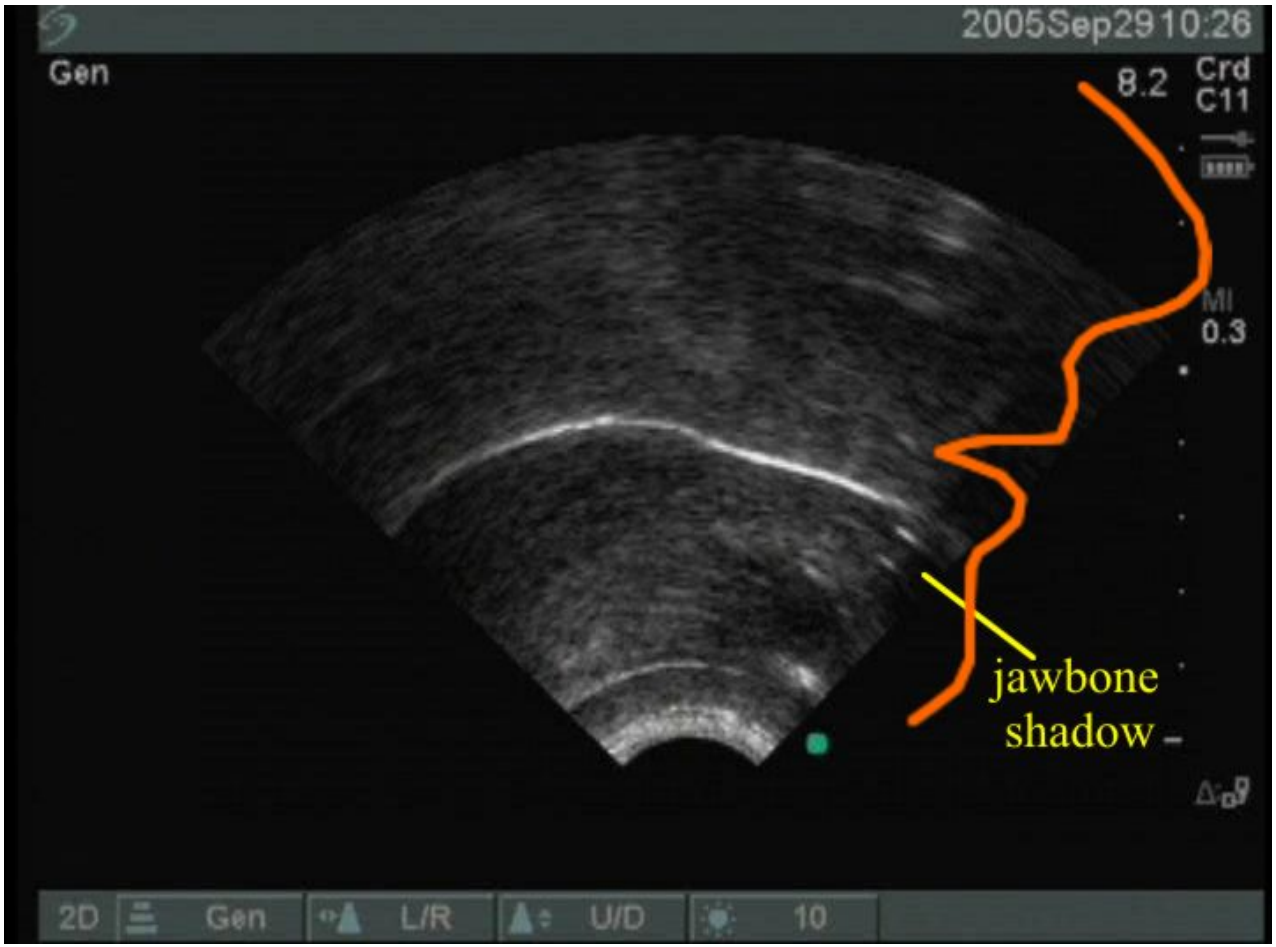

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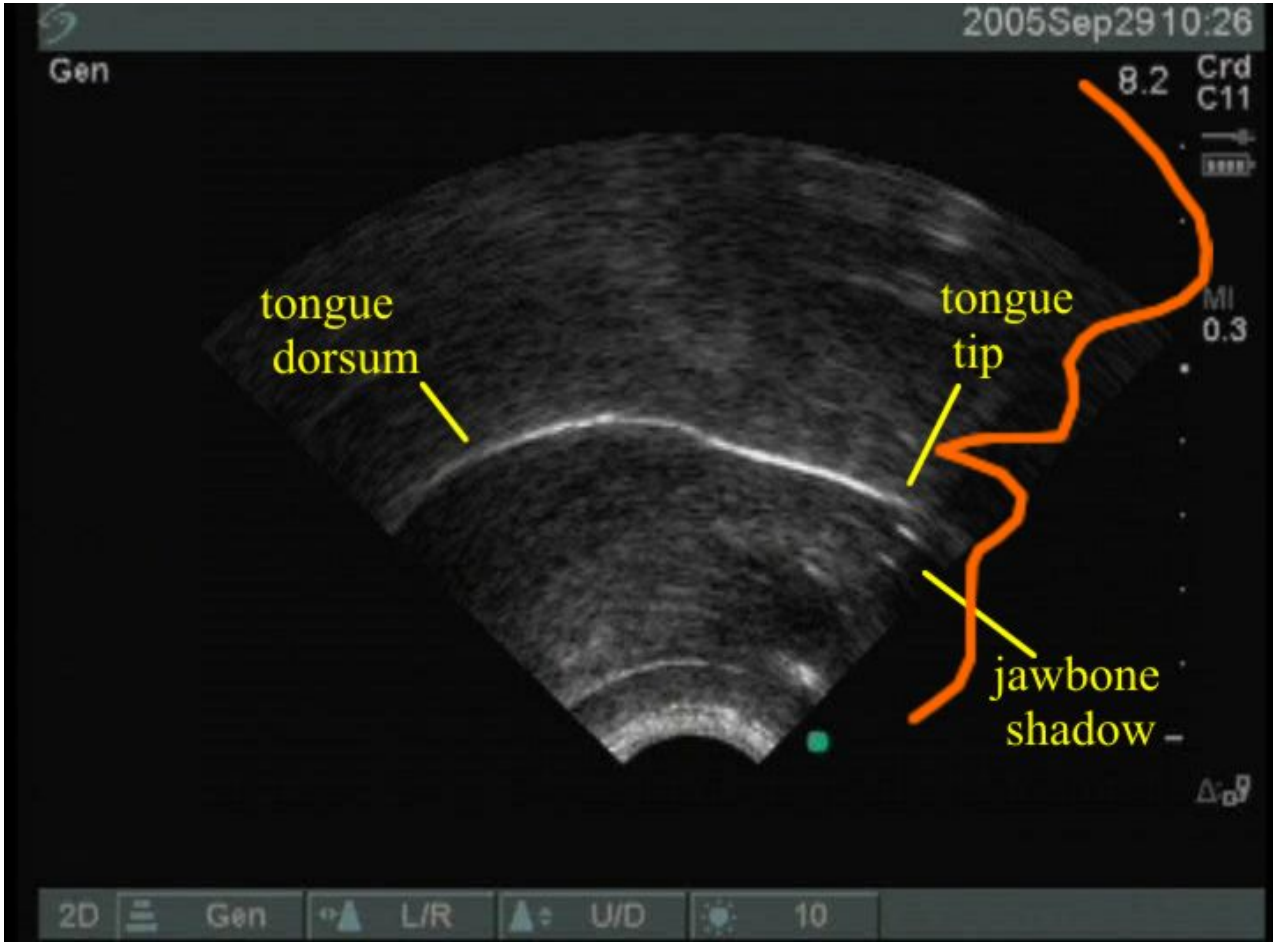

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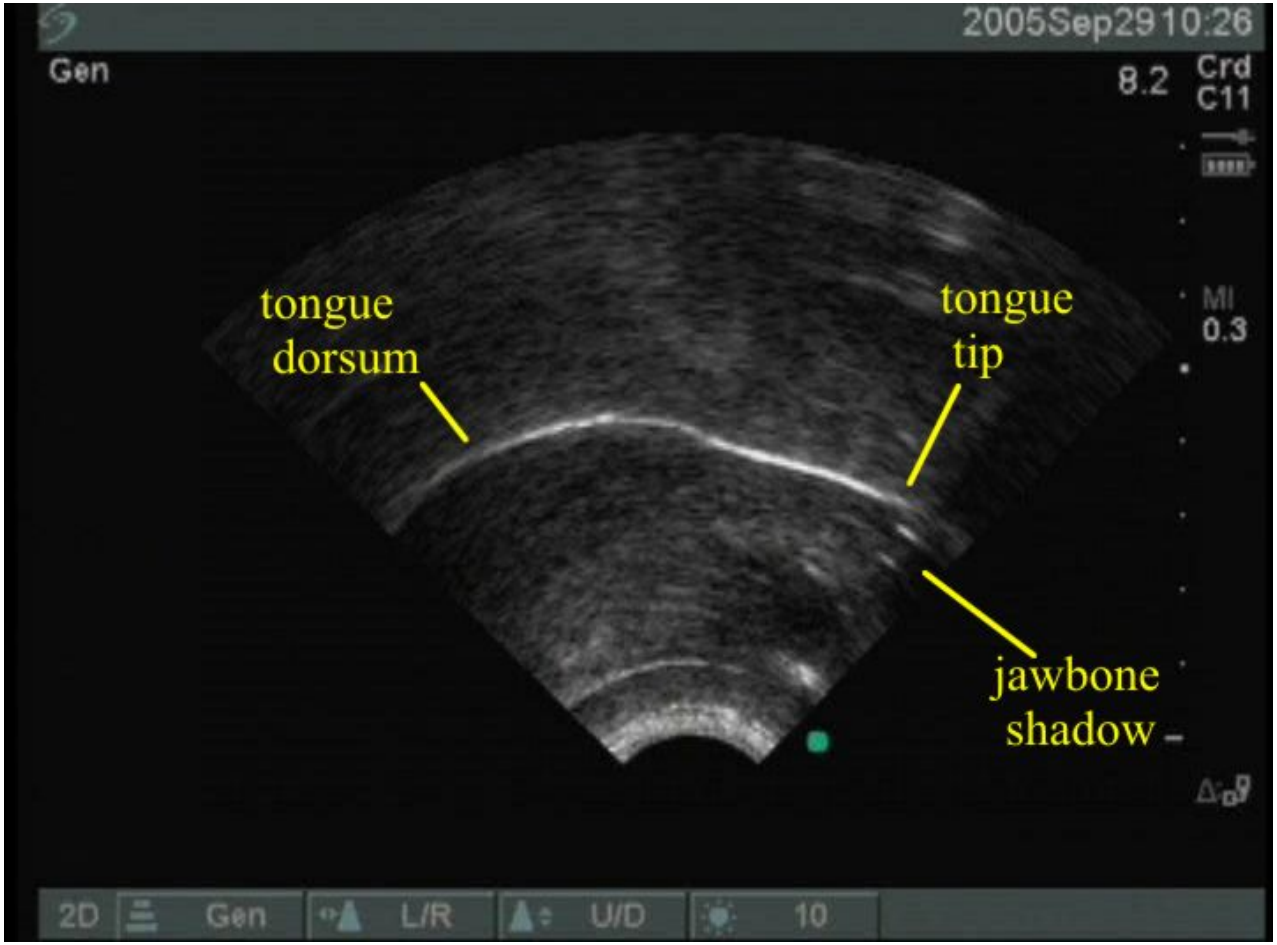


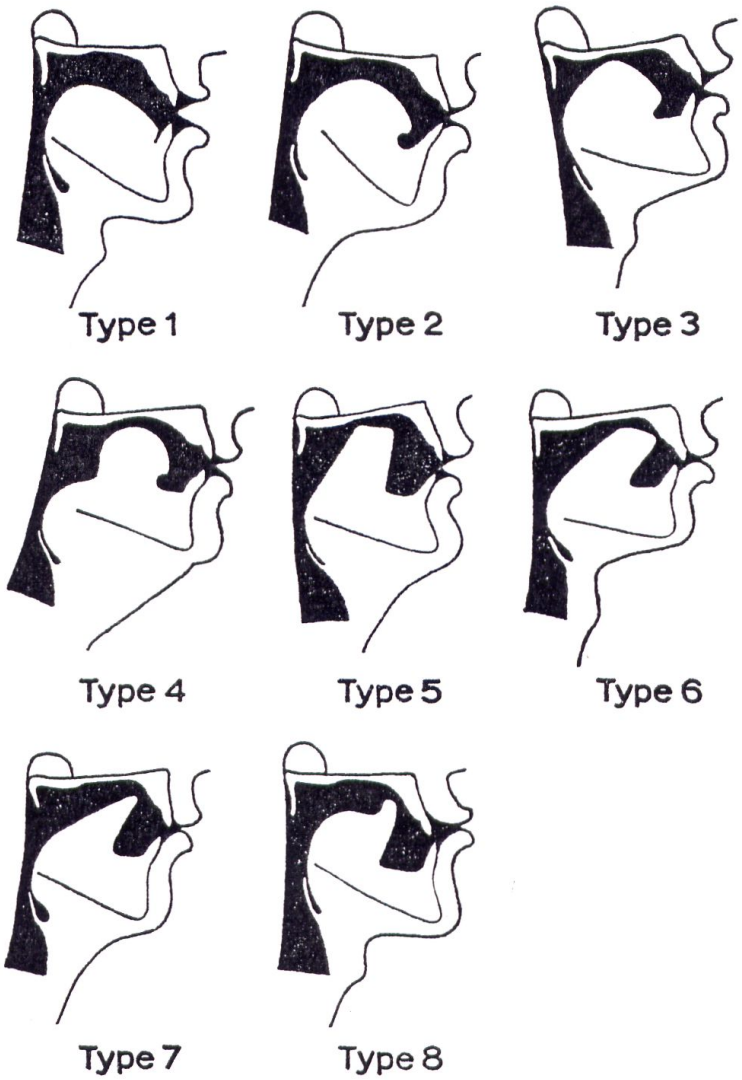
Retroflex: r08's 'frog'

Bunched: r08's 'Shriek'

Bunched: r15's 'morph'

Coarticulated bunched: r15's 'torch'

/ɹ/ production strategies:



Total	27 subjects

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Type 3 only

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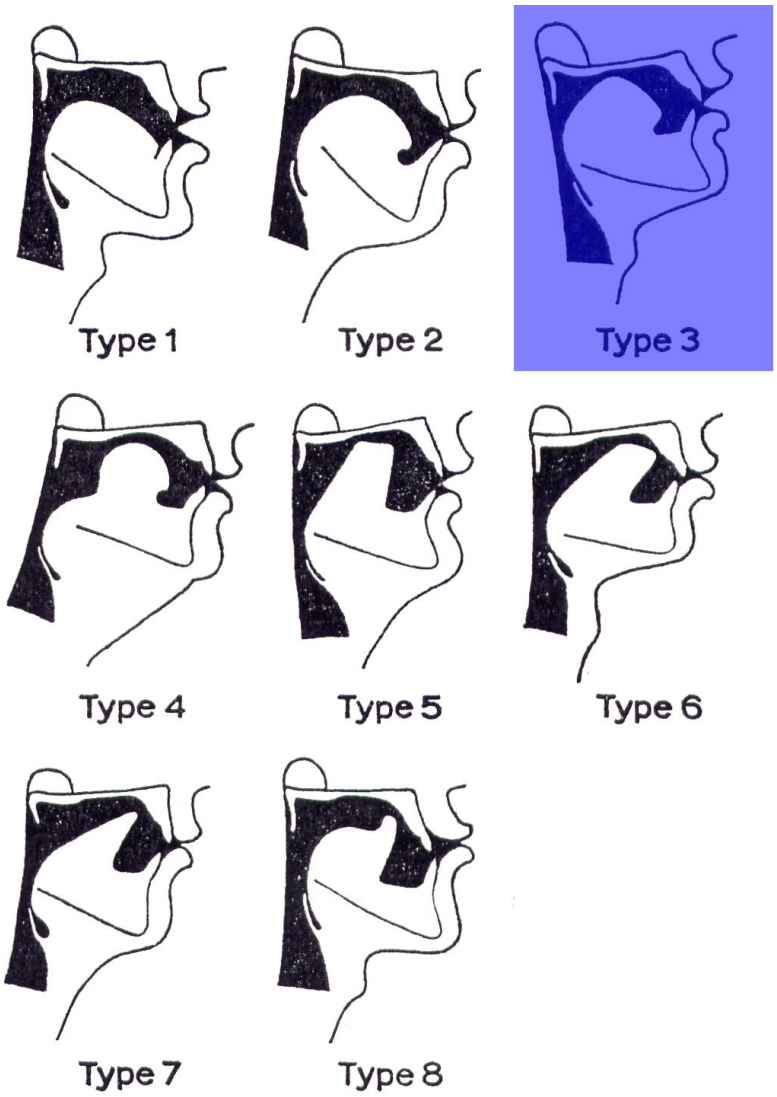
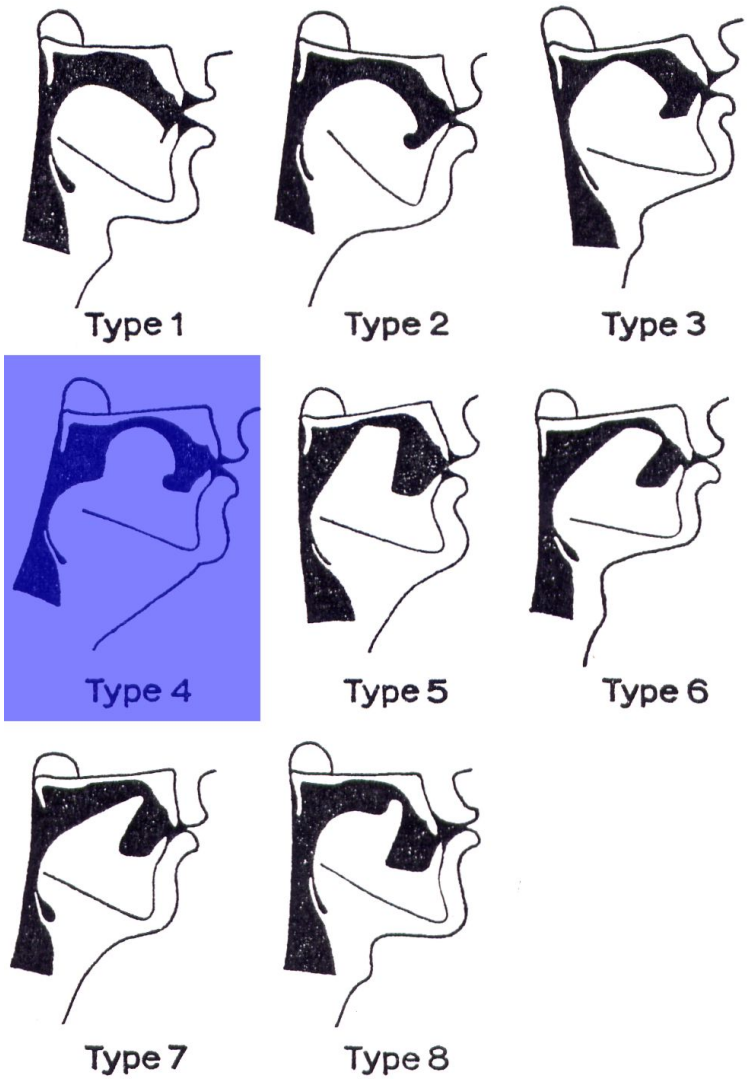


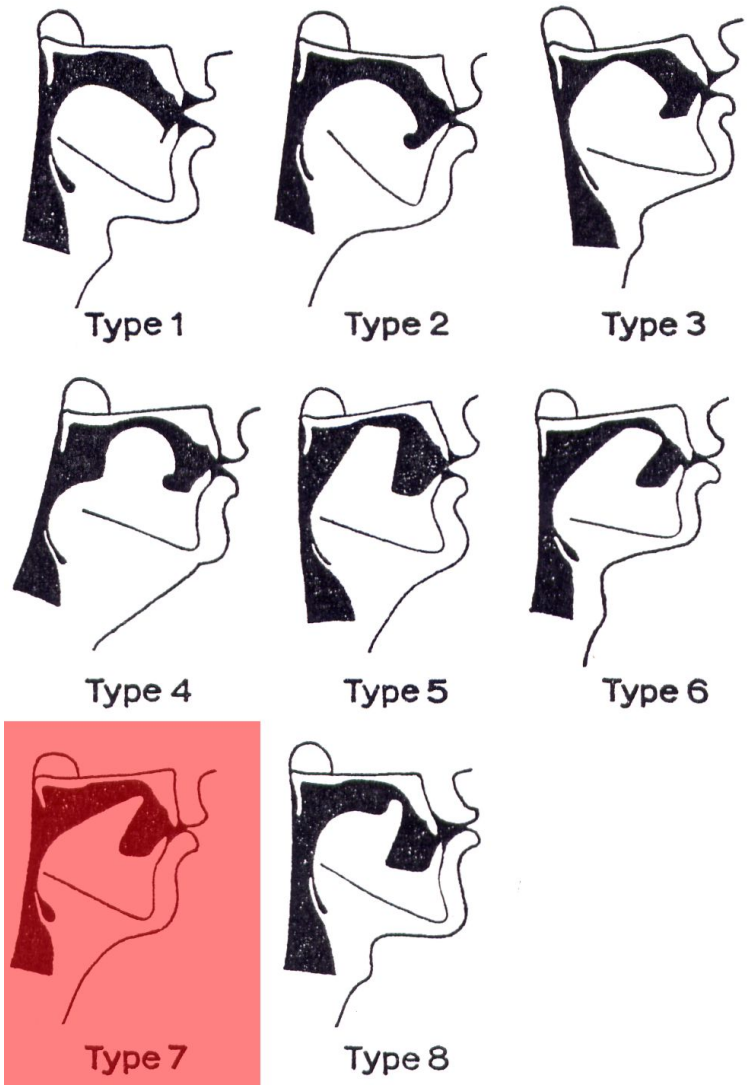
/ɹ/ production strategies:

Type 3 only	1
Type 4 only	10
Total	27 subjects



/ɹ/ production strategies:

Type 3 only	1
Type 4 only	9
Type 7 only	1
Total	27 subjects



/ɹ/ production strategies:

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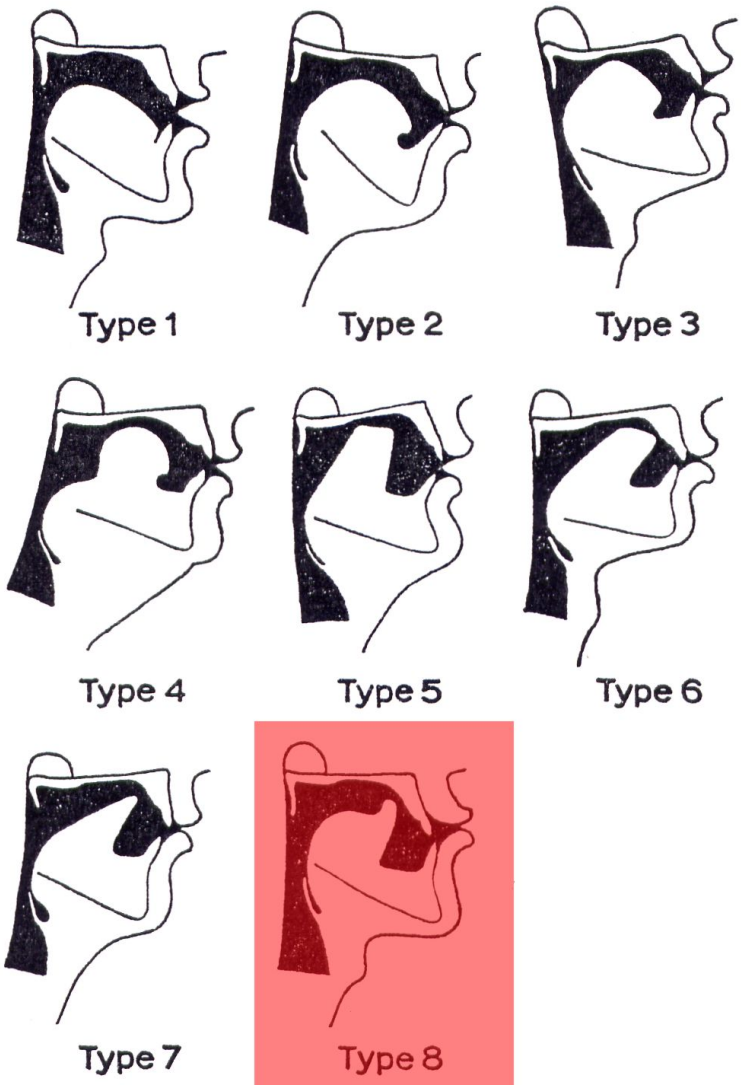
Type 4 only	10
Type 7 only	1
Type 8 only	1
Total	27 subjects



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Types 4/5/6	2
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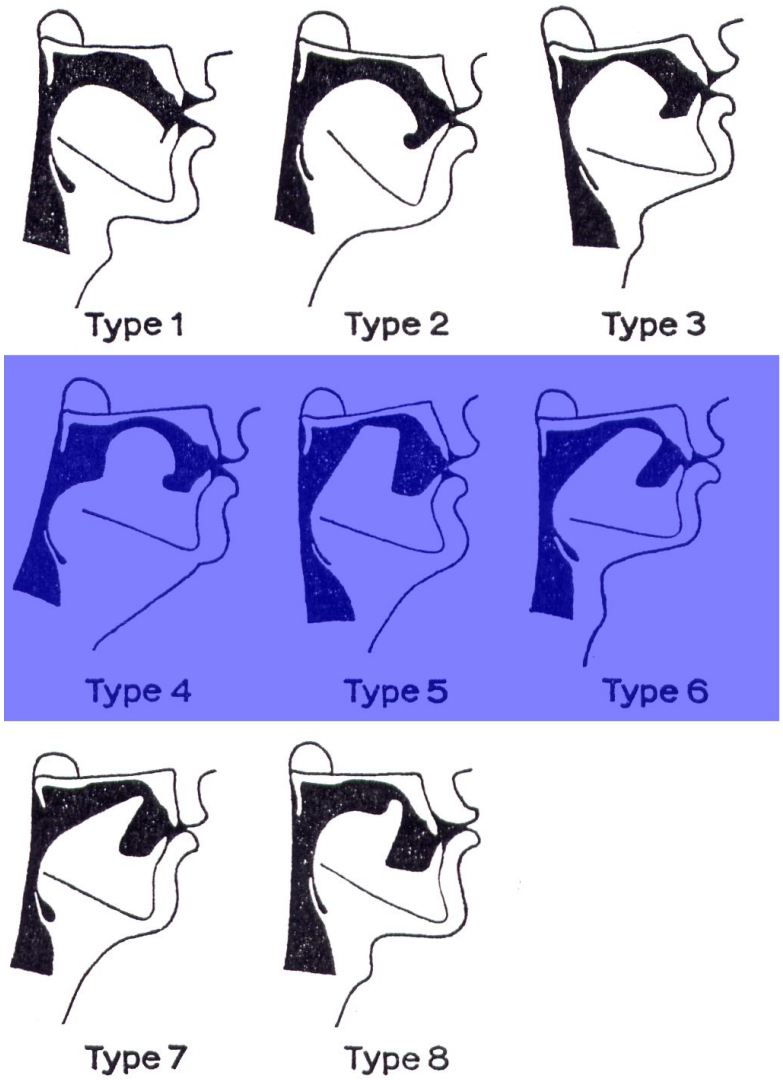

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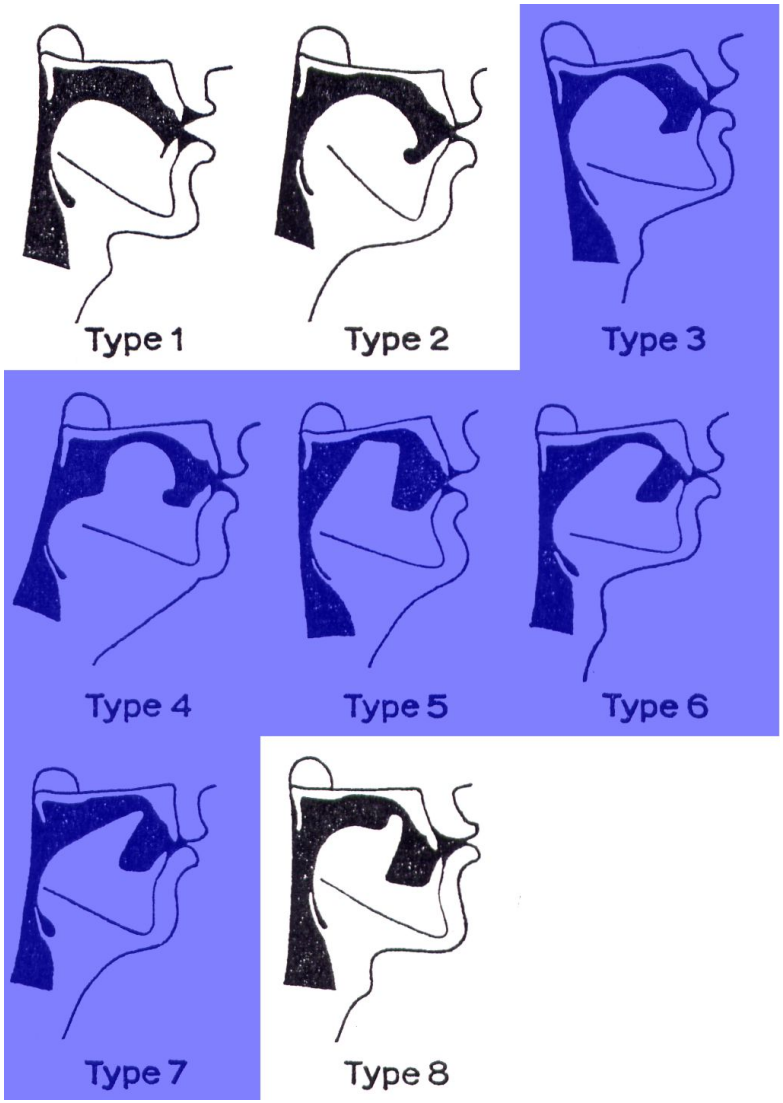

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Types 3-7	1
3-6 vs. 7-8	11
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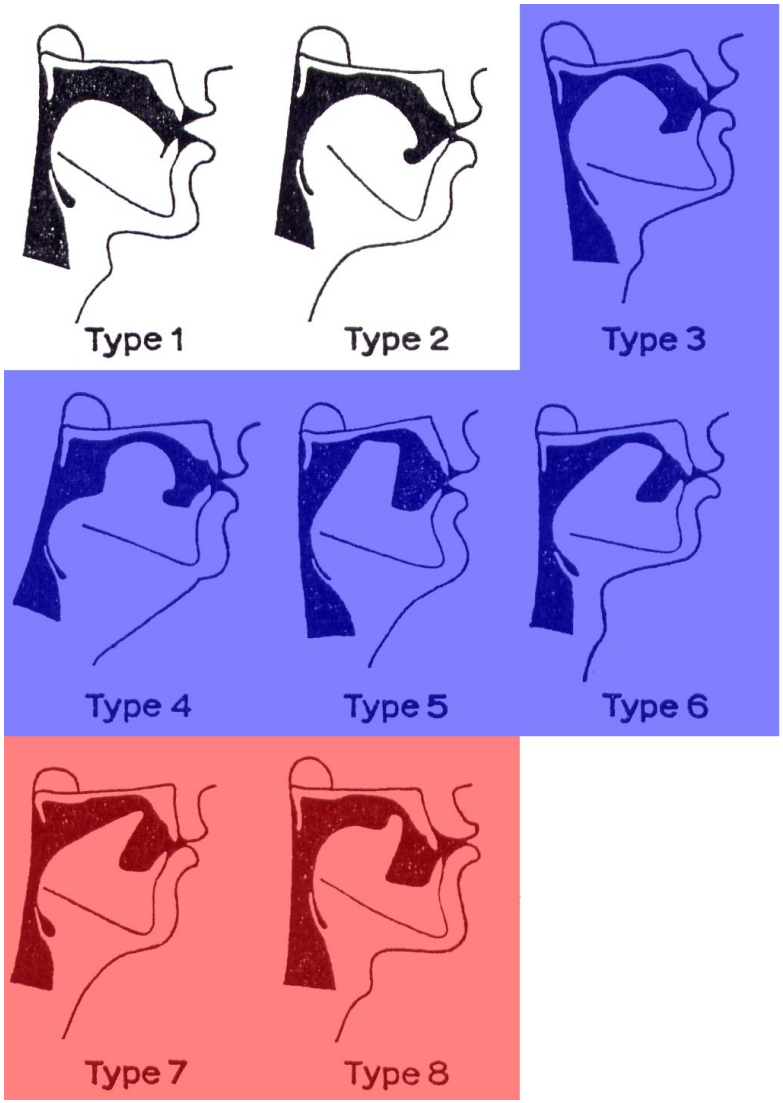

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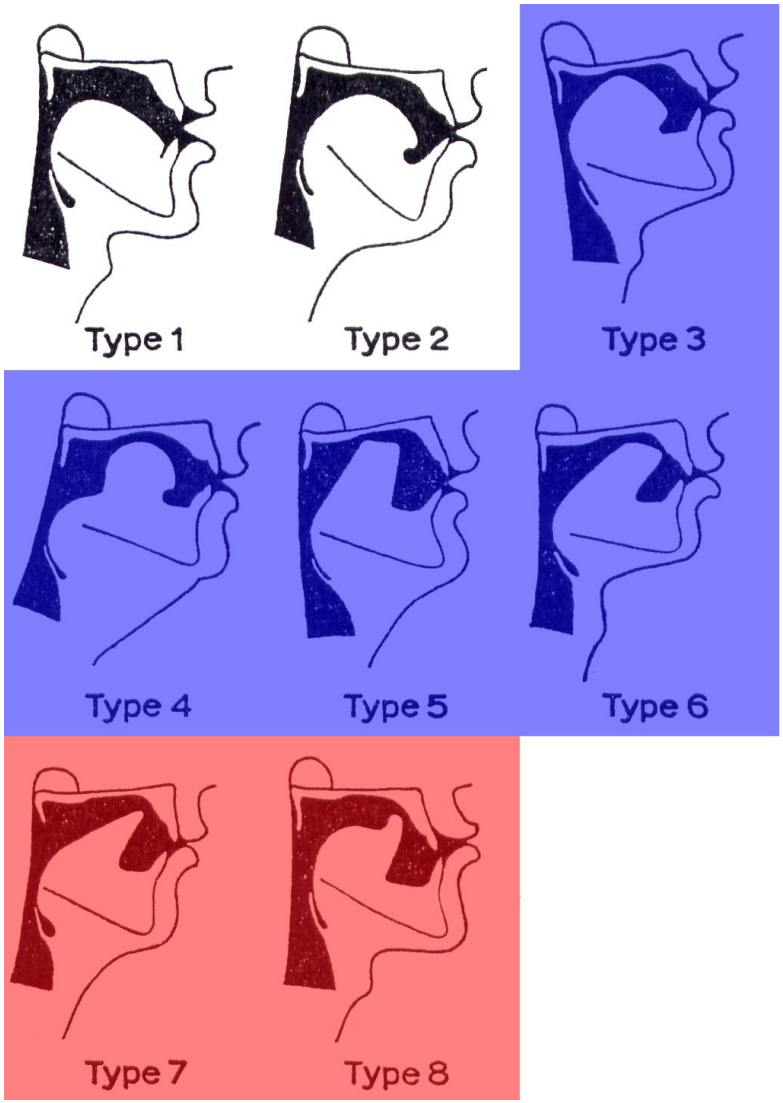
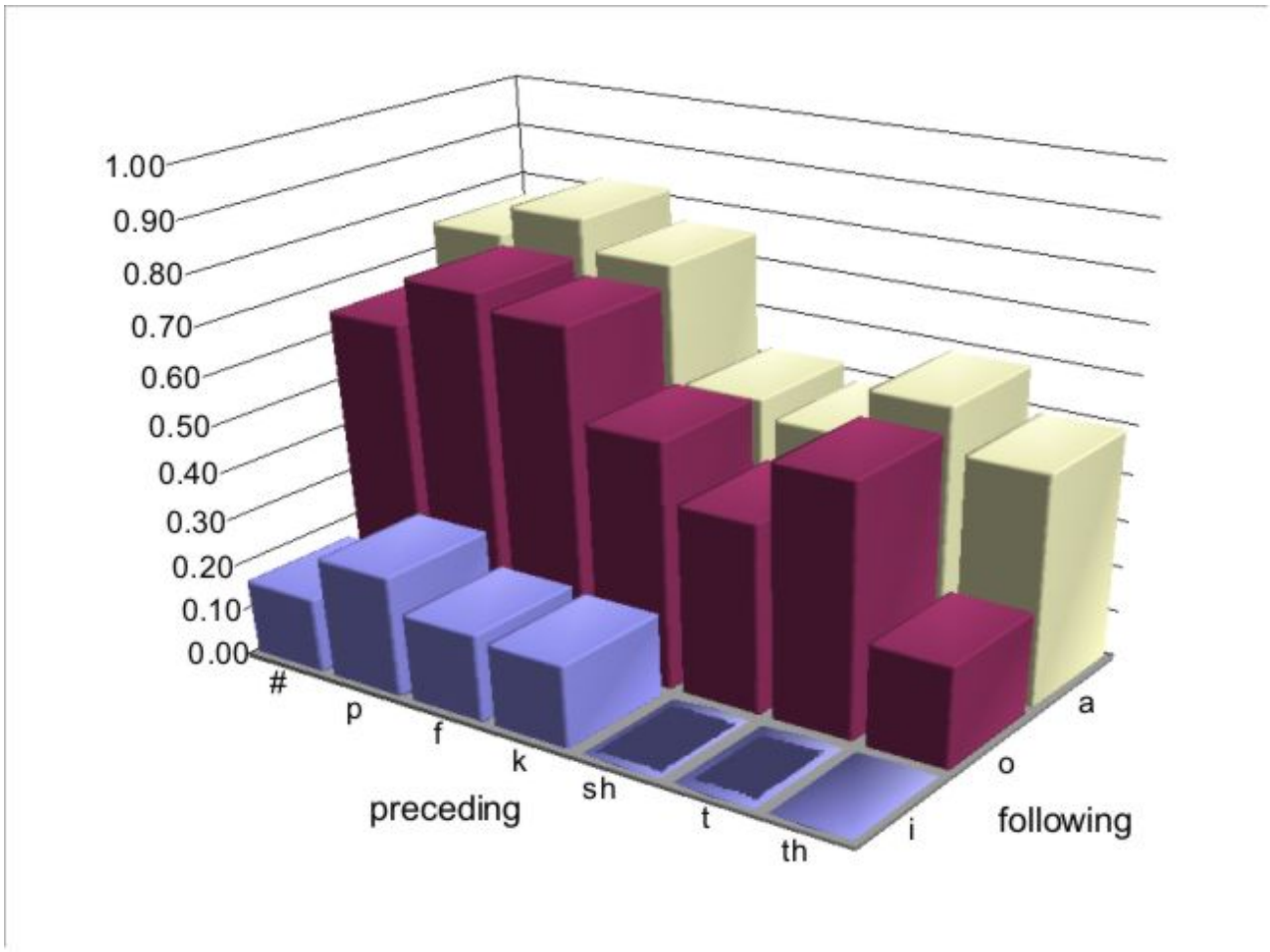


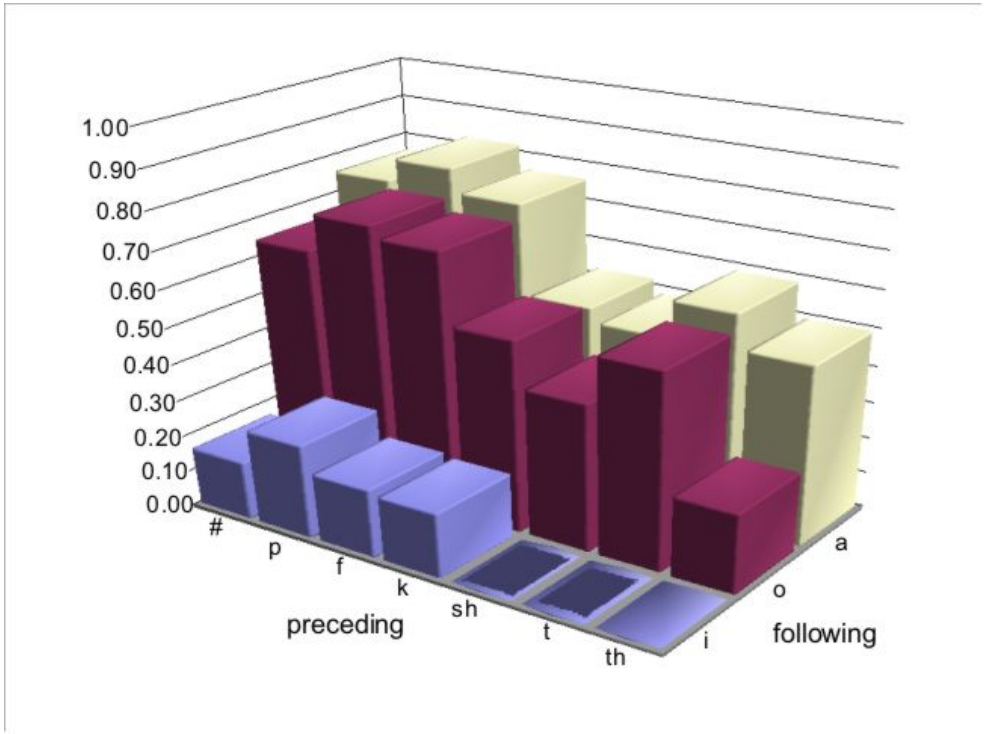
Average retroflexion rates for prevocalic /ɹ/ (11 subjects)



Generalizations: prevocalic /ɹ/

Retroflexion rates:

- (C)ra, (C)ro > (C)ri



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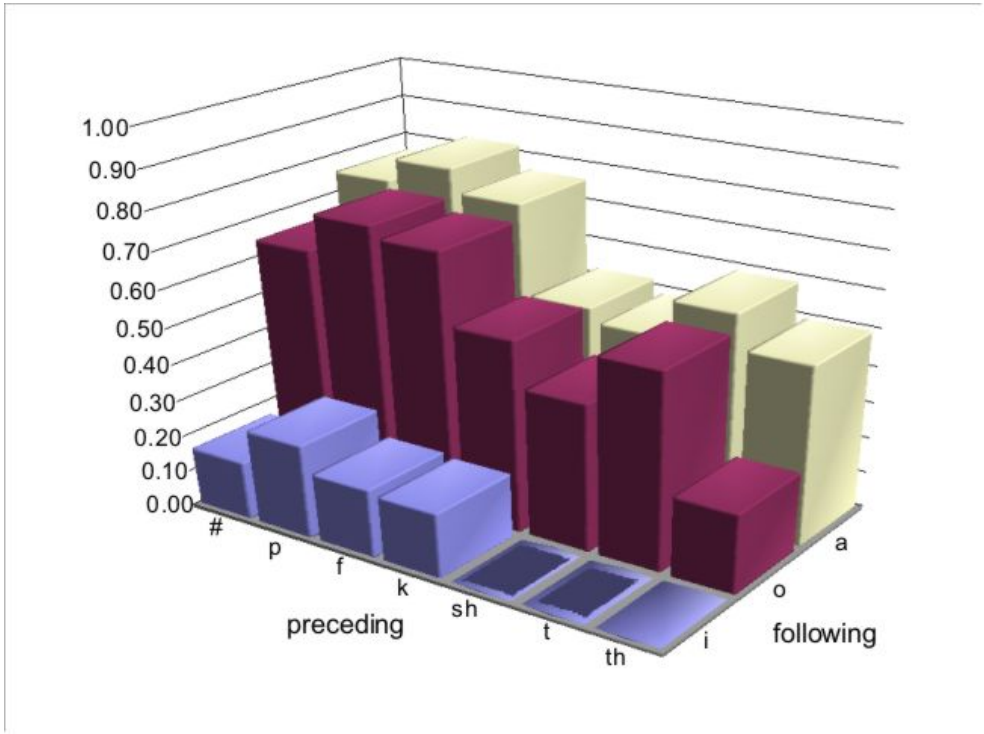
- #rV, prV, frV > krV, ʃrV, trV, θrV



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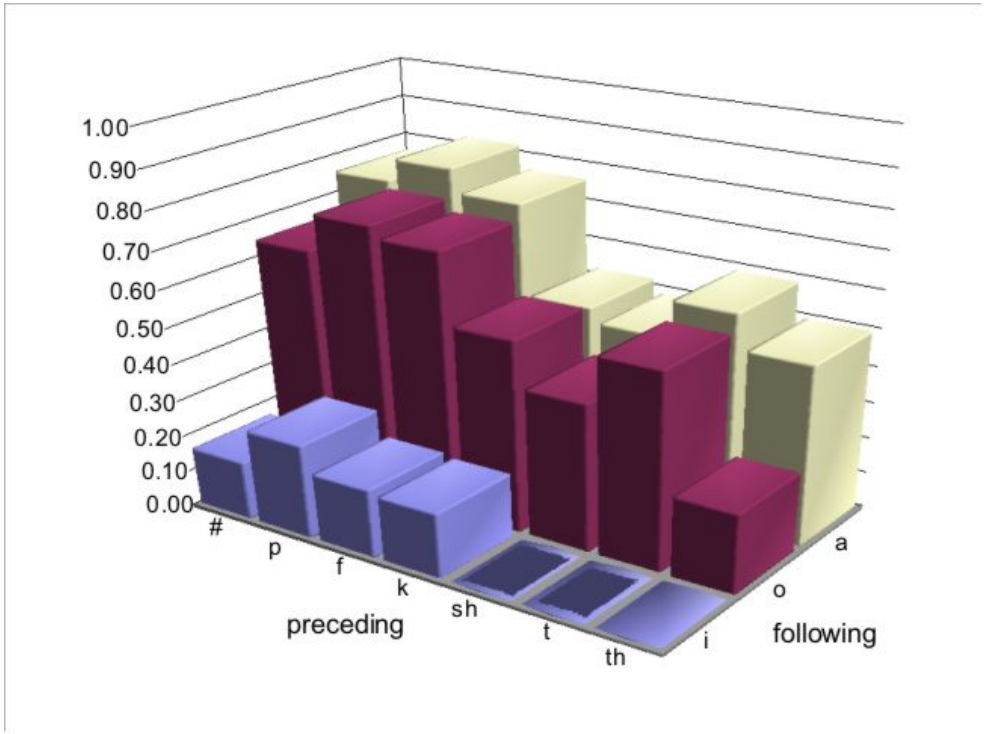

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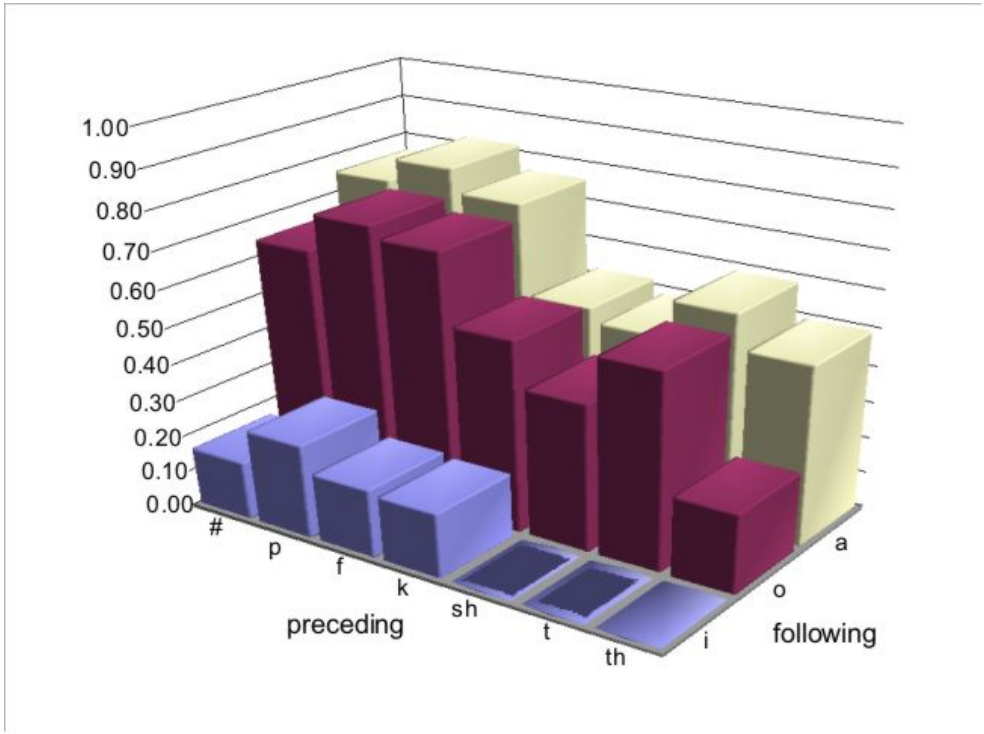
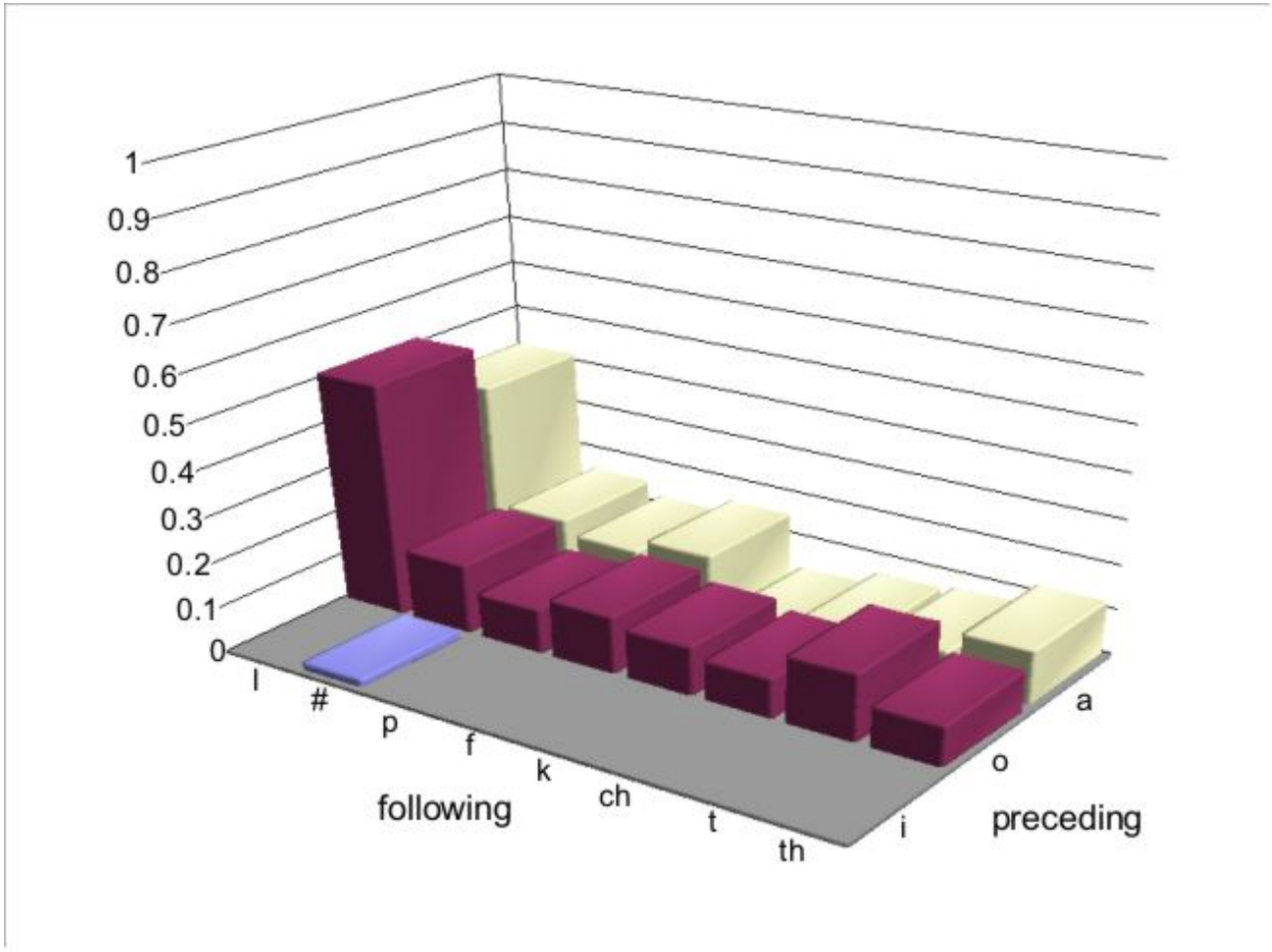
Discourage retroflexion:

- high front vowel
- lingual consonants, especially coronals



Average retroflexion rates for postvocalic /ɹ/ (11 subjects)



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Retroflexion rates:

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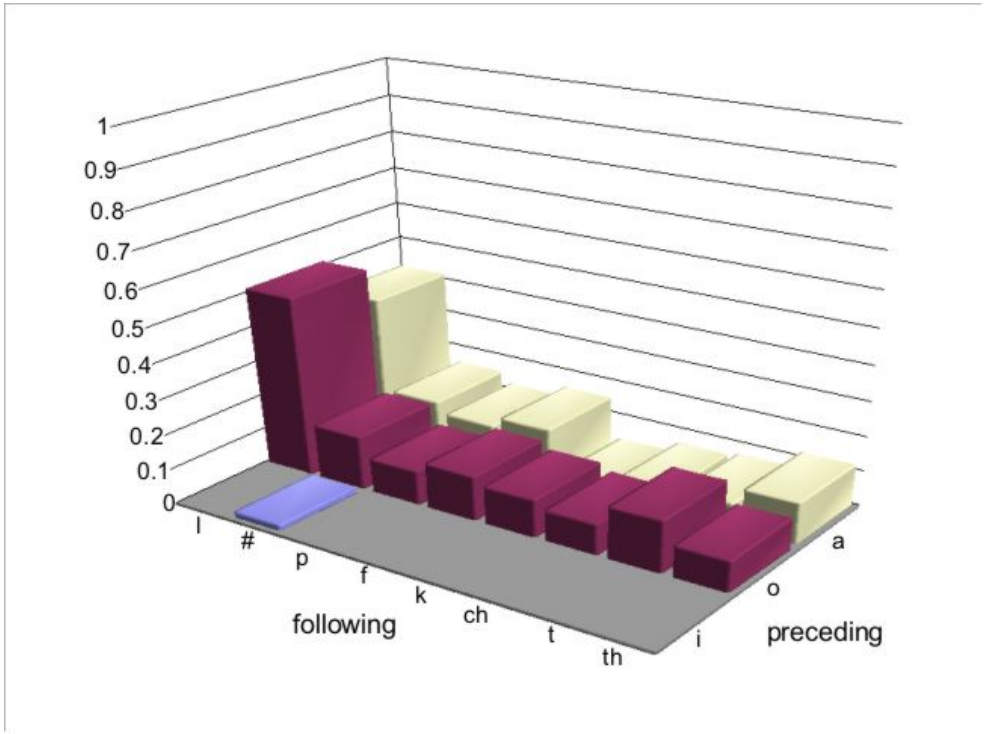

Generalizations: postvocalic /ɹ/

Retroflexion rates:

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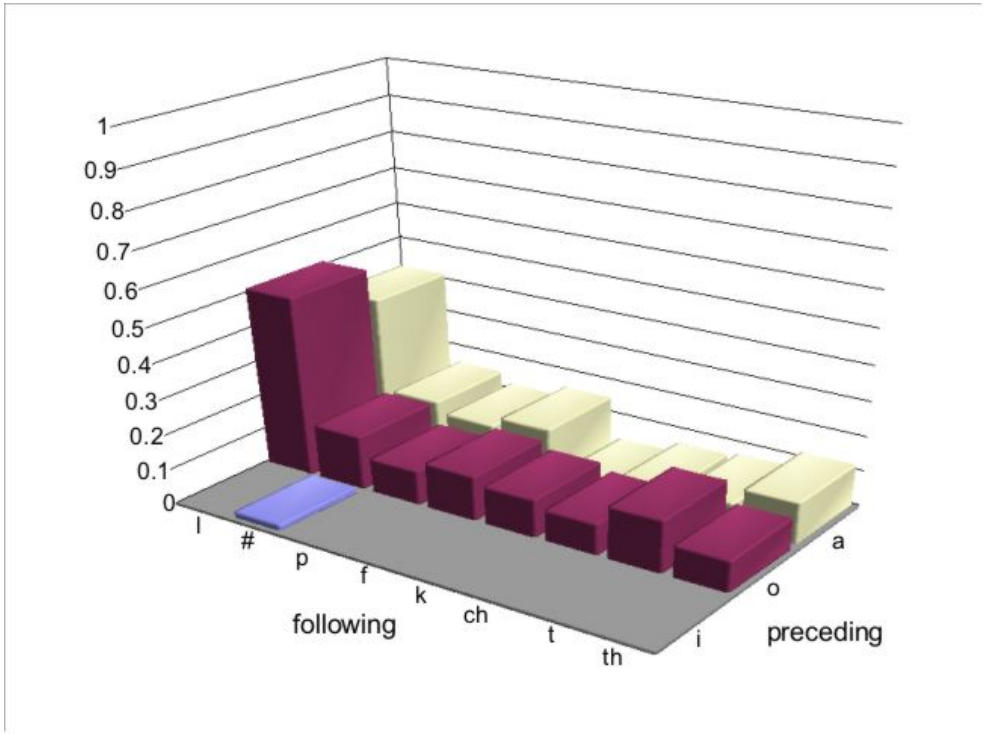
- highest Vrl



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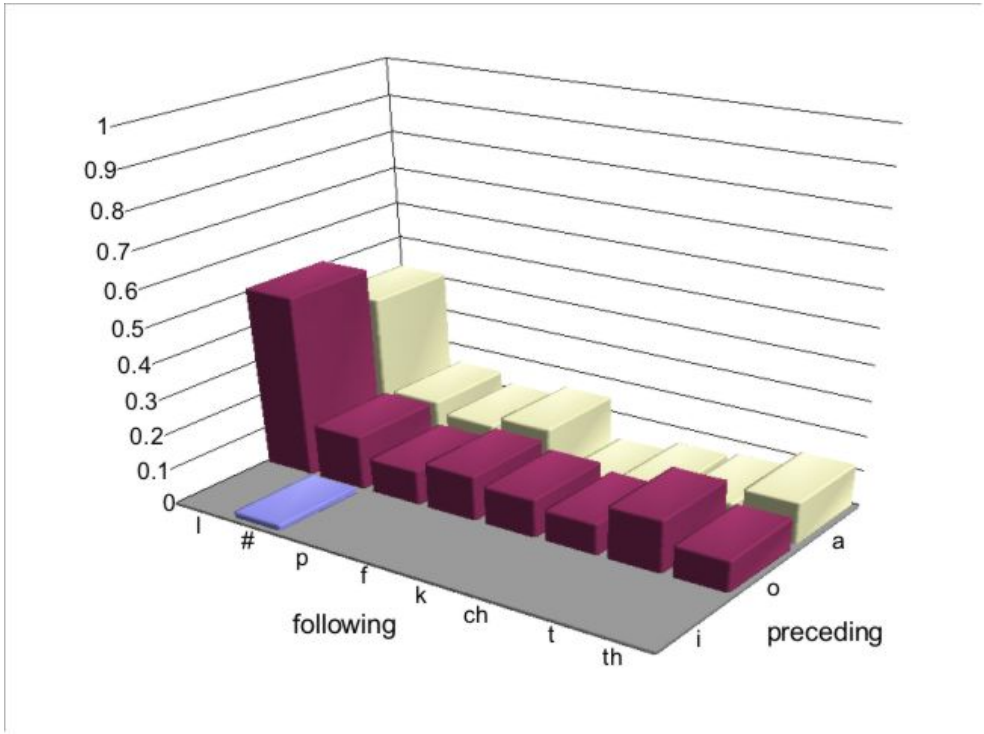
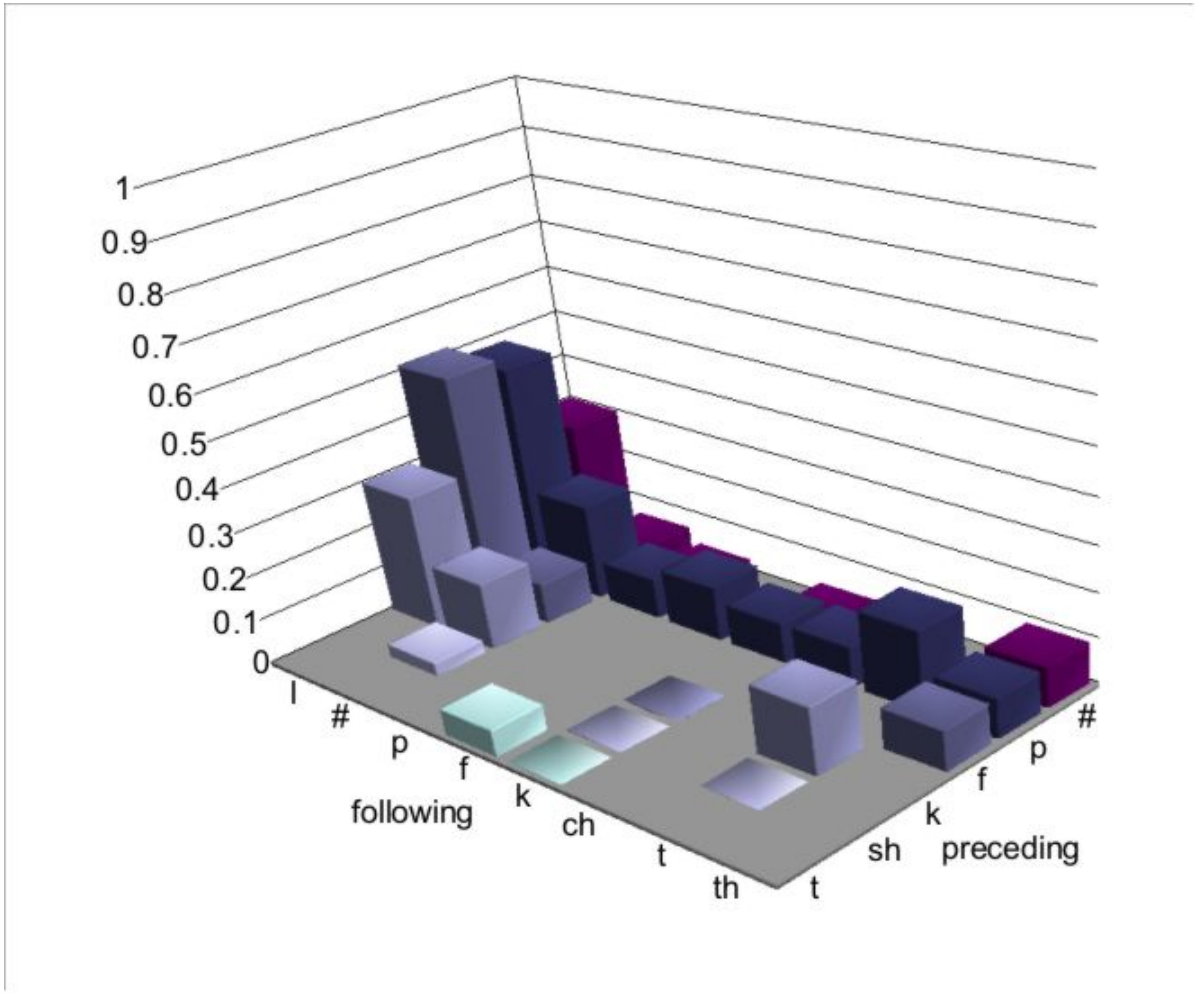
- ar(C), or(C) $>$ ir(C)



Average retroflexion rates for syllabic /ɹ/ (11 subjects)



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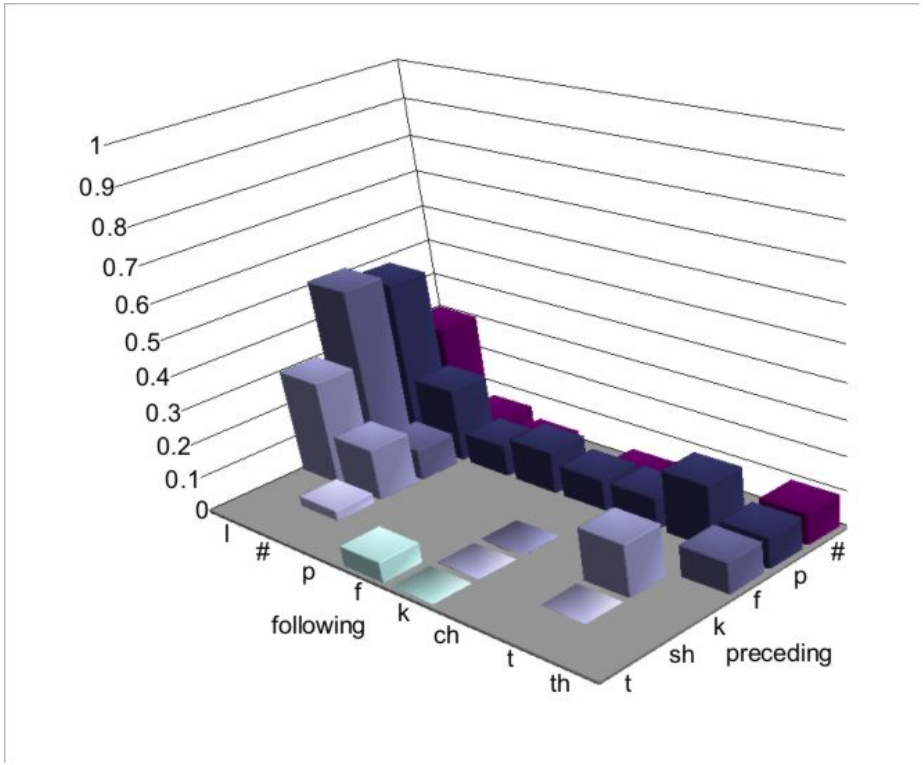

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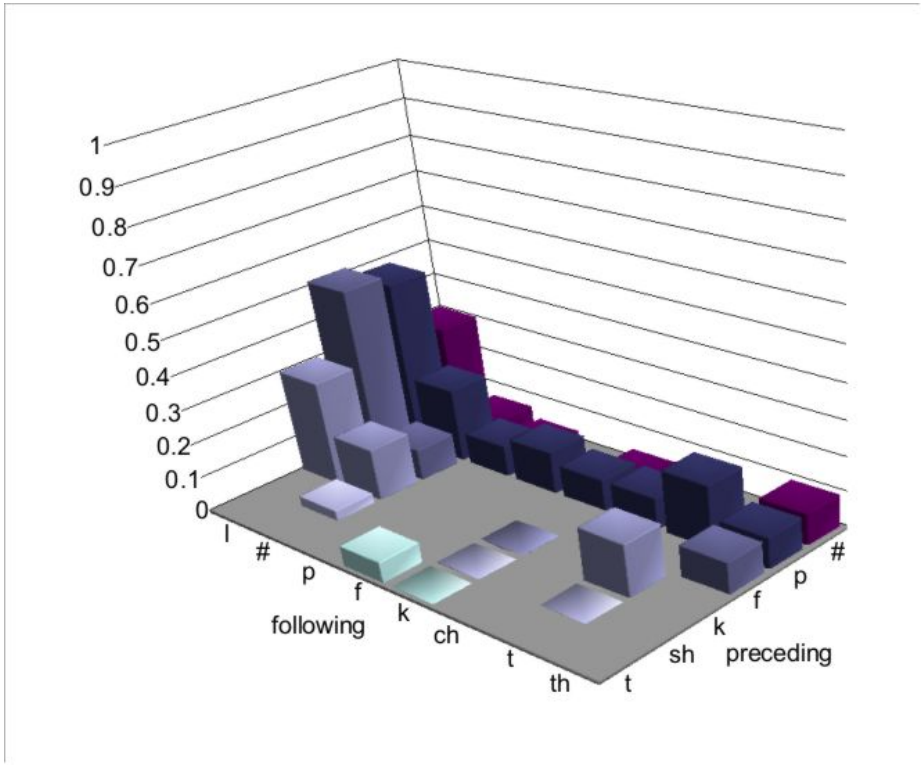
Retroflexion rates:

- low overall
- highest (C)rl



Generalizations: syllabic /ɹ/

Retroflexion rates:

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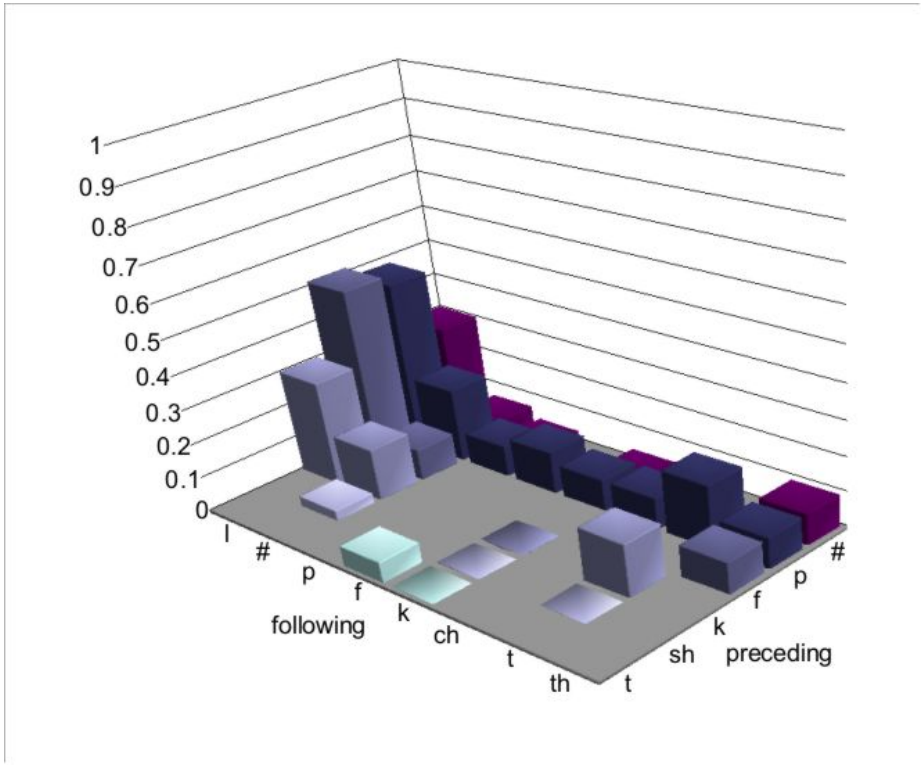
- highest (C)rl
- higher prV, frV



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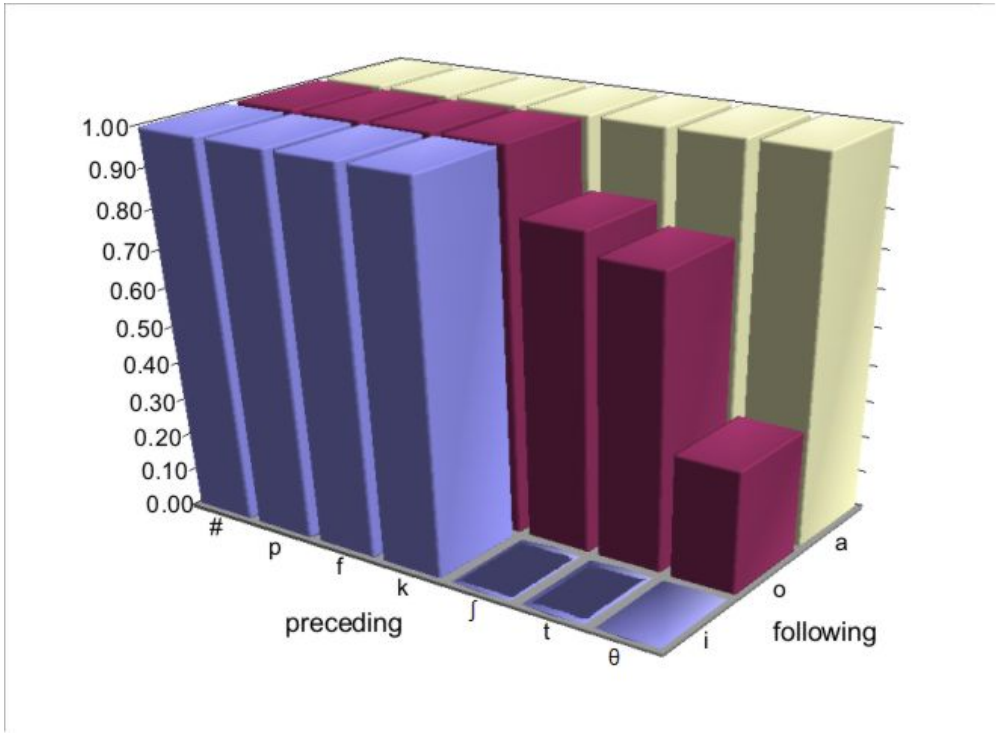
- Average retroflexion rates are highest before vowels and /l/.
- Average retroflexion rates next to different segments are phonetically sensible:
  - Less retroflexion next to segments that place demands on the tongue that are antagonistic with retroflexion
  - More retroflexion where segments do not interfere or where tongue body position is compatible with retroflexion

Categorical retroflexion

- Nine speakers have some environments with 100% retroflexion.



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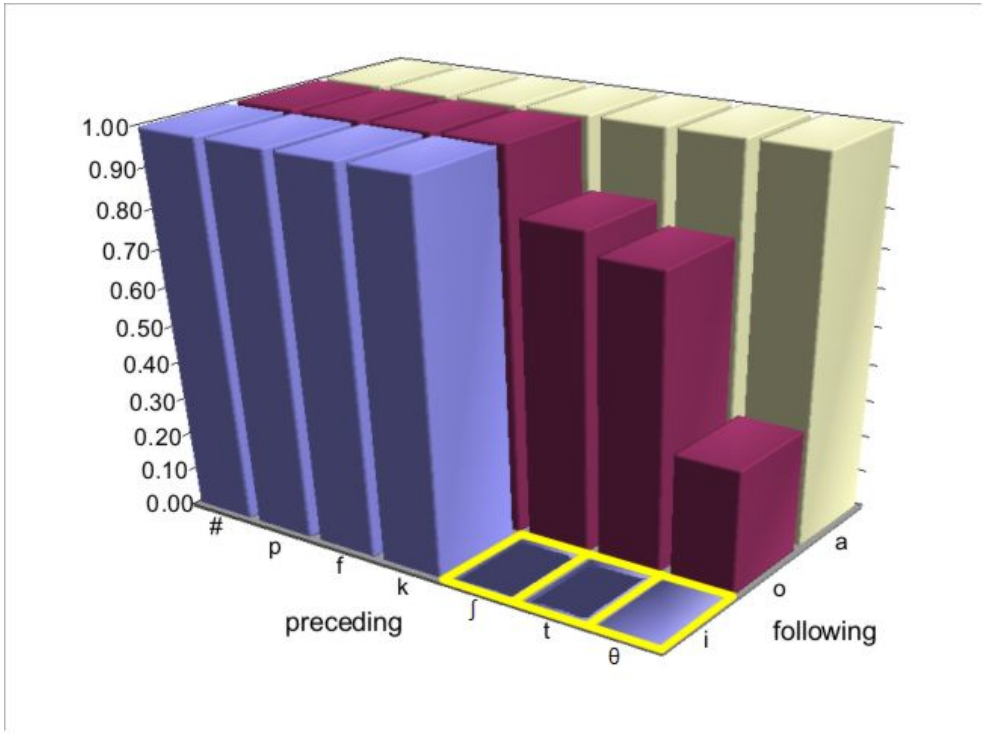
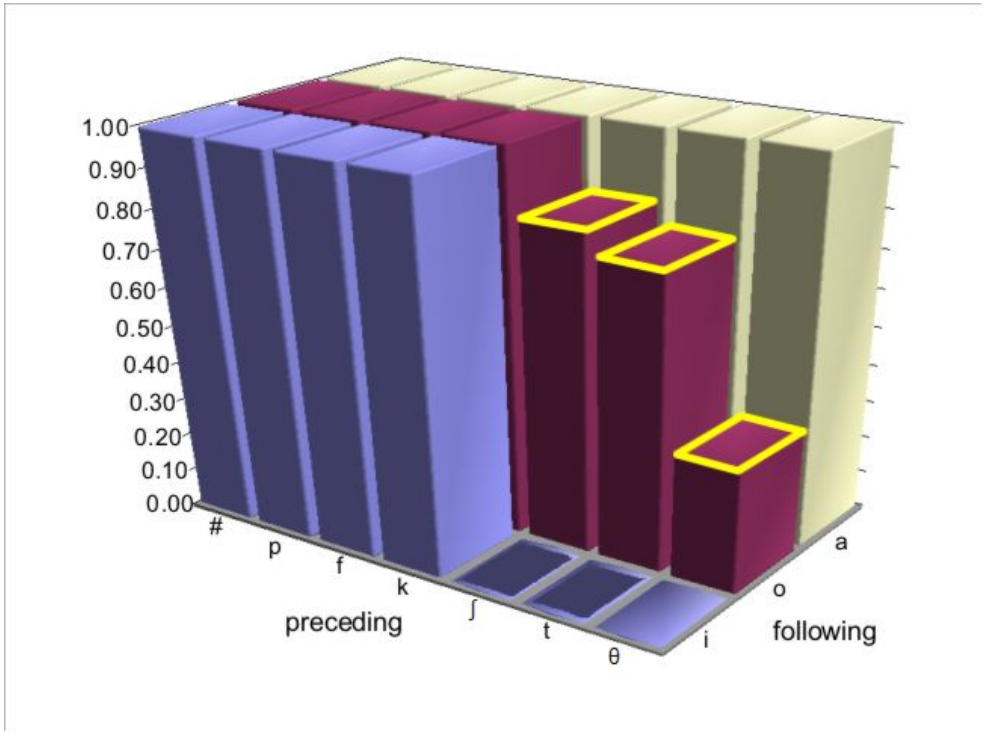
- Nine speakers have some environments with 100% retroflexion.
- r19 retroflexes everywhere but ʃri, tri, θri



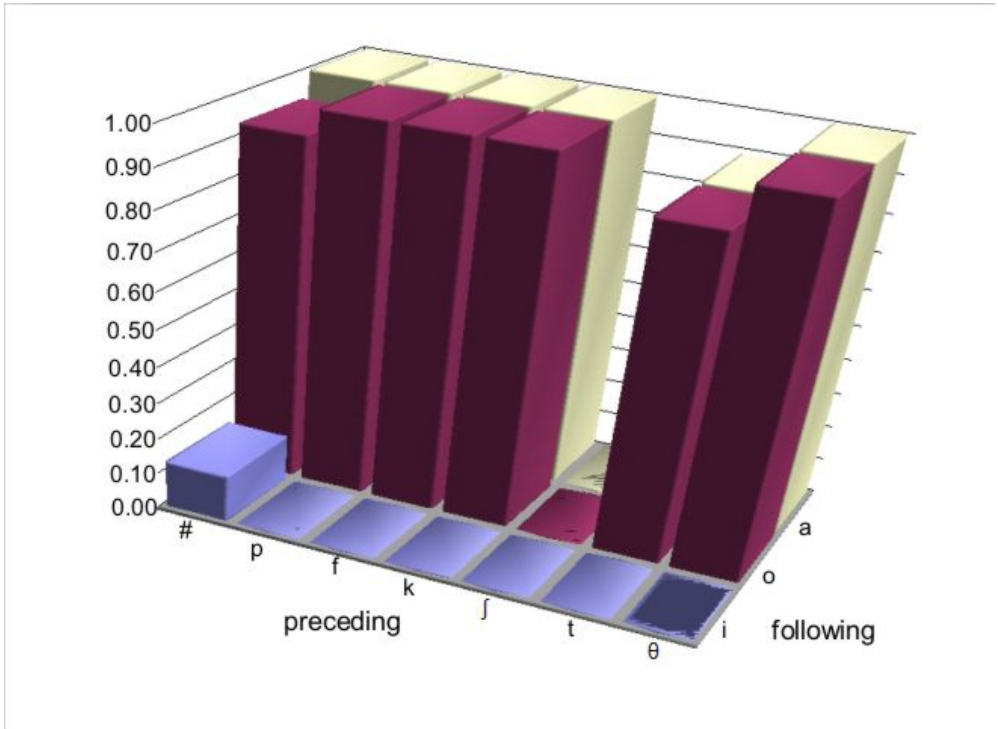
Categorical retroflexion

- Nine speakers have some environments with 100% retroflexion.
- r19 retroflexes everywhere but ʃri, tri, θri
- often bunches ʃro, tro, θro



Systematic gaps

- Some speakers have systematic gaps.



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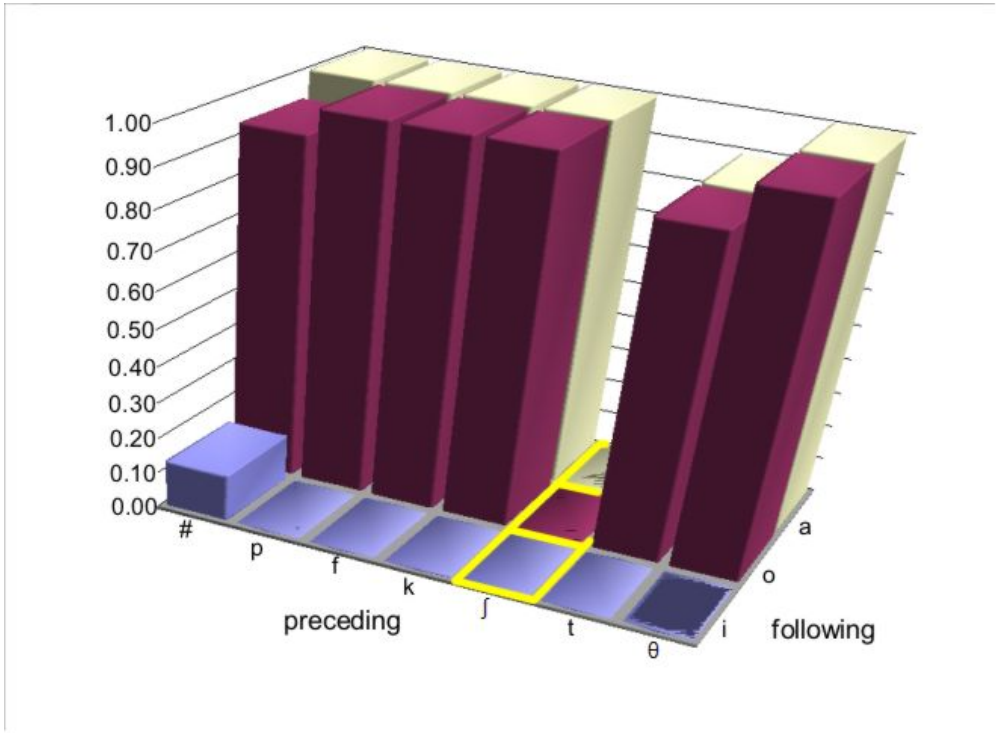
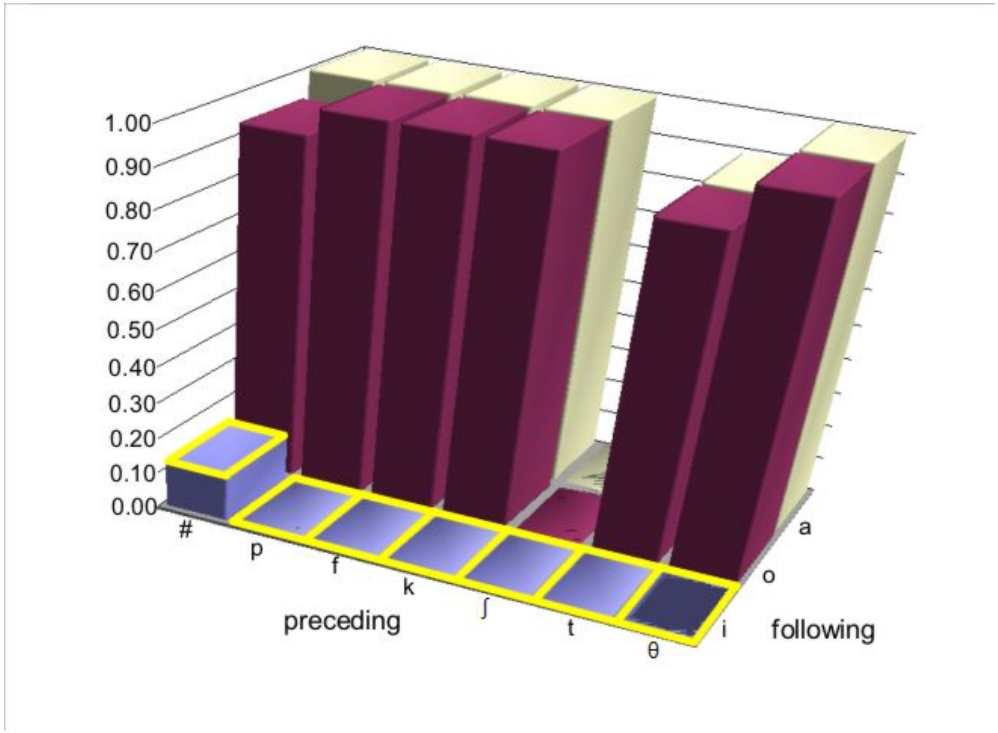


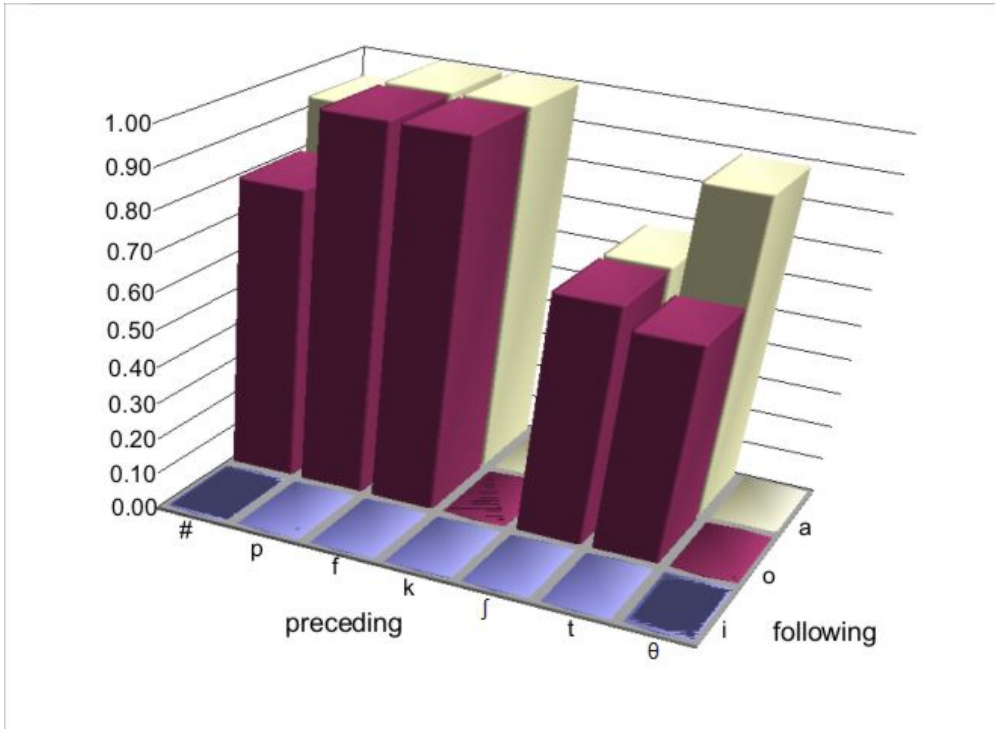
Systematic gaps

- Some speakers have systematic gaps.
- r08 doesn't retroflex in ʃrV
- almost never retroflexes in Cri



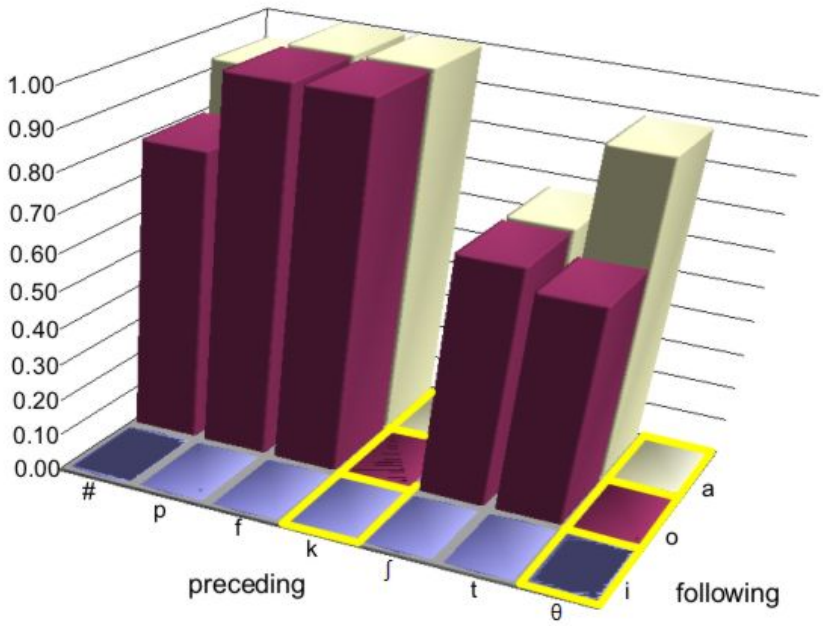
Systematic gaps

- Other speakers have *other* gaps.



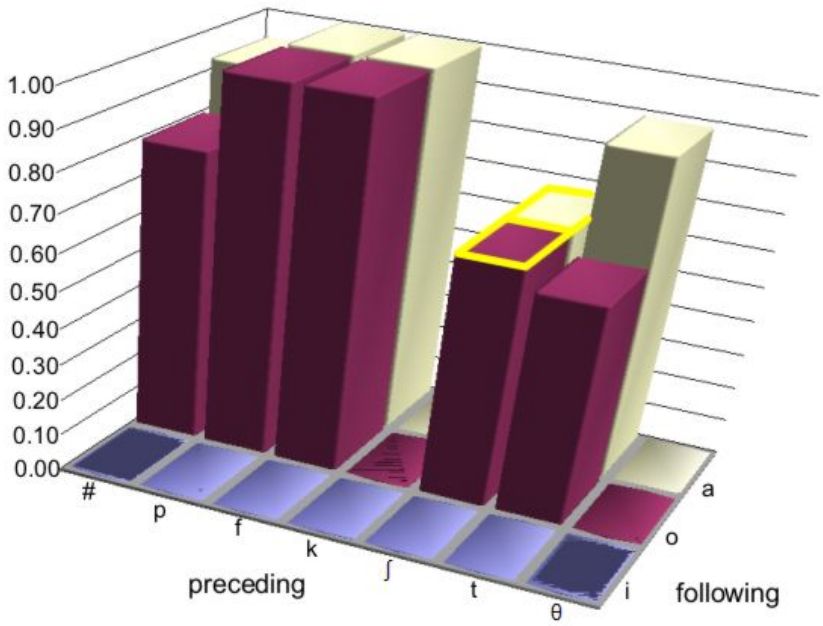
Systematic gaps

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



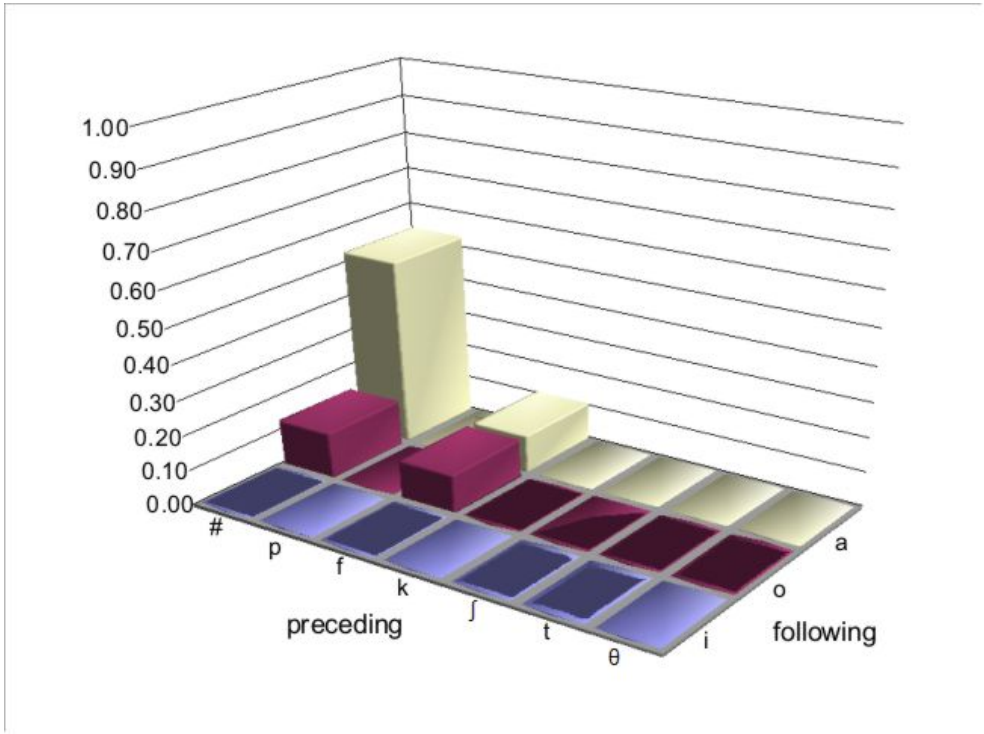
Systematic gaps

- Other speakers have *other* gaps.
- r17 doesn't retroflex in krV or θrV
- but *does* retroflex in ʃrV



Sporadic retroflexion

- Three speakers have only sporadic retroflexion.



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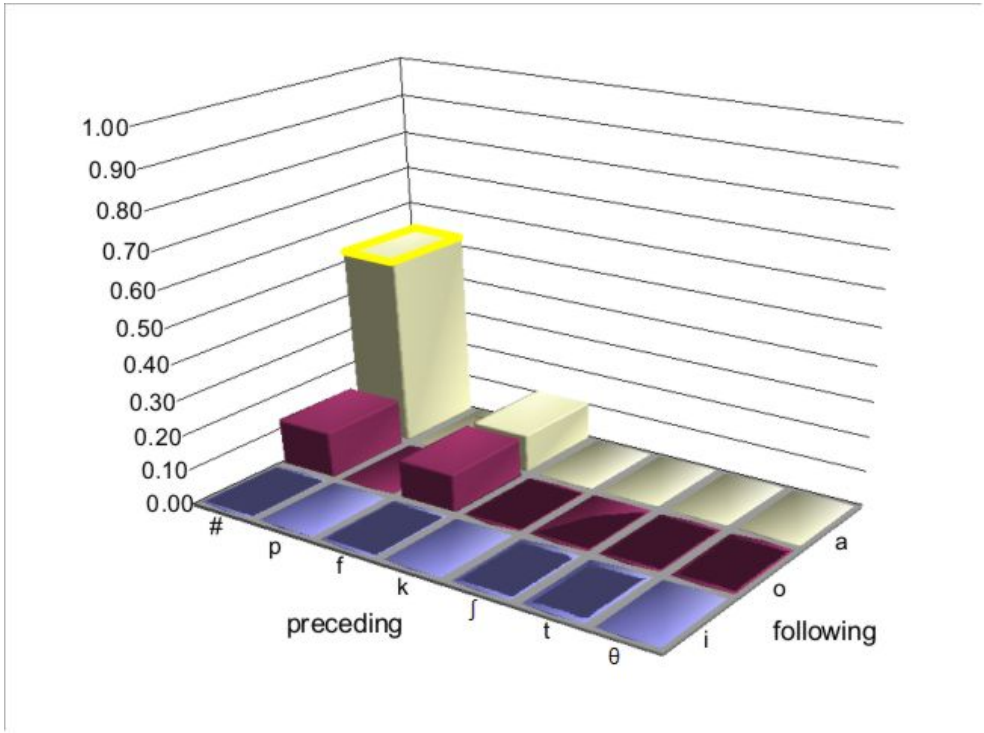
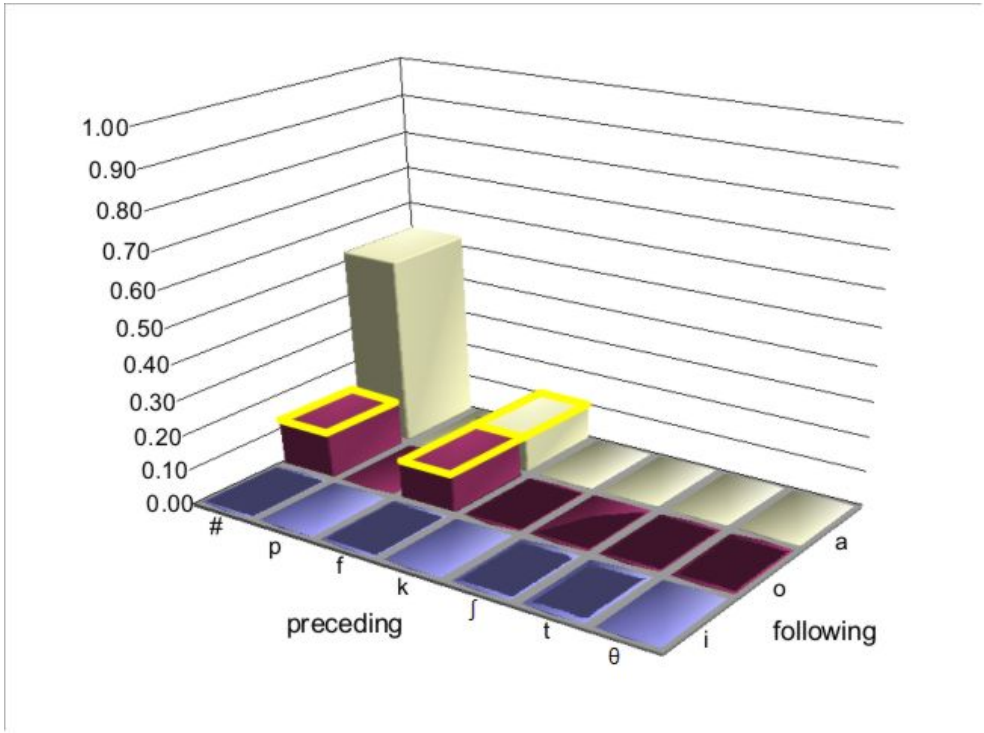


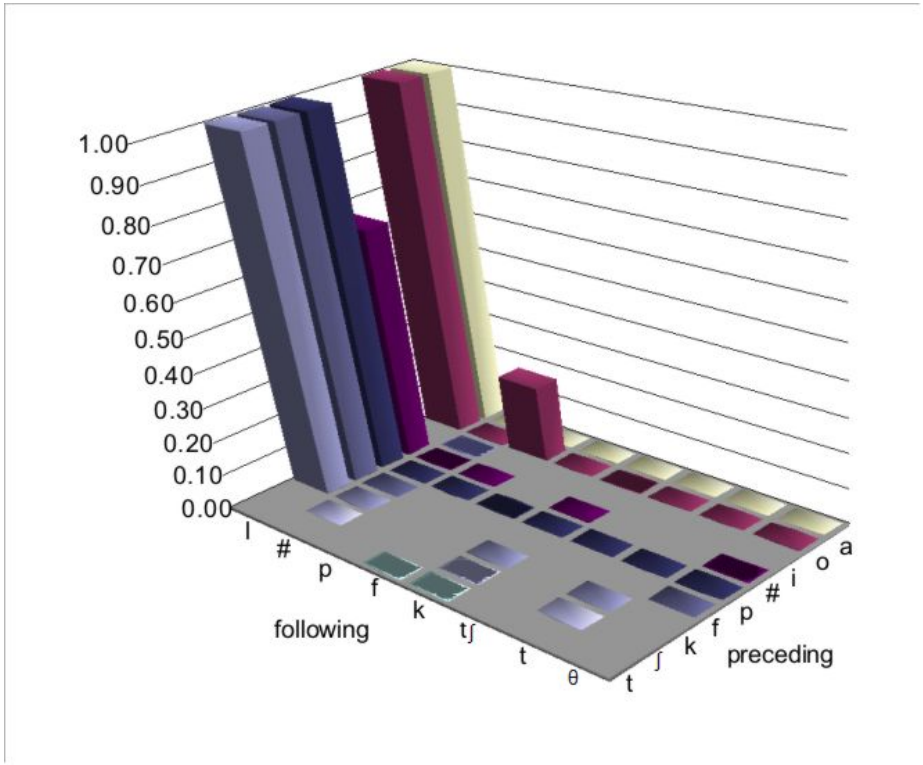
Sporadic retroflexion

- Three speakers have only sporadic retroflexion.
- r01 has some retroflexion in #ra
- and occasional retroflexion in #ro, fra, fro



Retroflexion before liquids

- Only eight subjects retroflex postvocalic or syllabic /ɹ/.



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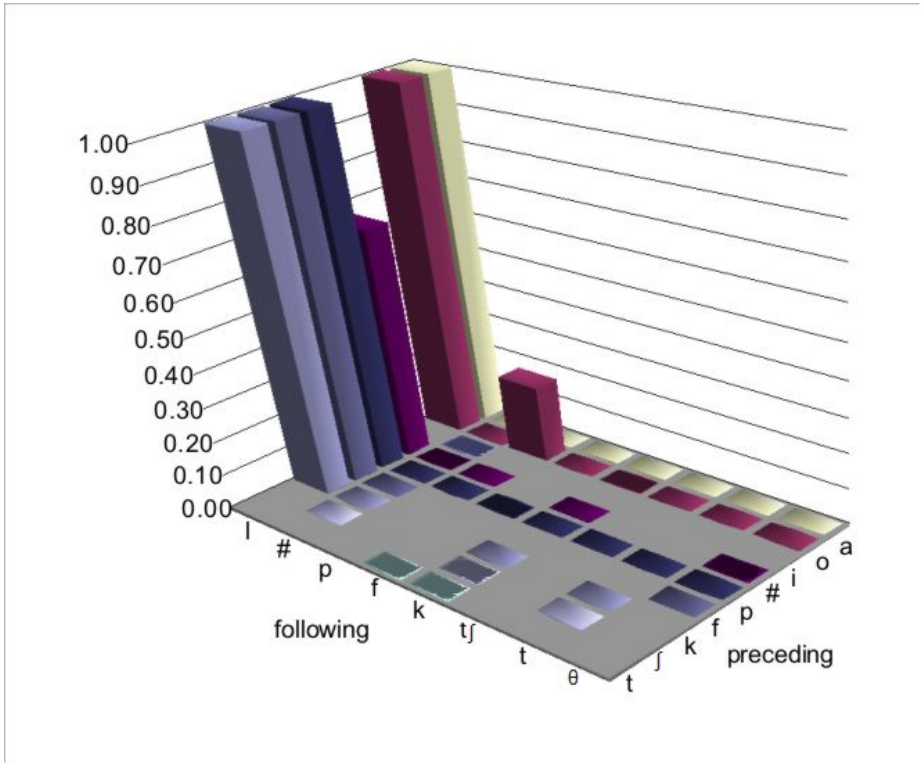

Retroflexion before liquids

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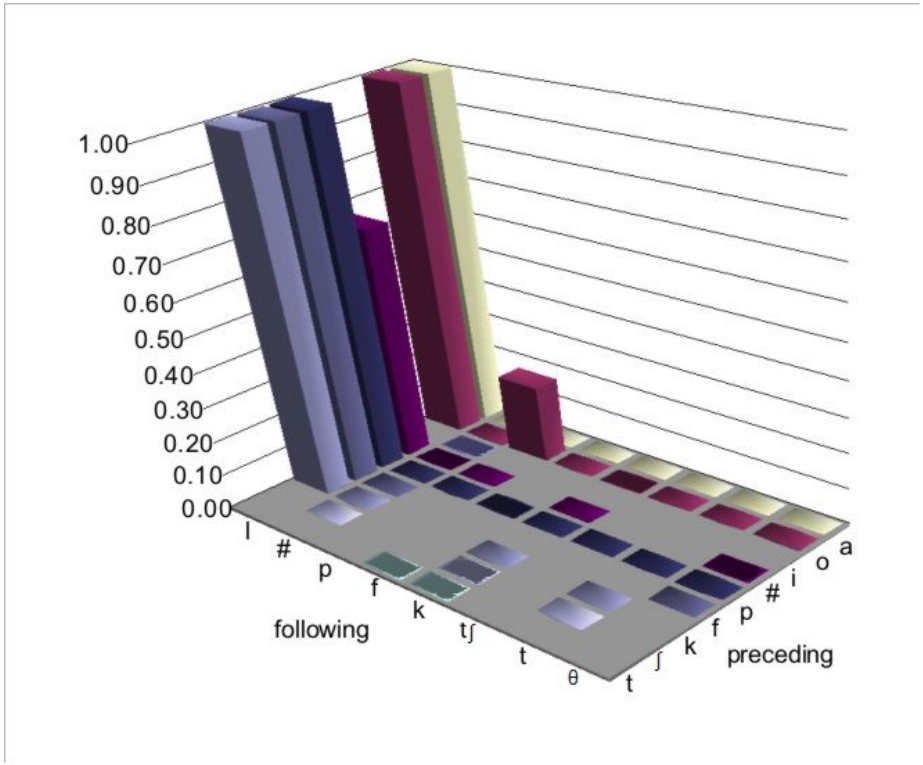
- r19 retroflexes in all pre-liquid contexts.



Retroflexion before other consonants

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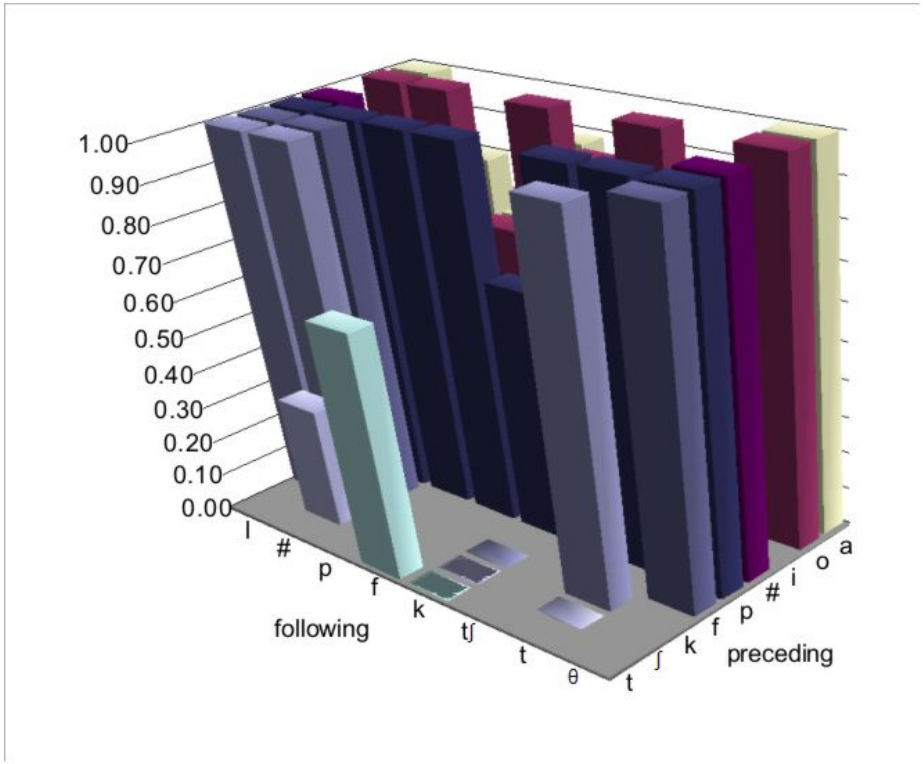

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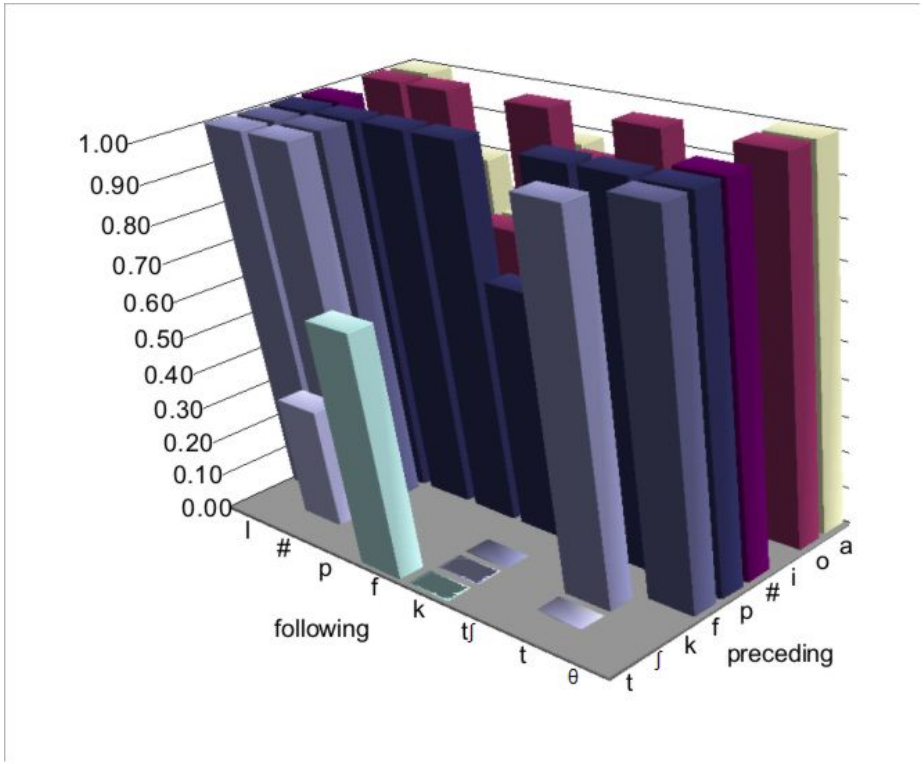
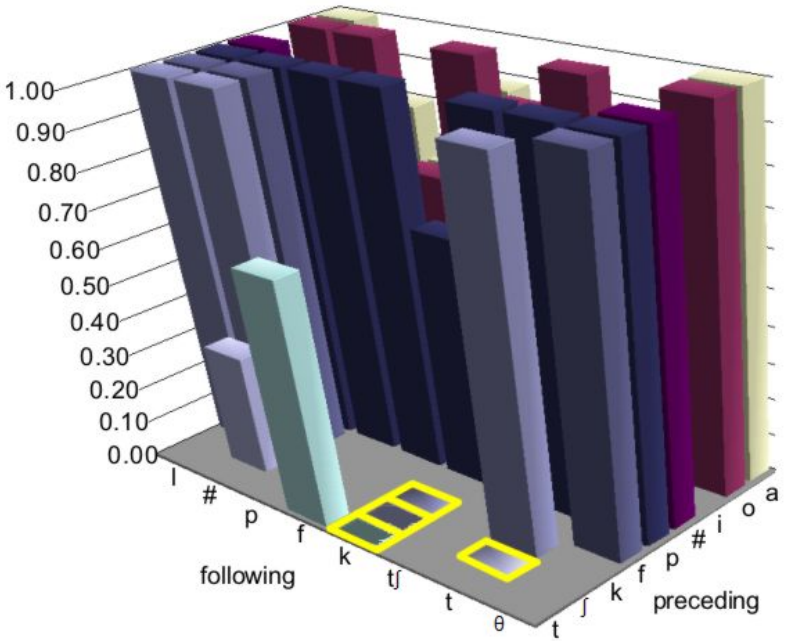


Retroflexion before other consonants

- Only four subjects regularly retroflex before any other consonants.
- r22 retroflexes in most nonprevocalic contexts.
- but never in krk, ʃrk, trk, or ʃrt



/ɹ/ allophony rules are. . .

- phonetically natural
- speaker-specific
- complex

/ɹ/ allophony rules are **phonetically natural**

- Bunched /ɹ/ typically occurs next to "bunched" consonants and vowels.

/ɹ/ allophony rules are **phonetically natural**

- Bunched /ɹ/ typically occurs next to "bunched" consonants and vowels.
- Retroflex /ɹ/ 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.

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- 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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Retroflexion next to labials, word boundary back vowels

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

Retroflexion before /l/

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

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- 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).

/ɹ/ allophony rules are **speaker-specific:**

- Different reactions to the same phonetic motivations

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

Different reactions to the same motivations

Context	Avg. rate	👫	🧍	🧍	🧍	🧍	👫	🧍	👫	👫	👩👩👩👩👩👩👩
C__{a o}											
# p f	.38	X	X	X	X	X	X	X	X	X	
velar	.29	X	X	X	X	X	X	X			
coronals	.26	X	X	X	X	X	X	X	X		
nonpreV											
__l	.25	X	X	X	X	X	X				
elsewhere	.11	X	X	X		X					
C__i											
# p f	.16	X	X		X	X					
velar	.15	X	X		X						
coronals	.07	X									

Different conditioning consonants

Subjects differ in what lingual Cs condition retroflexion.

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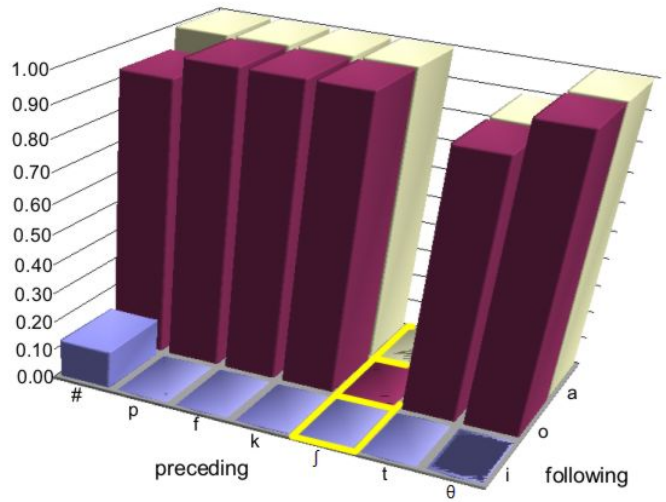
- Some differences may be attributed to speaker-specific articulatory motivations.
- Some differences are not obviously rooted in different articulatory motivations.

Different conditioning consonants. Why?

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



r08

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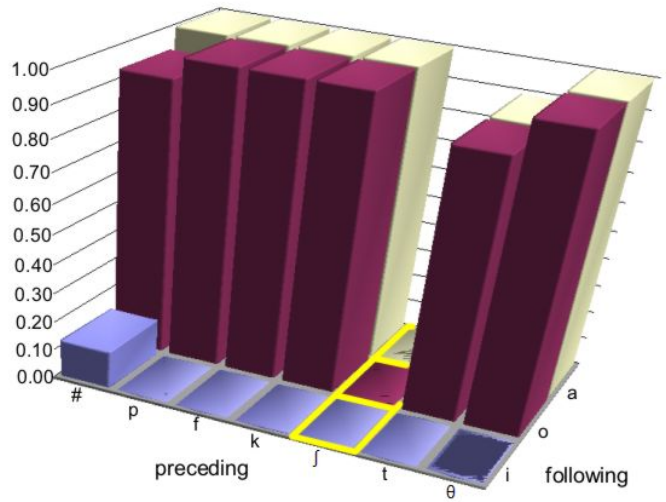
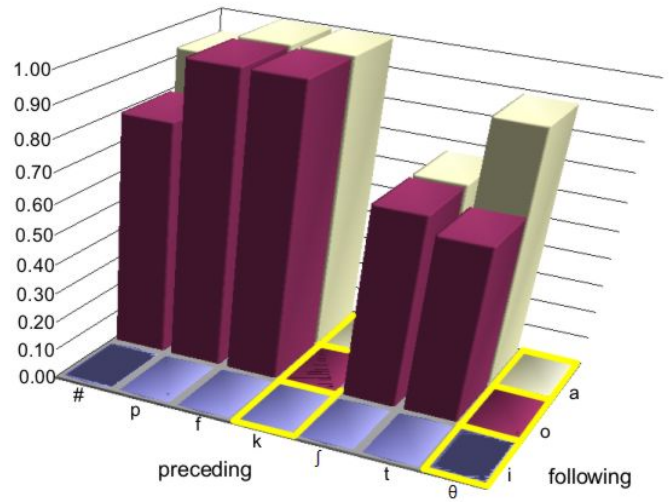


r08

r17 retroflexes after /ʃ/, but not after /k/ or /θ/.



r17

Speaker-specific motivations: [ʃ]

'Shrop'

r08 (bunched):

r17 (retroflex):

Speaker-specific motivations?: [k]

'Crop'

r08 (retroflex):

r17 (bunched):

Speaker-specific motivations?: [θ]

'throb'

r08 (retroflex):

r17 (bunched):

/ɹ/ allophony rules are **complex**

- Different conditioning segments for different syllable positions

/ɹ/ allophony rules are **complex**

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- 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/ → retroflex / {# p f k}__{a o} ∨ p__i ∨ θ__a

Retroflexion before and after consonants

Consonants that allow retroflexion of a following /ɹ/.

r19	r22	r27	r04	r26	r08	r32	r17	r01	r10	r06
#	#	#	#	#	#	#	#	#	#	#
p	p	p	p	p	p	p	p		p	p
f	f	f	f	f	f	f	f	f		f
k	k	k	k	k	k	k				
ʃ	ʃ	ʃ	ʃ	ʃ			ʃ			
t	t	t	t	t	t	t	t		t	
θ	θ	θ	θ	θ	θ	θ				

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#	#	#	#	#	#	#	#	#	#	#
p	p	p	p	p	p	p	p		p	p
f	f	f	f	f	f	f	f	f		f
k	k	k	k	k	k	k				
ʃ	ʃ	ʃ	ʃ	ʃ			ʃ			
t	t	t	t	t	t	t	t		t	
θ	θ	θ	θ	θ	θ	θ				

Retroflexion before /a o/ and /i/

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

r19	r22	r27	r04	r26	r08	r32	r17	r01	r10	r06
#	#	#	#	#	#	#	#	#	#	#
p	p	p	p	p	p	p	p		p	p
f	f	f	f	f	f	f	f	f		f
k	k	k	k	k	k	k				
ʃ	ʃ	ʃ	ʃ	ʃ			ʃ			
t	t	t	t	t	t	t	t		t	
θ	θ	θ	θ	θ	θ	θ				

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r19	r22	r27	r04	r26	r08	r32	r17	r01	r10	r06
#	#	#	#	#	#	#	#	#	#	#
p	p	p	p	p	p	p	p		p	p
f	f	f	f	f	f	f	f	f		f
k	k	k	k	k	k	k				
ʃ	ʃ	ʃ	ʃ	ʃ			ʃ			
t	t	t	t	t	t	t	t		t	
θ	θ	θ	θ	θ	θ	θ				

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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- such complex conditioning environments.

These are different from typical sound patterns.

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*.

Why is /ɹ/ allophony different?

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Why is /ɹ/ allophony different?

- The difference between allophones is inaudible.
- 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 /ɹ/ allophony pattern might:
  - iron out speaker-specific articulatory differences,
  - tend to favor an easily learned variant.

If /ɹ/ allophony grew up. . .

Possible "ironed out" conventionalized /ɹ/ allophony patterns:

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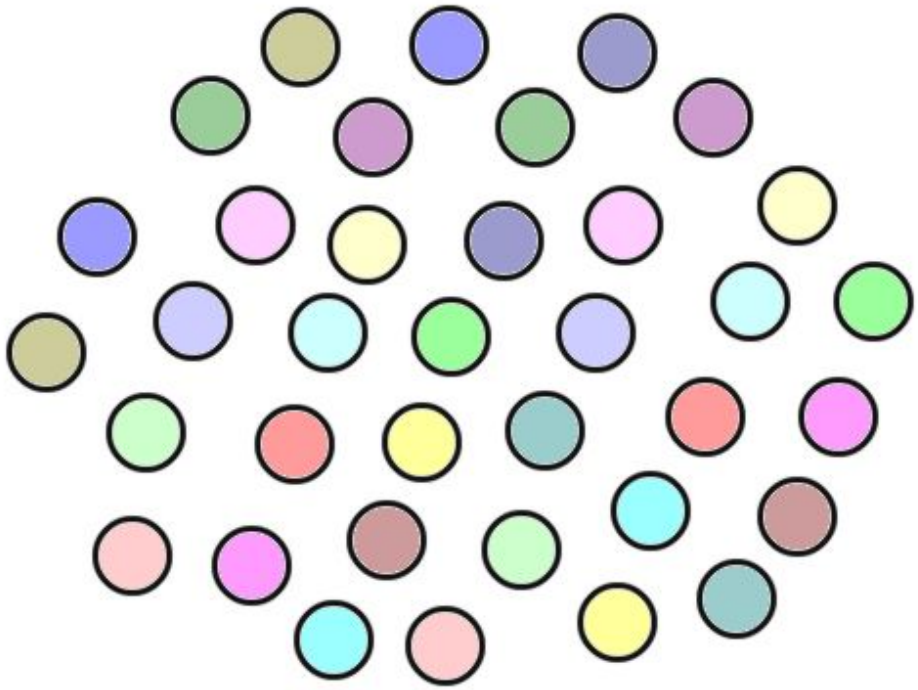
- These patterns resemble each other to the extent that:
  - variants are easily produced with a human vocal tract
  - they have the same acoustic result (e.g. low F3)
- Idiosyncratic sound patterns: the pool of variation from which new conventional patterns could be drawn

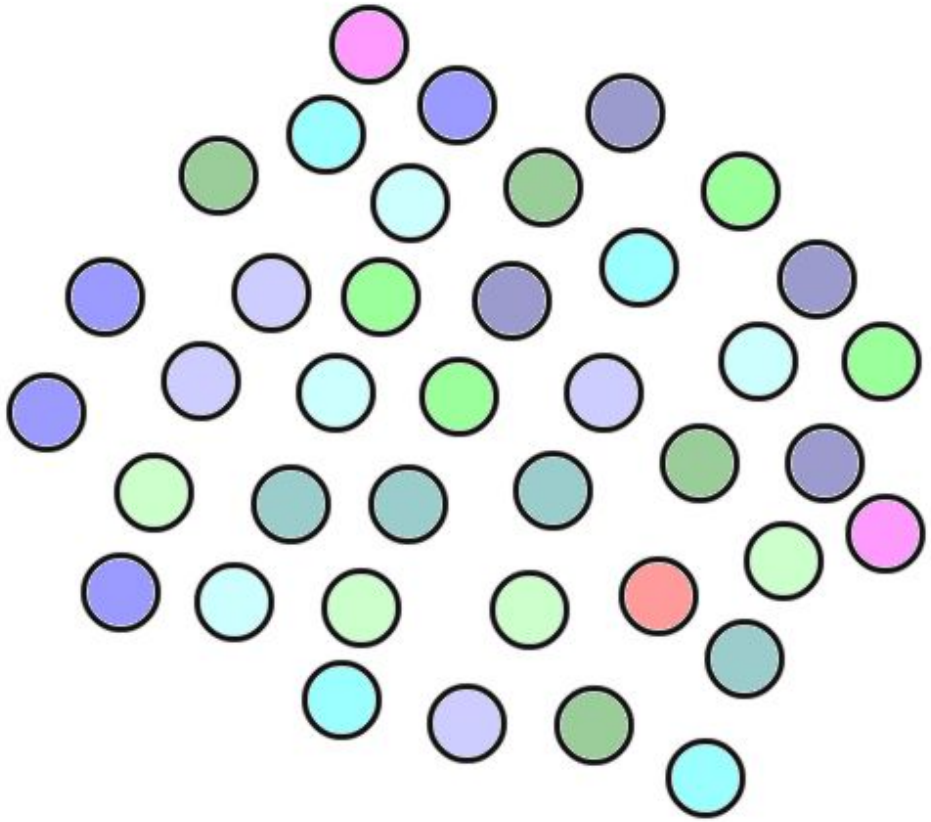
The eternal youth of /ɹ/ allophony...

Many possible /ɹ/ allophony patterns.



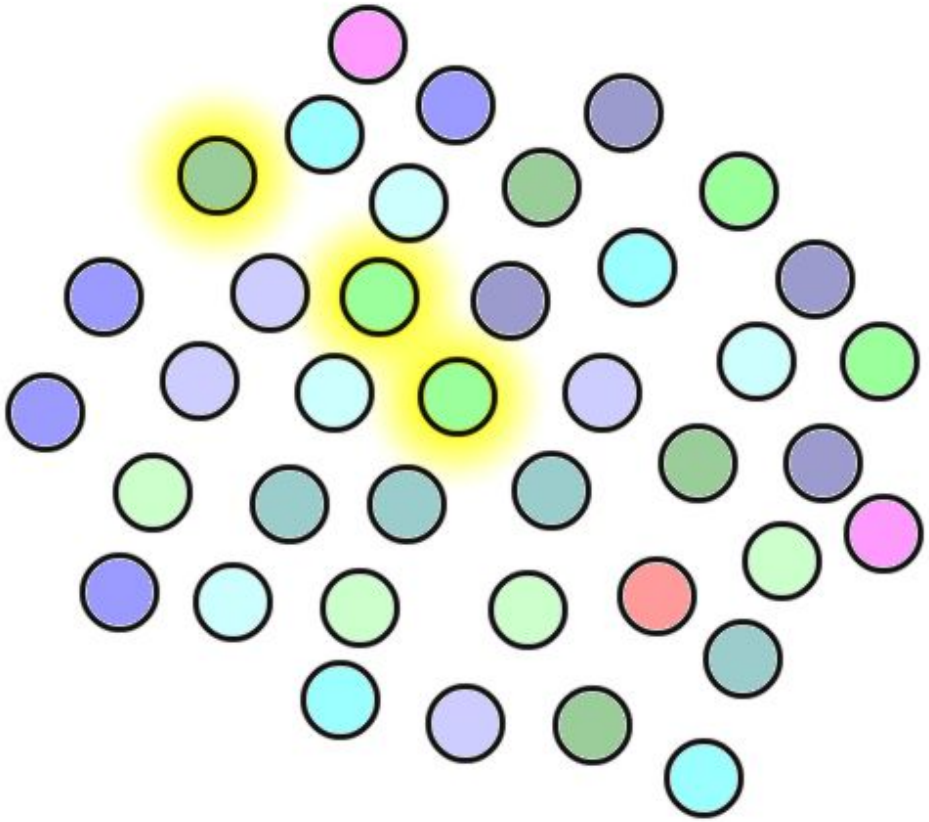
The eternal youth of /ɹ/ allophony...

Biased toward phonetically natural ones.



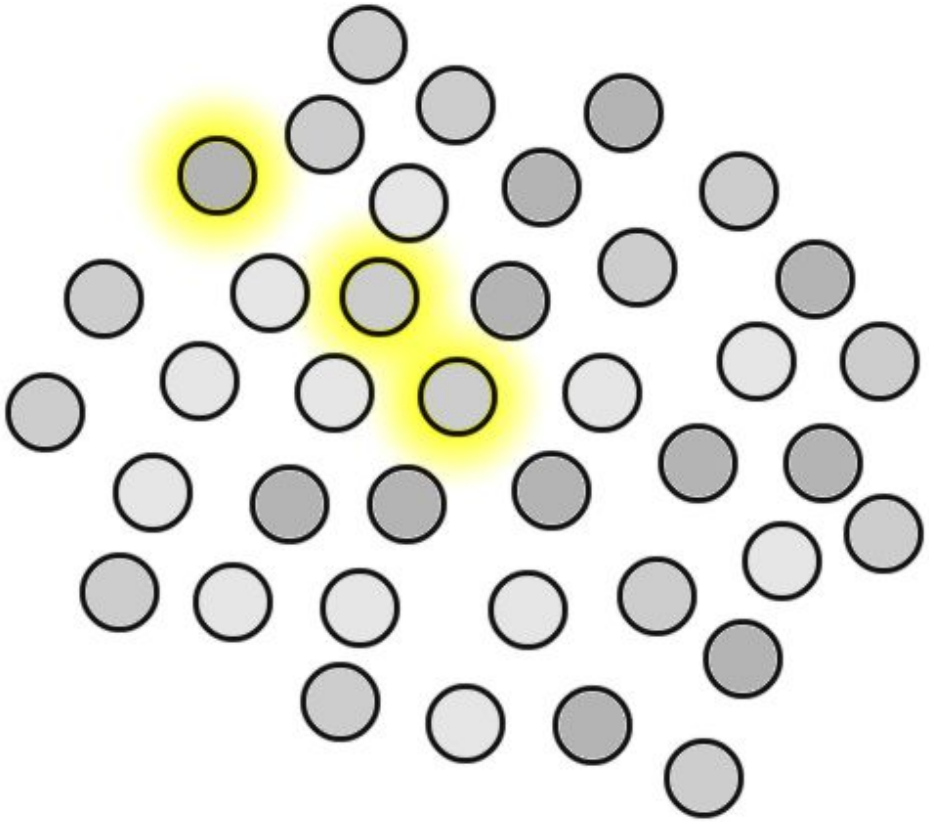
The eternal youth of /ɹ/ allophony...

Only the acoustic properties (low F3) can gain social significance.



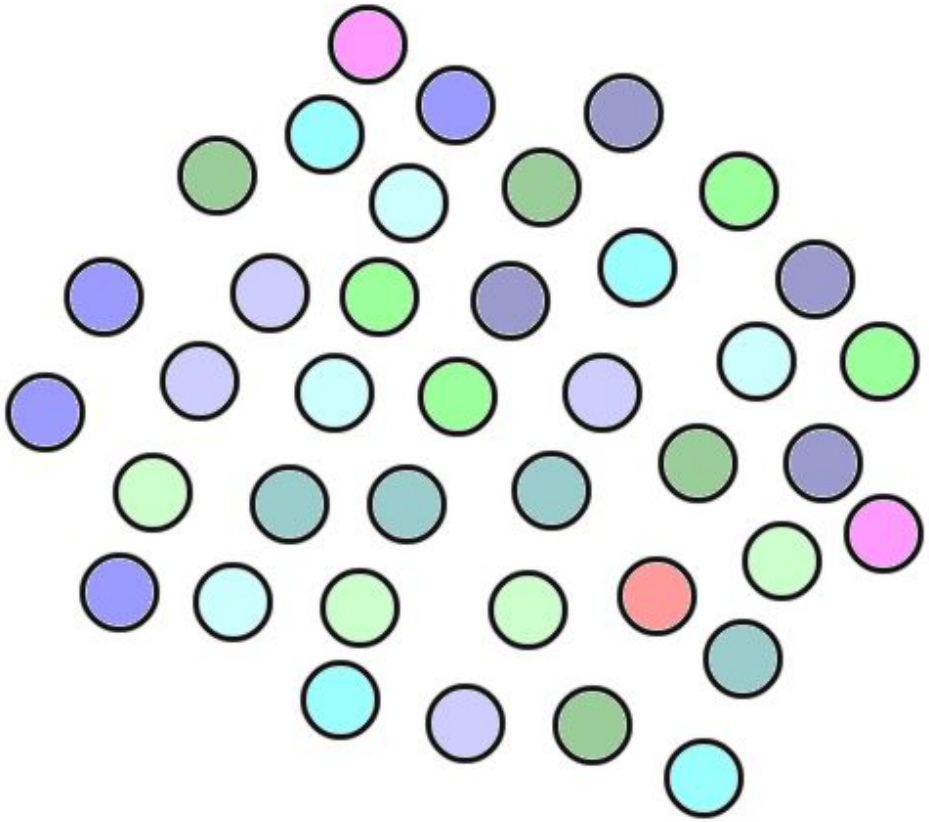
The eternal youth of /ɹ/ allophony...

Perceptually, there is no evidence of articulatory differences.



The eternal youth of /ɹ/ allophony...

Articulatorily, /ɹ/ allophony is stuck at an early stage.



Getting stuck in the pool of variation means. . .

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Getting stuck in the pool of variation means...

- /ɹ/ allophony is stuck at an early stage of its development
- No convergence on a common pattern
- No simplification
- Variants of the pattern still tend to be phonetically natural.

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- Different sound patterns can emerge in response to the same phonetic motivation (depending on which variant is ultimately conventionalized).

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- Sound patterns can be both phonetically natural and complex.
- Phonetic naturalness and simplicity can be byproducts of the development of a sound pattern.
- They need not emerge together.

Thank you