An Apparent Time Study of (str) Retraction and /tɹ/ - /dɹ/ Affrication in Raleigh, NC English

Lyra Magloughlin[a] and Eric Wilbanks[b]

University of Ottawa[a] — UC Berkeley[b]

November 5, 2016

NWAV 45 – Vancouver, BC

Acknowledgements

Lyra Magloughlin
University of Ottawa

Lyra and I would like to extend our thanks to:

- NCSU Linguistics, especially Jeff Mielke and Robin Dodsworth
- Audiences at LabPhon15 Turbulent Sounds workshop and Berkeley Phonetics/Phonology Phorum
- NSF Grant #BCS-1451475 awarded to Jeff Mielke
- UC Berkeley Graduate Division Conference Travel Grant
- uOttawa Faculty of Graduate and Post-Doctoral Studies
- OGS and SSHRC Doctoral Scholarships

Background

Consonantal Changes

What are the principles shaping the synchronic relationship between consonantal sound changes?

Consonantal Changes

What are the principles shaping the synchronic relationship between consonantal sound changes?

- Investigations of vocalic chain shifts are well-represented in sociolinguistics

Consonantal Changes

What are the principles shaping the synchronic relationship between consonantal sound changes?

- Investigations of vocalic chain shifts are well-represented in sociolinguistics
- Historical linguistics has approached this question diachronically (e.g., Grimm's Law, Verner's Law)

Consonantal Changes

What are the principles shaping the synchronic relationship between consonantal sound changes?

- Investigations of vocalic chain shifts are well-represented in sociolinguistics
- Historical linguistics has approached this question diachronically (e.g., Grimm's Law, Verner's Law)
- But there's still a lot we don't know about the synchronic realization of linked consonantal changes (Thomas, 2001, p. 283)

Case Study

Today we present work from a project on two consonantal sound changes in progress in Raleigh, North Carolina English.

(str) Retraction
and
/tɹ/-/dɹ/ Affrication

Motivations

Various proposed phonetic motivations for (str) retraction:

Motivations

Various proposed phonetic motivations for (str) retraction:

A. Assimilation to affricated /t/ in /tɹ/ cluster

Motivations

Various proposed phonetic motivations for (str) retraction:

A. Assimilation to affricated /t/ in /tɹ/ cluster
   - /stʃ/ → [ʃtʃ]; e.g., `this chap', `last year' (Lawrence, 2000; Preston, 2016)

Motivations

Various proposed phonetic motivations for (str) retraction:

A. Assimilation to affricated /t/ in /tɹ/ cluster
   - /stʃ/ → [ʃtʃ]; e.g., `this chap', `last year' (Lawrence, 2000; Preston, 2016)

B. Assimilation to /ɹ/ (Shapiro, 1995)

Motivations

Various proposed phonetic motivations for (str) retraction:

A. Assimilation to affricated /t/ in /tɹ/ cluster
   - /stʃ/ → [ʃtʃ]; e.g., `this chap', `last year' (Lawrence, 2000; Preston, 2016)

B. Assimilation to /ɹ/ (Shapiro, 1995)
   - Evidence of baseline retraction in /spɹ/, /skɹ/ clusters (Baker et al., 2011; Stevens & Harrington, 2016)

Motivations

Various proposed phonetic motivations for (str) retraction:

A. Assimilation to affricated /t/ in /tɹ/ cluster
   - /stʃ/ → [ʃtʃ]; e.g., `this chap', `last year' (Lawrence, 2000; Preston, 2016)

B. Assimilation to /ɹ/ (Shapiro, 1995)
   - Evidence of baseline retraction in /spɹ/, /skɹ/ clusters (Baker et al., 2011; Stevens & Harrington, 2016)

No investigation of these two processes in same corpus of speakers.

Predictions

If (str) is retracting in response to /tɹ/ affrication:

Predictions

If (str) is retracting in response to /tɹ/ affrication:

1. /tɹ/ affrication will precede (str) retraction at the community level

Predictions

If (str) is retracting in response to /tɹ/ affrication:

1. /tɹ/ affrication will precede (str) retraction at the community level
2. Individuals who are retracting /s/ should also be affricating /tɹ/

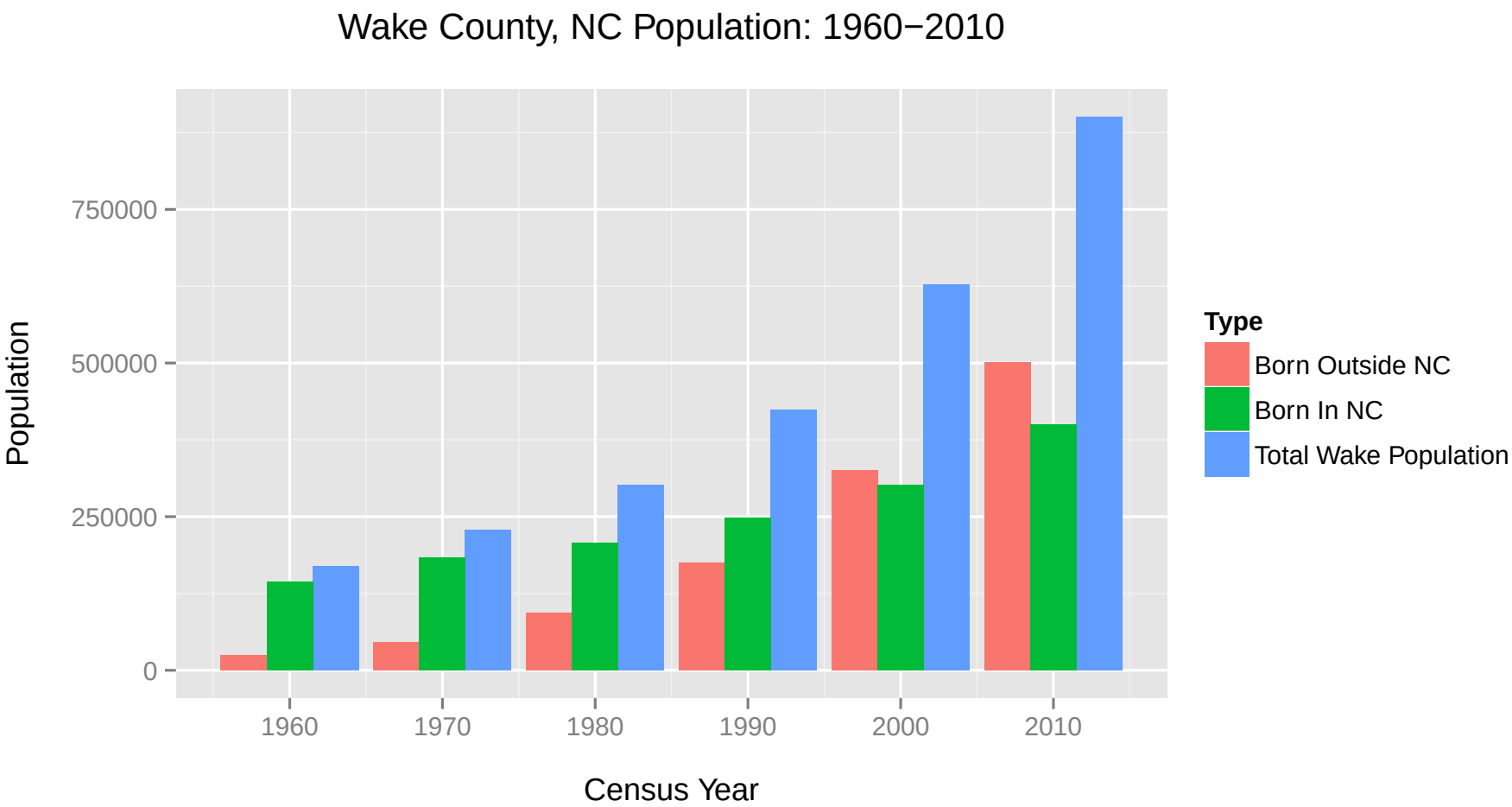
Raleigh, North Carolina (NC)

- Raleigh is a large urban center in the American South with a population of around 450,000

Raleigh, North Carolina (NC)

- Raleigh is a large urban center in the American South with a population of around 450,000
- Large influx of workers from the North during the tech boom of the 1960-70s

Rapid Demographic Shift



Ideal Testing Ground

- Area of intense dialect contact and leveling (Kerswill & Williams, 2005)

Ideal Testing Ground

- Area of intense dialect contact and leveling (Kerswill & Williams, 2005)
- Rapid transition away from the SVS and other Southern features (Dodsworth & Kohn, 2012; Dodsworth, 2014)

Corpus Breakdown

In both analyses that follow, data come from **140 sociolinguistic interviews from a corpus of (300+) Raleigh, NC natives** (Dodsworth & Kohn, 2012).

Generation	Birthyear Range	Women	Men	Total
1	1923-1954	28	27	55
2	1955-1978	32	24	56
3	1979-1996	15	14	29
		75	65	**140**

Table 1: Demographic breakdown of Raleigh speakers under analysis

Orthographically transcribed and force-aligned using P2FA (Yuan & Liberman, 2008)

(str) Retraction

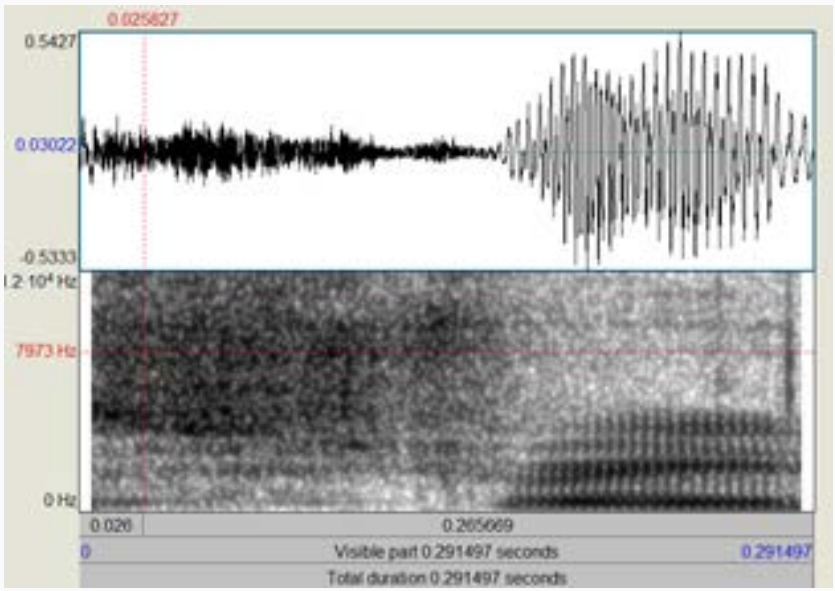
(str) Retraction

Background

(str) Retraction

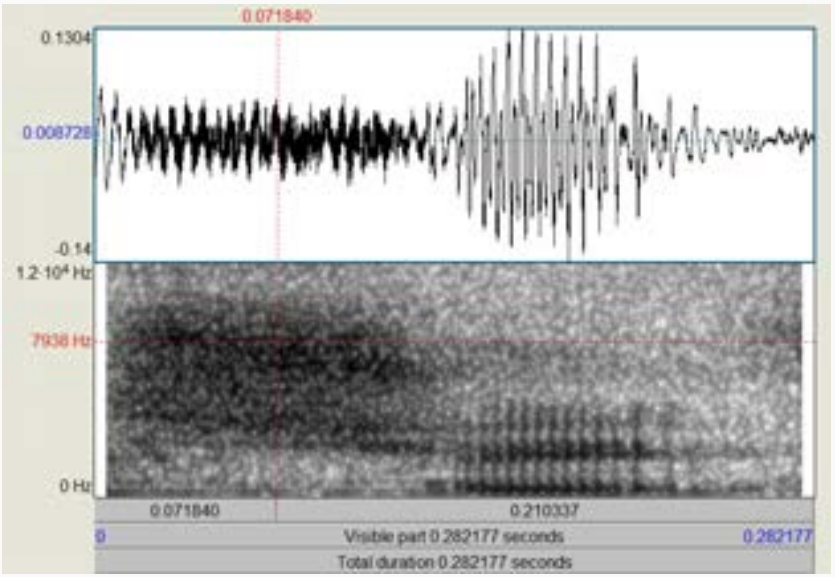
Female b. 1961

other part of the street
street
s



Female b. 1991

live down the street
street
s



Widely Distributed

(str) Retraction has been observed across many regions of the English-speaking world:

Widely Distributed

(str) Retraction has been observed across many regions of the English-speaking world:

1. **The US** (Baker et al., 2011; Durian, 2007; Gylfadottir, 2015; Labov, 1984)

Widely Distributed

(str) Retraction has been observed across many regions of the English-speaking world:

1. **The US** (Baker et al., 2011; Durian, 2007; Gylfadottir, 2015; Labov, 1984)
2. **The UK** (Bass, 2009; Glain, 2014)

Widely Distributed

(str) Retraction has been observed across many regions of the English-speaking world:

1. **The US** (Baker et al., 2011; Durian, 2007; Gylfadottir, 2015; Labov, 1984)
2. **The UK** (Bass, 2009; Glain, 2014)
3. **New Zealand** (Lawrence, 2000)

Linguistic and Social Factors

Common Factors conditioning retraction:

Linguistic and Social Factors

Common Factors conditioning retraction:

1. Word **medial position** (*restrict*) favors retraction over initial position (*street*) (Durian, 2007; Gylfadottir, 2015)

Linguistic and Social Factors

Common Factors conditioning retraction:

1. Word **medial position** (*restrict*) favors retraction over initial position (*street*) (Durian, 2007; Gylfadottir, 2015)
    - Durian (2007) hypothesizes change started in medial position, but this hasn't been directly observed

Linguistic and Social Factors

Common Factors conditioning retraction:

1. Word **medial position** (*restrict*) favors retraction over initial position (*street*) (Durian, 2007; Gylfadottir, 2015)
    - Durian (2007) hypothesizes change started in medial position, but this hasn't been directly observed
2. **Age**: more retraction over apparent time. (Durian, 2007; Gylfadottir, 2015)

Linguistic and Social Factors

Common Factors conditioning retraction:

1. Word **medial position** (*restrict*) favors retraction over initial position (*street*) (Durian, 2007; Gylfadottir, 2015)
    - Durian (2007) hypothesizes change started in medial position, but this hasn't been directly observed
2. **Age**: more retraction over apparent time. (Durian, 2007; Gylfadottir, 2015)
3. **Prosodic Structure**: more retraction phrase-initially (Phillips, 2016)

Linguistic and Social Factors (cont.)

Sex Differentiation:

- Rapid Anonymous Surveys suggest that retracted variants are produced more by men (Bass, 2009; Durian, 2007; Hinrichs et al., 2015)

Linguistic and Social Factors (cont.)

Sex Differentiation:

- Rapid Anonymous Surveys suggest that retracted variants are produced more by men (Bass, 2009; Durian, 2007; Hinrichs et al., 2015)
- However, sociophonetic analyses of spontaneous corpora have not replicated a sex effect (Durian, 2007; Gylfadottir, 2015)

Linguistic and Social Factors (cont.)

Sex Differentiation:

- Rapid Anonymous Surveys suggest that retracted variants are produced more by men (Bass, 2009; Durian, 2007; Hinrichs et al., 2015)
- However, sociophonetic analyses of spontaneous corpora have not replicated a sex effect (Durian, 2007; Gylfadottir, 2015)
- Gylfadottir (2015) hypothesizes that in Philadelphia the change has advanced past a female-lead; retraction is characteristic of both sexes in younger speakers

(str) Retraction

Analysis

Measurement

- All /s/ and /ʃ/ tokens automatically extracted

Measurement

- All /s/ and /ʃ/ tokens automatically extracted
- Only speakers with > 4 (str) tokens considered

Measurement

- All /s/ and /ʃ/ tokens automatically extracted
- Only speakers with > 4 (str) tokens considered
- 99,150 tokens remain for analysis
    - 81,437 /s/, 15,135 /ʃ/, 2,578 (str)

Retraction Ratio

Following Baker et al. (2011) we use **Retraction Ratio** as our dependent measure of (str), essentially speaker-internal Center of Gravity (COG) normalization.

Retraction Ratio

Following Baker et al. (2011) we use **Retraction Ratio** as our dependent measure of (str), essentially speaker-internal Center of Gravity (COG) normalization.

$$\textbf{Retraction Ratio} = \frac{(\text{speaker mean } /\int/ \text{ COG} - \text{Observed COG})}{(\text{speaker mean } /\int/ \text{ COG} - \text{speaker mean } /s/ \text{ COG})}$$

Token with Retraction Ratio closer to 1: more like /ʃ/
Token with Retraction Ratio closer to 0: more like /s/

Modeling

Linear mixed-effects modeling in R using *lme4* (Bates et al., 2015).

Models constructed in a nested fashion using AIC decrease to determine improved model fit Burnham & Anderson (2004)

Best fit model includes:

Modeling

Linear mixed-effects modeling in R using *lme4* (Bates et al., 2015).

Models constructed in a nested fashion using AIC decrease to determine improved model fit Burnham & Anderson (2004)

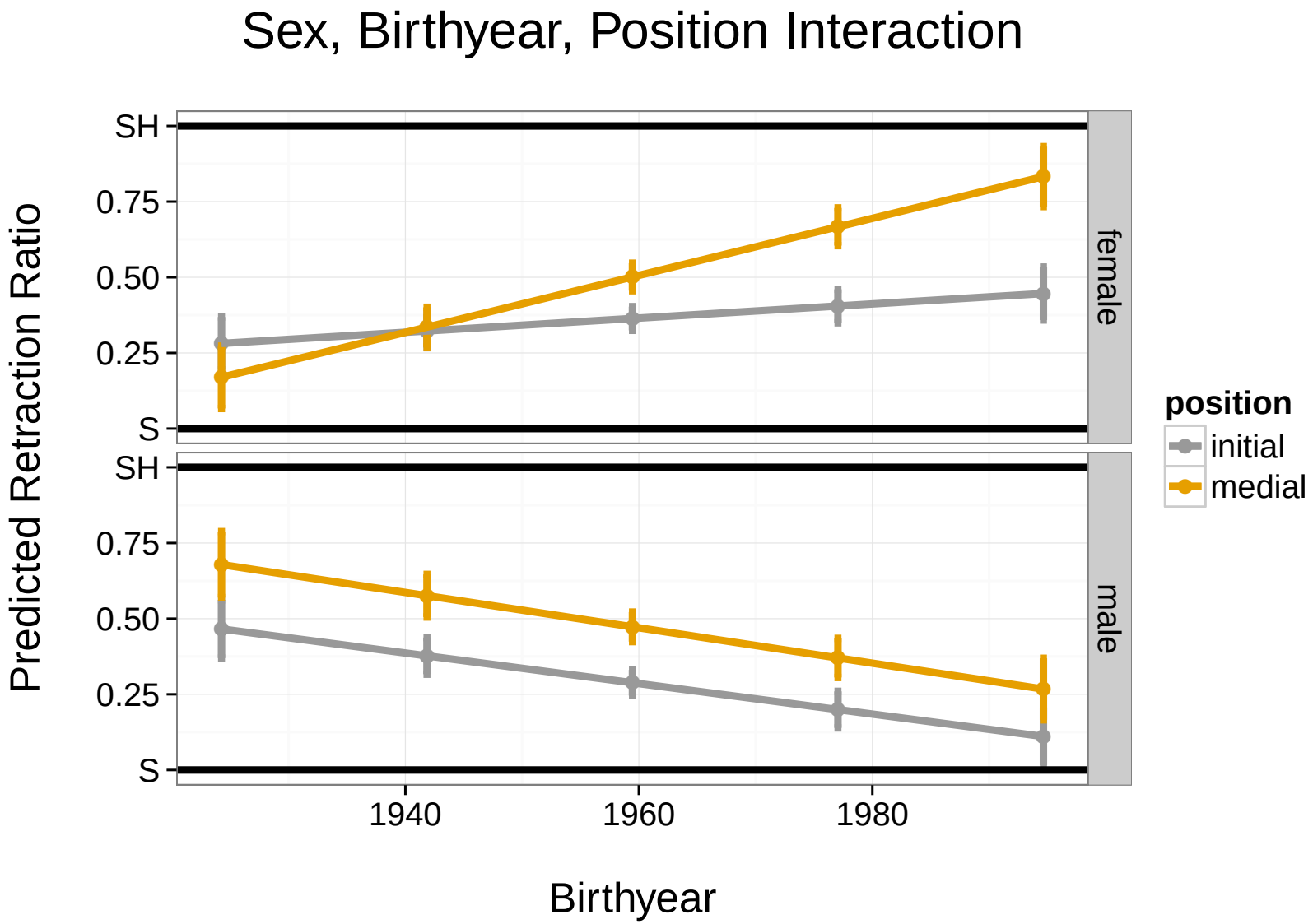
Best fit model includes:

- Four-way interaction between Word Position - Phone Type - Sex - Birthyear
- Fixed effects of phon. environment
- Random intercepts for Speaker and Word

---

lmer(cog.ratio.inv ~ left + right + position * phone * sex * birthyear.z + (log.dur|speaker_id) + (1|word),REML=F,data=df)

Model Coefficients: Just (str)



(str) Retraction

Interim Summary

Interim Summary

Interim Summary

1. Women leading (str) retraction, dramatic change in apparent time

Interim Summary

1. Women leading (str) retraction, dramatic change in apparent time
2. But only in medial position ('restructure')

Interim Summary

1. Women leading (str) retraction, dramatic change in apparent time
2. But only in medial position ('restructure')
3. If anything, men are becoming less retracted

/tɹ/ - /dɹ/ Affrication

/tɹ/ - /dɹ/ Affrication

Affrication of /t/,/d/ before /ɹ/ (e.g., 'truck' [tʃɹʌk]) is discussed as a feature of many varieties of English (Cruttenden, 2014, p. 192).

/tɹ/ - /dɹ/ Affrication

Affrication of /t/,/d/ before /ɹ/ (e.g., 'truck' [tʃɹʌk]) is discussed as a feature of many varieties of English (Cruttenden, 2014, p. 192).

To our knowledge, there is no work investigating community level changes in this phenomenon.

Instrumental Measure

Acoustic measures of affrication are difficult to apply to non-lab data.

Instrumental Measure

Acoustic measures of affrication are difficult to apply to non-lab data.

Measures used for distinguishing unaffricated and affricated /t/ in /tw/ clusters (Smith, 2013) **could not reliably distinguish between pre-vocalic /t/ and /tʃ/** in our conversational data, even after substantial correction and subsegmentation of automatic segment boundaries.

- Center of Gravity during burst
- Normalized rise time (from onset of burst to point of max intensity)
- Duration

Machine Classification

As such, we turn to a method based on Yuan & Liberman (2011).

Machine Classification

As such, we turn to a method based on Yuan & Liberman (2011).

The stops in /tɹ/ - /dɹ/ clusters are **force-aligned twice**, once using acoustic models of the **stops**, and once using acoustic models of the corresponding **affricates**.

Machine Classification

As such, we turn to a method based on Yuan & Liberman (2011).

The stops in /tɹ/ - /dɹ/ clusters are **force-aligned twice**, once using acoustic models of the **stops**, and once using acoustic models of the corresponding **affricates**.

A(ffrication)-scores are calculated by subtracting likelihood scores of the affricate alignment by the likelihood scores of the stop alignment (normalized for duration).

Machine Classification - Example

'tree'

- Aligned as /tɹi/
- Aligned as /tʃɹi/

Machine Classification - Example

'tree'

- **Aligned as /tɹi/**
- Likelihood score = 1254.72

- **Aligned as /tʃɹi/**
- Likelihood score = 1285.91

Machine Classification - Example

'tree'

- **Aligned as /tɹi/**
- Likelihood score = 1254.72

- **Aligned as /tʃɹi/**
- Likelihood score = 1285.91

A-score $= 1285.91 - 1254.72 = 31.19$
This token is more similar to /tʃ/ than /t/.

Positive A-Score = more affricate-like
Negative A-Score = more stop-like

Analysis

- All tokens of /tɹ/ and /dɹ/ automatically extracted

Analysis

- All tokens of /tɹ/ and /dɹ/ automatically extracted
- /tɹ/: 5170 tokens; /dɹ/: 2384 tokens
- A-Score calculated for each token

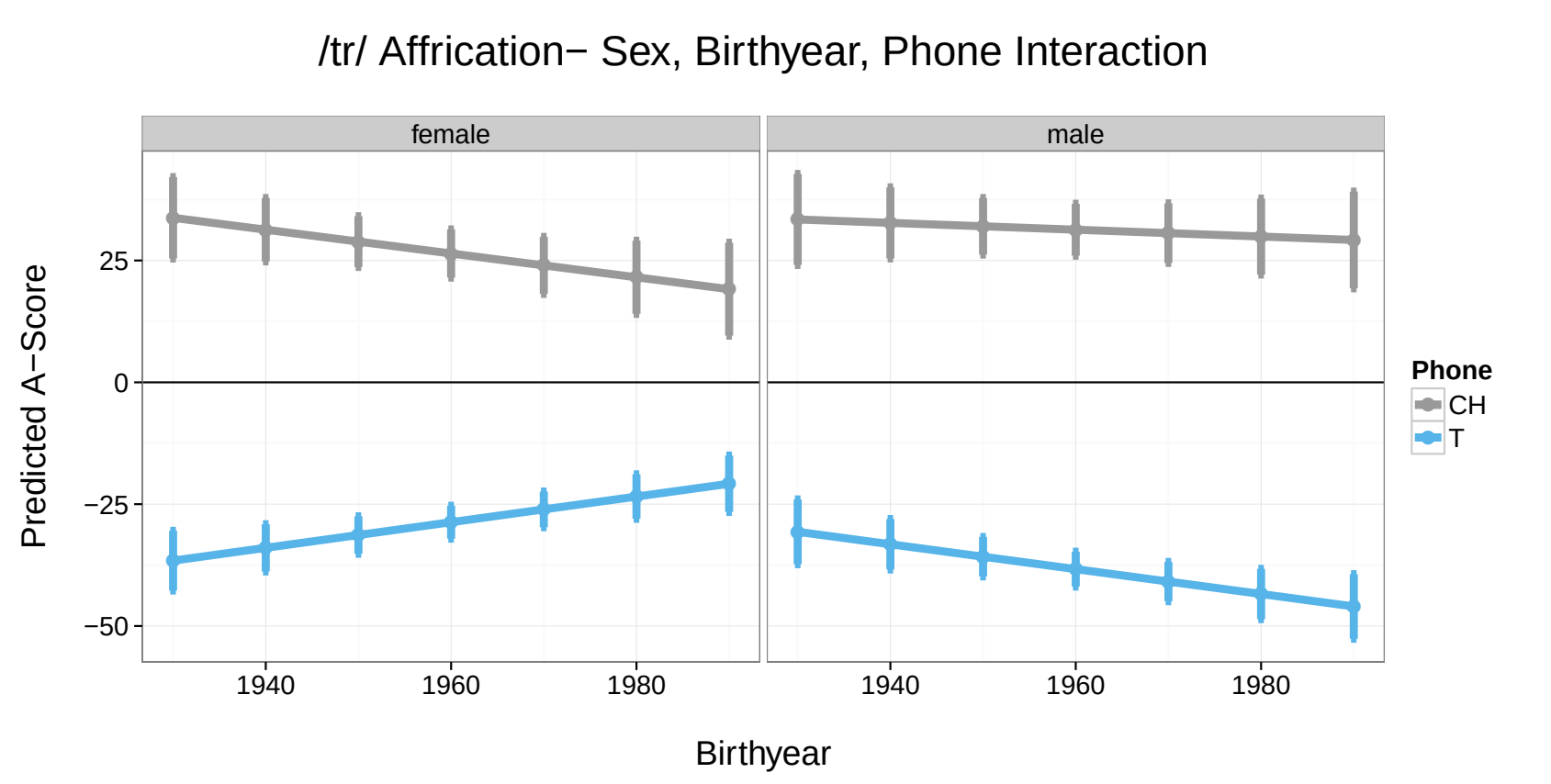
Analysis

- All tokens of /tɹ/ and /dɹ/ automatically extracted
- /tɹ/: 5170 tokens; /dɹ/: 2384 tokens
- A-Score calculated for each token
- As before, mixed effects linear models constructed in nested fashion using AIC as measure of improved fit

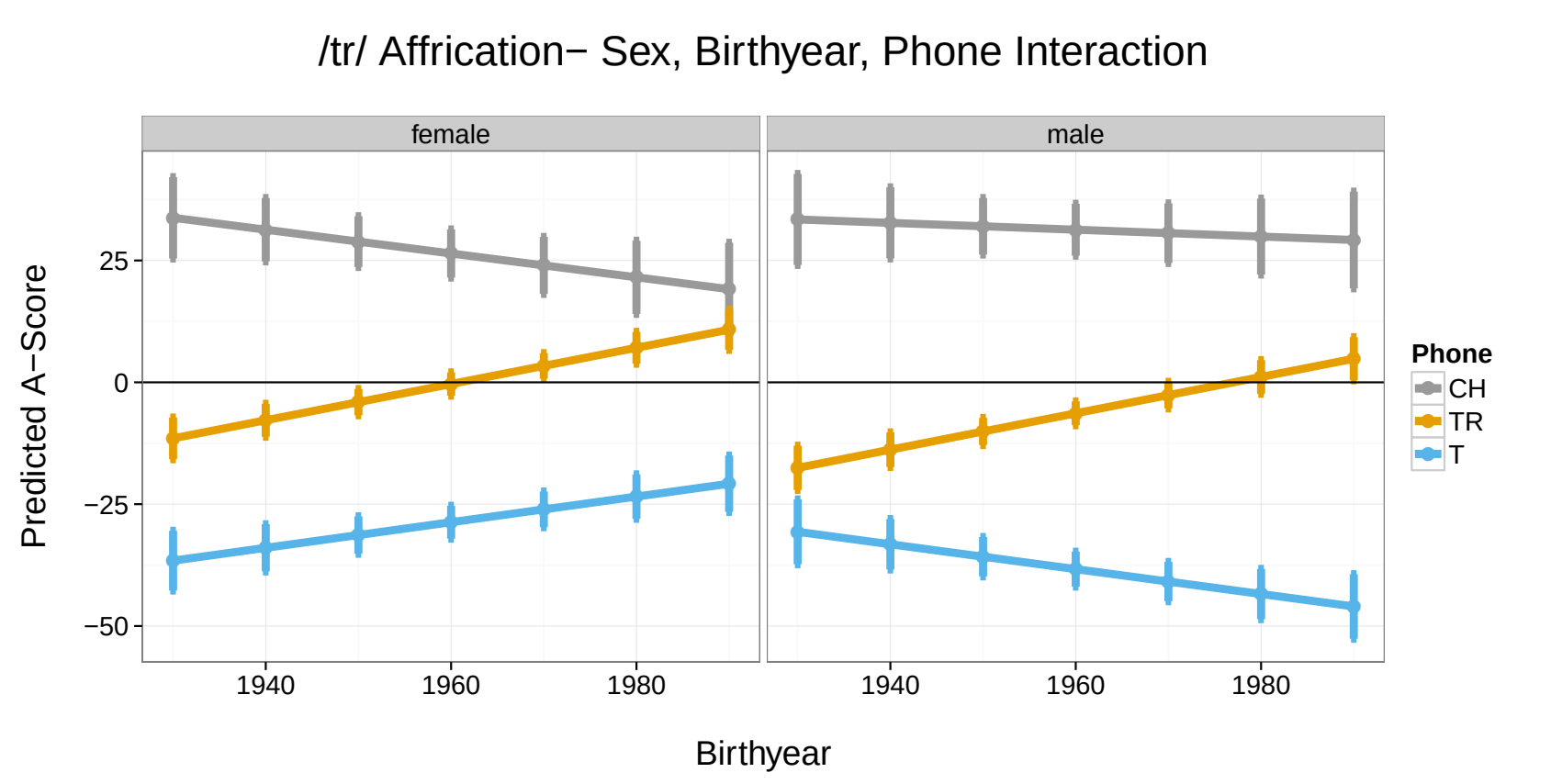
/tɹ/ - /dɹ/ Affrication

/tɹ/ Modeling

/tɹ/ Apparent Time



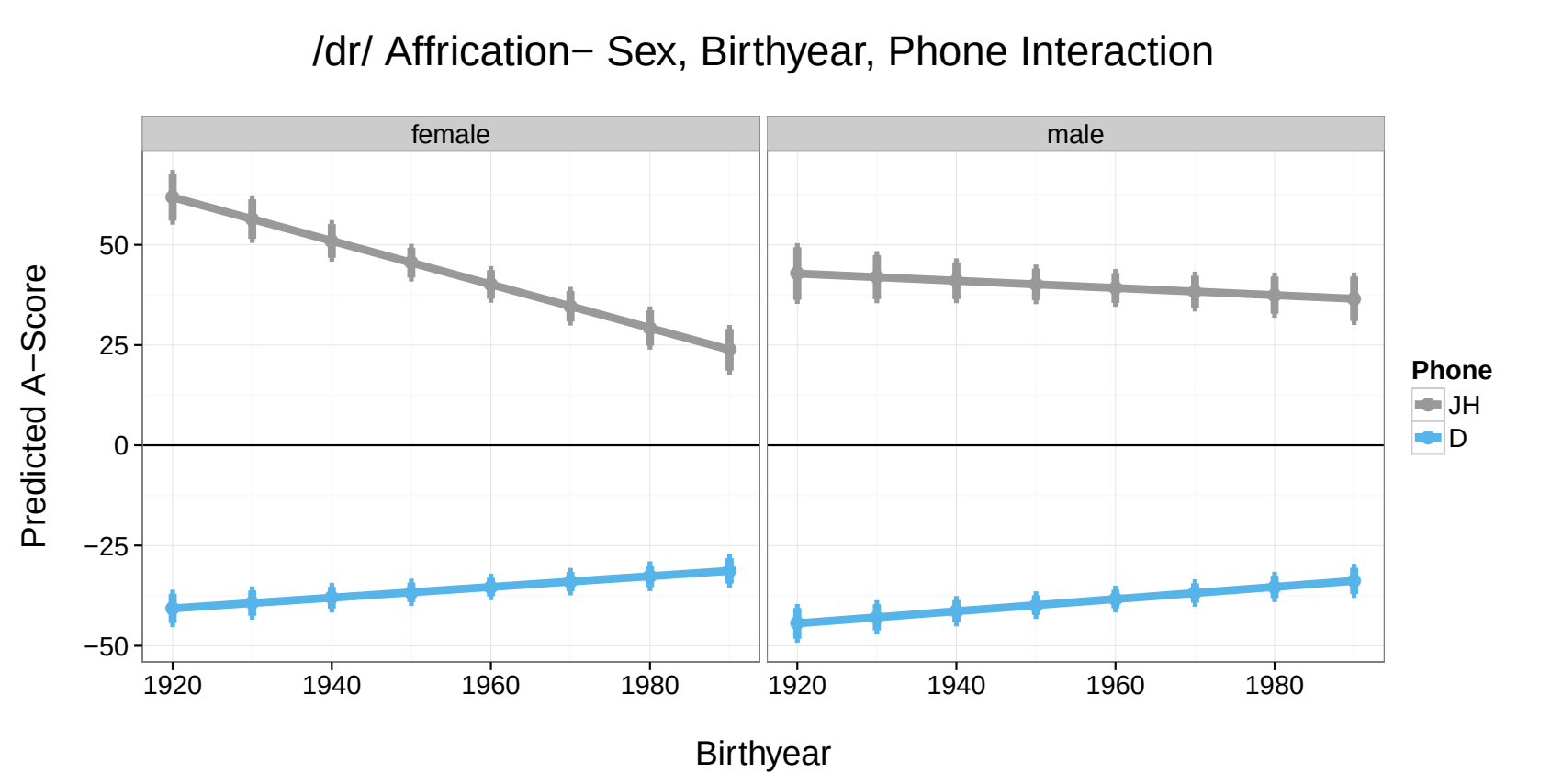
/tɹ/ Apparent Time



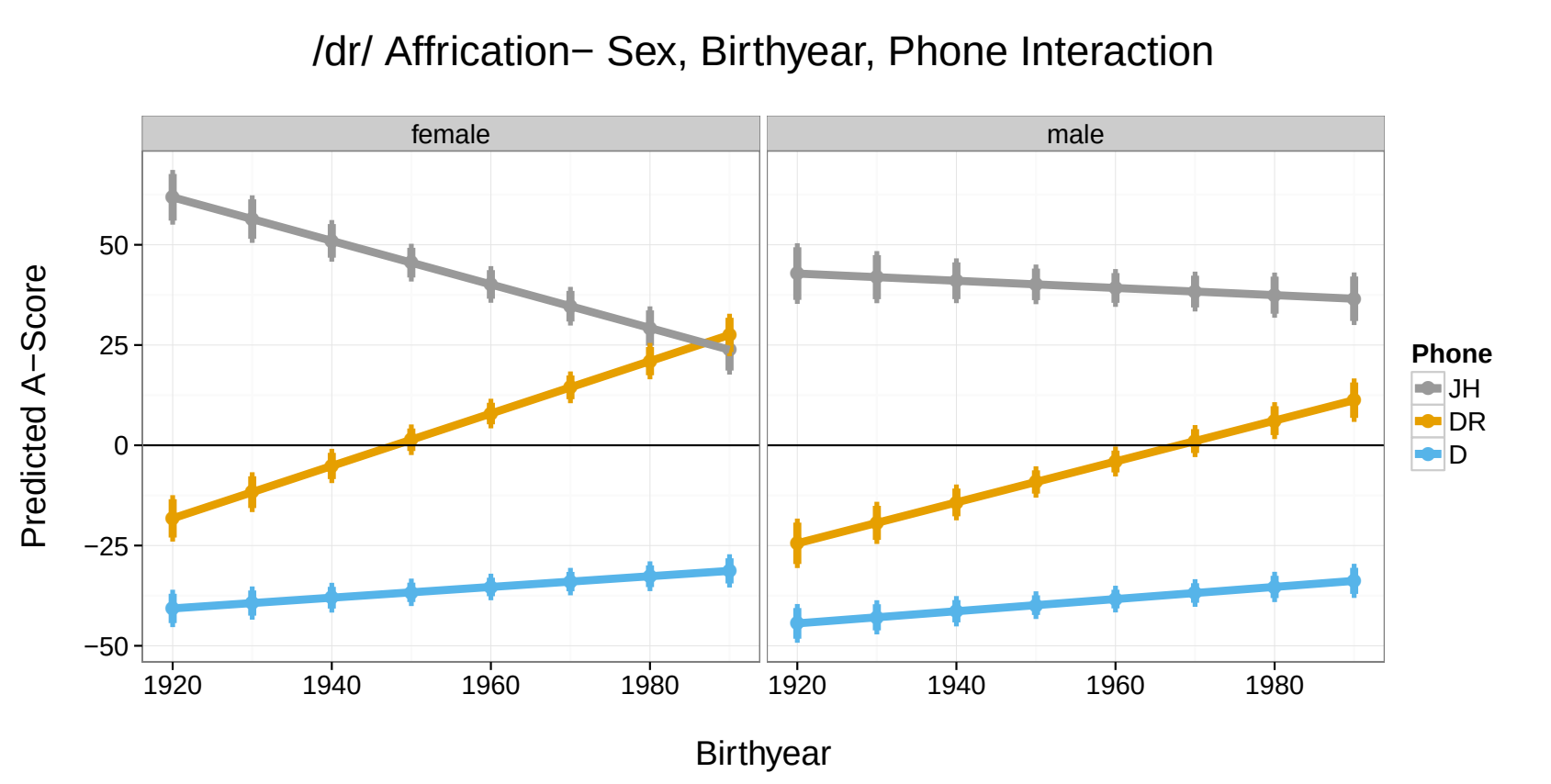
/tɹ/ - /dɹ/ Affrication

/dɹ/ Modeling

/dɹ/ Apparent Time



/dɹ/ Apparent Time



/tɹ/ - /dɹ/ Affrication

Interim Summary

Interim Summary

- /tɹ/ and /dɹ/ affrication is a robust change in progress in Raleigh

Interim Summary

- /tɹ/ and /dɹ/ affrication is a robust change in progress in Raleigh
- Nearly overlapping A-Scores with phonological affricates, most advanced for women.

Interim Summary

- /tɹ/ and /dɹ/ affrication is a robust change in progress in Raleigh
- Nearly overlapping A-Scores with phonological affricates, most advanced for women.
- Predates (str) retraction

Link Between Retraction and Affrication

Predictions

Recall our predictions if /tr/ affrication is one of the causes of (str) retraction:

Predictions

Recall our predictions if /tr/ affrication is one of the causes of (str) retraction:

1. ( ) /tɹ/ affrication will precede (str) retraction at the community level

Predictions

Recall our predictions if /tr/ affrication is one of the causes of (str) retraction:

1. ( ) /tɹ/ affrication will precede (str) retraction at the community level
2. ( ) Individuals who retract the most should also affricate the most

Predictions

Recall our predictions if /tr/ affrication is one of the causes of (str) retraction:

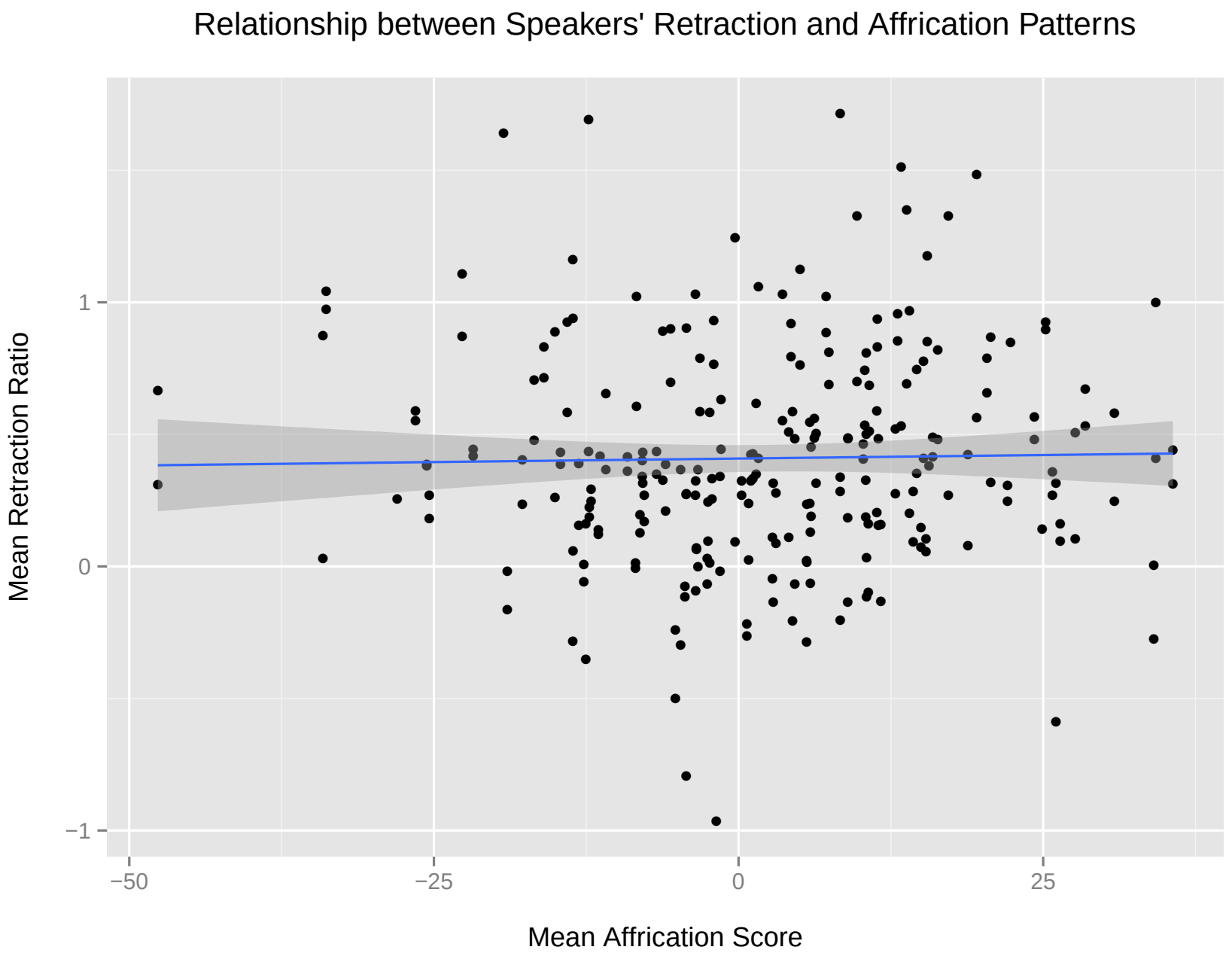
1. (✓) /tɹ/ affrication will precede (str) retraction at the community level
2. ( ) Individuals who retract the most should also affricate the most

Predictions

Recall our predictions if /tr/ affrication is one of the causes of (str) retraction:

1. (✓) /tɹ/ affrication will precede (str) retraction at the community level
2. (??) Individuals who retract the most should also affricate the most

Speaker Means for Retraction and Affrication



Predictions

Recall our predictions if /tɹ/ affrication is one of the causes of (str) retraction:

1. (✓) /tɹ/ affrication will precede (str) retraction at the community level

Predictions

Recall our predictions if /tɹ/ affrication is one of the causes of (str) retraction:

1. (✓) /tɹ/ affrication will precede (str) retraction at the community level
2. ( ) Individuals who retract the most should also affricate the most

Predictions

Recall our predictions if /tɹ/ affrication is one of the causes of (str) retraction:

1. (✓) /tɹ/ affrication will precede (str) retraction at the community level
2. (XX) Individuals who retract the most should also affricate the most

Takehome Points

1. (str) Retraction beginning in Raleigh, currently emerging in speech of young women in medial environments

Takehome Points

1. (str) Retraction beginning in Raleigh, currently emerging in speech of young women in medial environments
2. /tɹ/ – /dɹ/ A-Scores nearly identical to phonological affricates for women. Men not far behind.

Takehome Points

1. (str) Retraction beginning in Raleigh, currently emerging in speech of young women in medial environments
2. /tɹ/ – /dɹ/ A-Scores nearly identical to phonological affricates for women. Men not far behind.
3. No correlation between speaker's affrication patterns and their retraction patterns. Suggests that /tɹ/ affrication is not cause of retraction

References

References

Baker, A., Archangeli, D., & Mielke, J. (2011). Variability in American English s-retraction suggests a solution to the actuation problem. *Language Variation and Change*, 23(03), 347--374.

Bass, M. (2009). Street or Shtreet? Investigating (str-) palatalisation in Colchester English. *Estro: Essex Student Research Online*, 1(1), 10--21.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1), 1--48.

Burnham, K. P. & Anderson, D. R. (2004). Multimodel Inference Understanding AIC and BIC in Model Selection. *Sociological Methods & Research*, 33(2), 261--304.

Cruttenden, A. (2014). *Gimson's pronunciation of English*. Oxford/New York: Routledge, 8th edition.

Dodsworth, R. (2014). Network Embeddedness and the Retreat from Southern Vowels in Raleigh. *University of Pennsylvania Working Papers in Linguistics*, 20(2).

Dodsworth, R. & Kohn, M. (2012). Urban rejection of the vernacular: The svs undone. *Language Variation and Change*, 24, 221--245.

Durian, D. (2007). Getting [ʃ] tronger Every Day?: More on Urbanization and the Socio-geographic Diffusion of (str) in Columbus, OH. *University of Pennsylvania Working Papers in Linguistics*, 13(2), 6.

Glain, O. (2014). Introducing contemporary palatalisation. In T. Lee (Ed.), *Proceedings of the First Postgraduate and Academic Researchers in Linguistics at York conference*.

Gylfadottir, D. (2015). Shtreets of Philadelphia: An Acoustic Study of /str/-retraction in a Naturalistic Speech Corpus. *University of Pennsylvania Working Papers in Linguistics*, 21(2).

Hinrichs, L., Bergs, A., Bohmann, A., Brozovsky, E., Hodge, B. P., Meemann, K., & Schultz, P. (2015). Sibilants and ethnic diversity: A Sociophonetic Study of Palatalized /s/ in STR-Clusters among Hispanic, White, and African-American Speakers of Texas English.

Kerswill, P. & Williams, A. (2005). New towns and koineization: linguistic and social correlates. 43(5), 1023--1048.

Labov, W. (1984). Field Methods of the Project on Linguistic Change and Variation. In J. Baugh & J. Schezer (Eds.), *Language in Use* (pp. 28--53). Prentice-Hall.

Lawrence, W. P. (2000). /str/ → /ʃtr/: ASSIMILATION AT A DISTANCE? *American Speech*, 75(1), 82--87.

Phillips, J. B. (2016). Phonological and prosodic conditioning of /s/-retraction in American English. Oral Presentation given at LabPhon16, Ithaca, NY.

Preston, D. (2016). Palatalization. Oral Presentation given at the New Ways of Analyzing Variation conference (NWAV) 45, November 2016.

Shapiro, M. (1995). A Case of Distant Assimilation: /str/ → /ʃtr/. *American Speech*, 70(1), 101--107.

Smith, B. (2013). *The Interaction of Speech Perception and Production in Laboratory Sound Change*. PhD thesis, Ohio State University.

Stevens, M. & Harrington, J. (2016). The phonetic origins of s-retraction: Acoustic and perceptual evidence from Australian English. *Journal of Phonetics*, 58, 118--134.

Thomas, E. R. (2001). *Sociophonetics: An Introduction*. Palgrave Macmillan.

Yuan, J. & Liberman, M. (2008). Speaker identification on the scotus corpus. Proceedings of Acoustics '08.

Yuan, J. & Liberman, M. (2011). /l/ variation in american english: A corpus approach. *Journal of Speech Sciences*, 1(2), 35--46.

Thank you!

Lyra Magloughlin

lyra@uottawa.ca

Eric Wilbanks

wilbanks_eric@berkeley.edu
http://ericwilbanks.github.io/

#NWAV45slides — @eric_wilbanks

Future Work

- Articulatory data analysis ongoing: relative timing of lip-rounding, tongue body retraction, link to /ɹ/ articulation
- Perceptual work; almost nothing except for Stevens & Harrington (2016)
    - Consider esp. the link between women as leaders in this change and sexual dimorphism/sibilant acoustics.
- Role of medial position in these changes: perception? articulation? prosody?

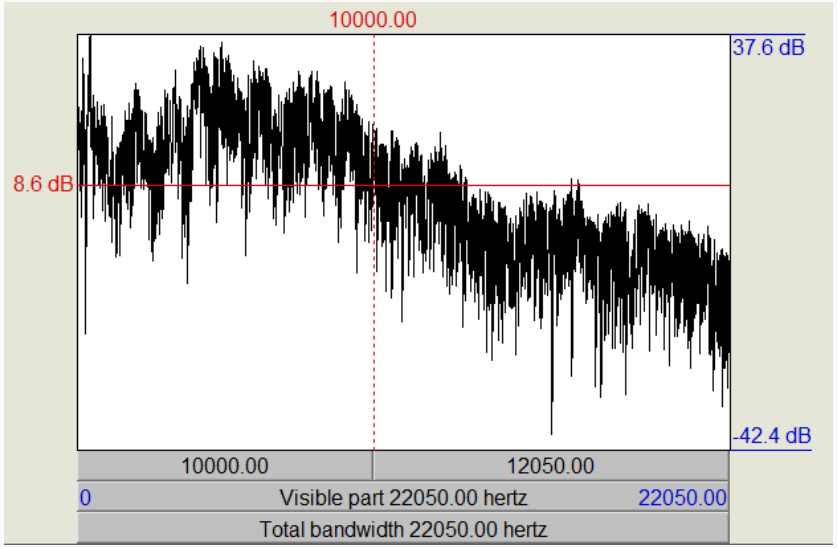
(str) Retraction

Female b. 1961

other part of the street

street

s

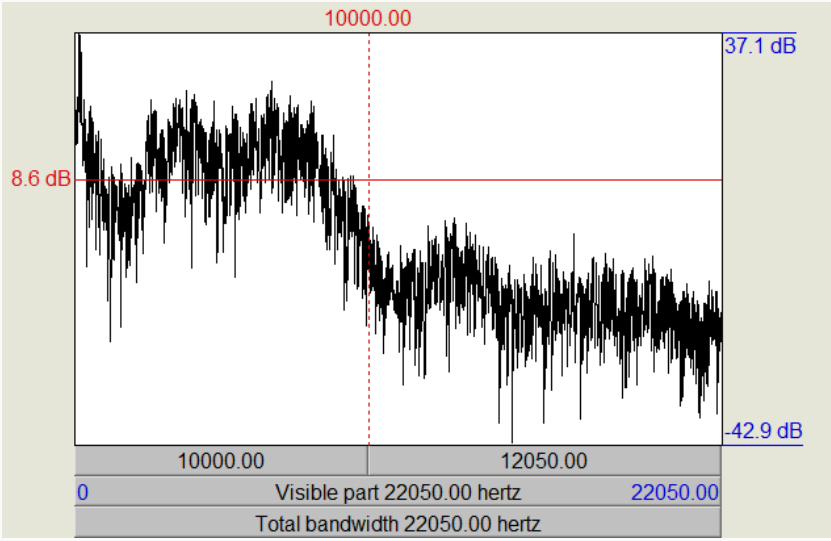


Female b. 1991

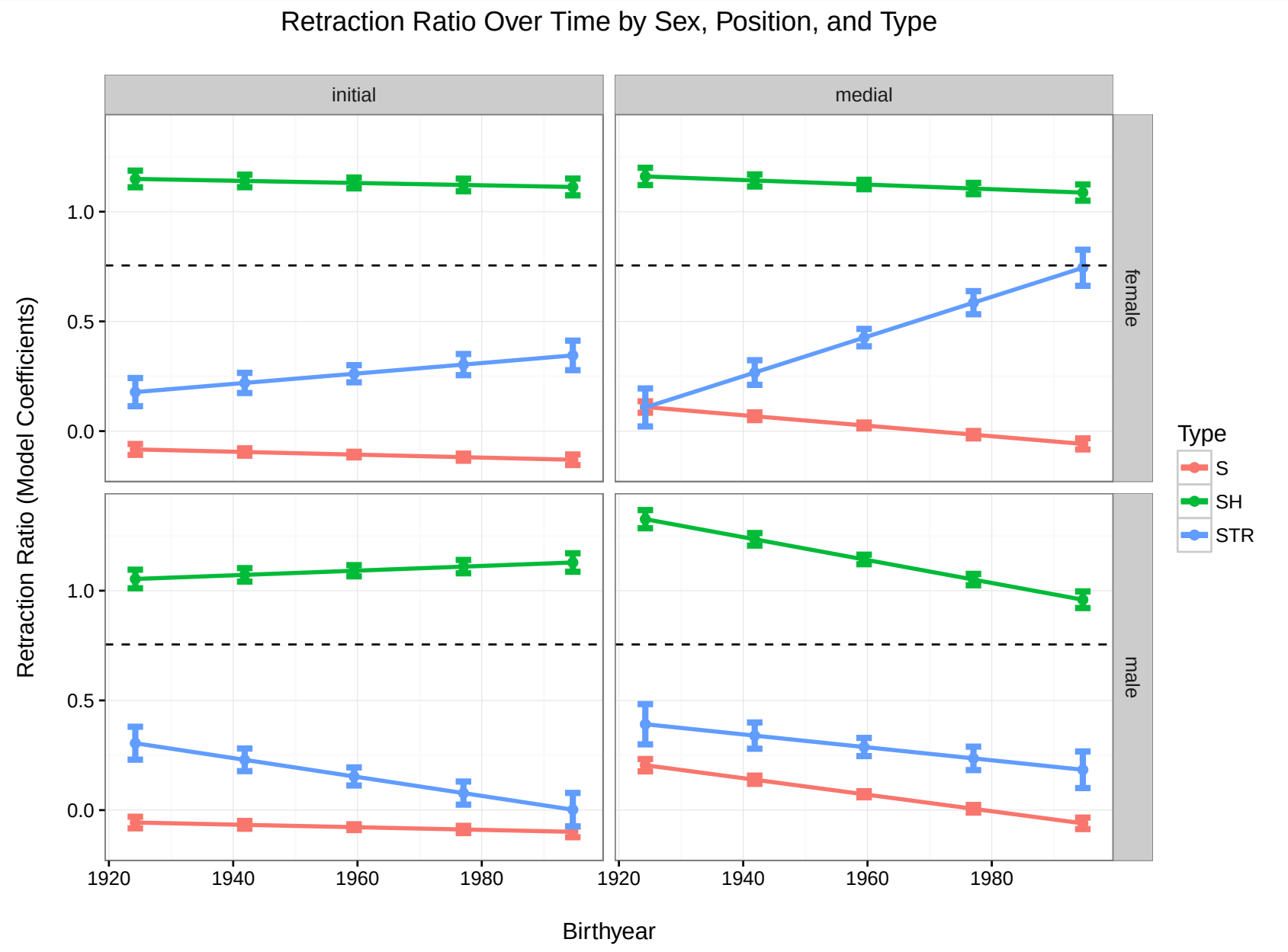
live down the street

street

s



Four-Way Interaction



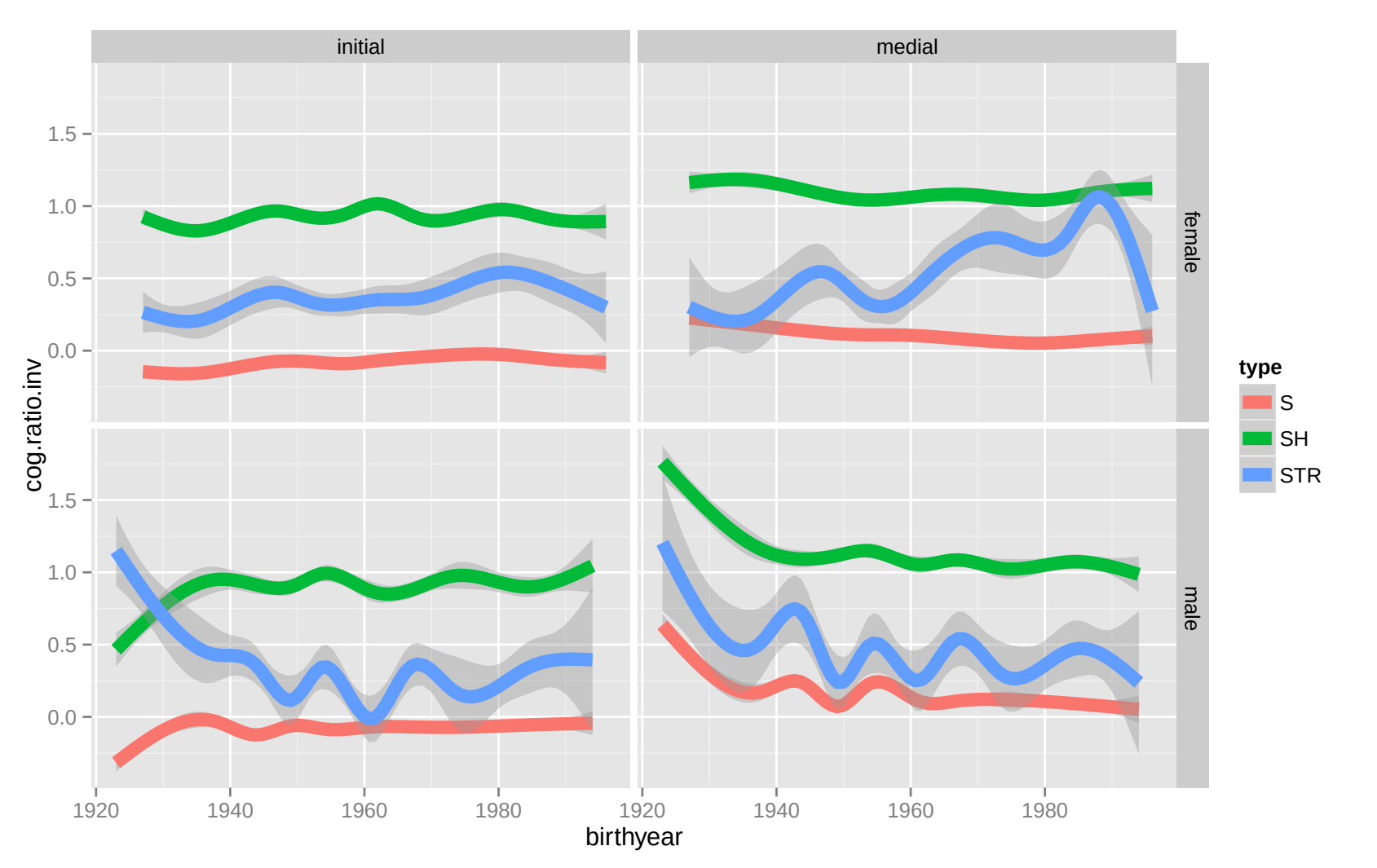
Male b. 1923

``Nothing is like it **used** to be, I mean, the only thing **constant** in life is change. And Raleigh has changed but it has changed in a good, positive **fashion**."

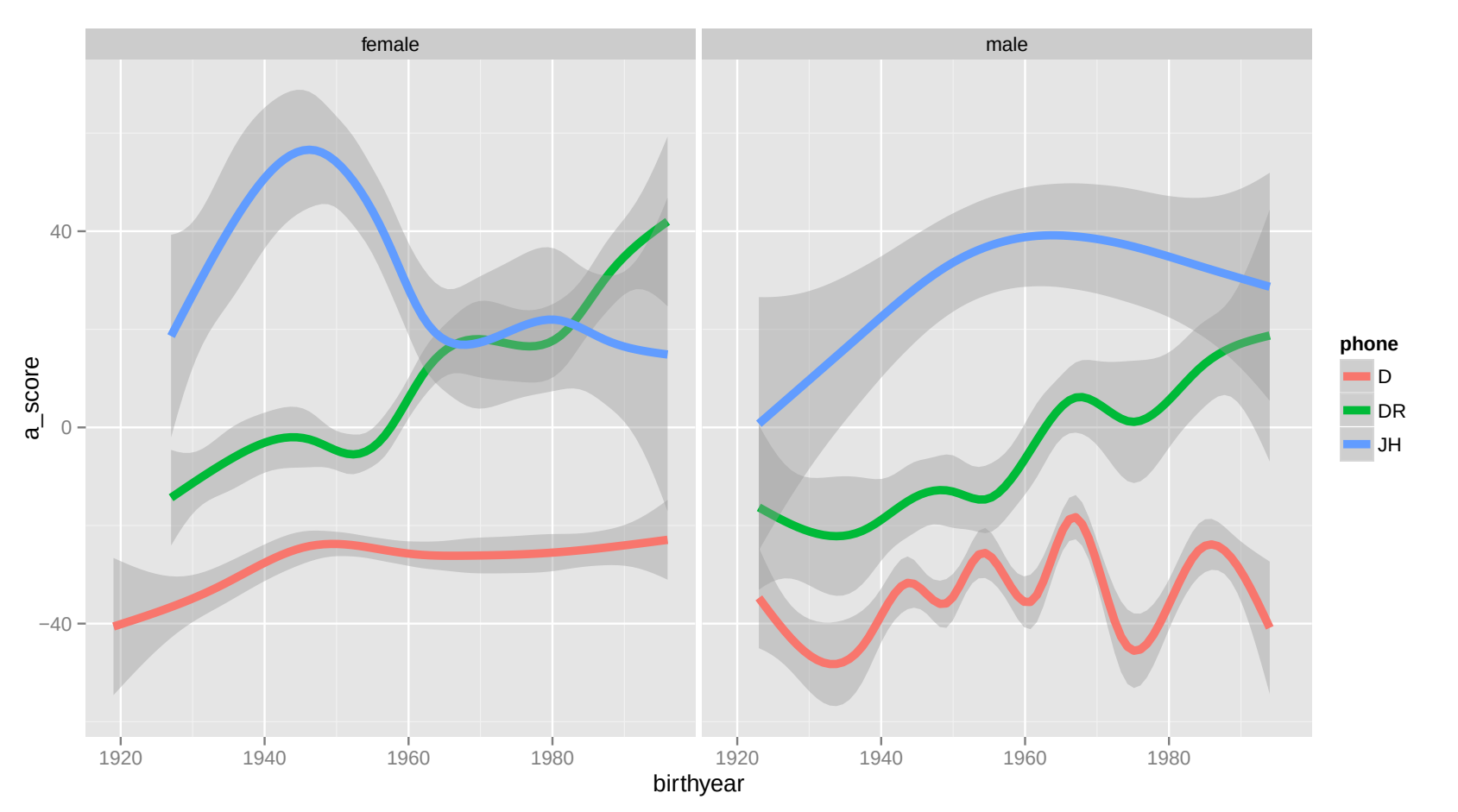
/str/ Extended Methods

1. Excluding tokens in contact with sibilants
2. Excluding tokens word or phrase finally
3. Band-pass filtered: 500-11000Hz
4. Power spectrum on 30ms window centered on midpoint of segment

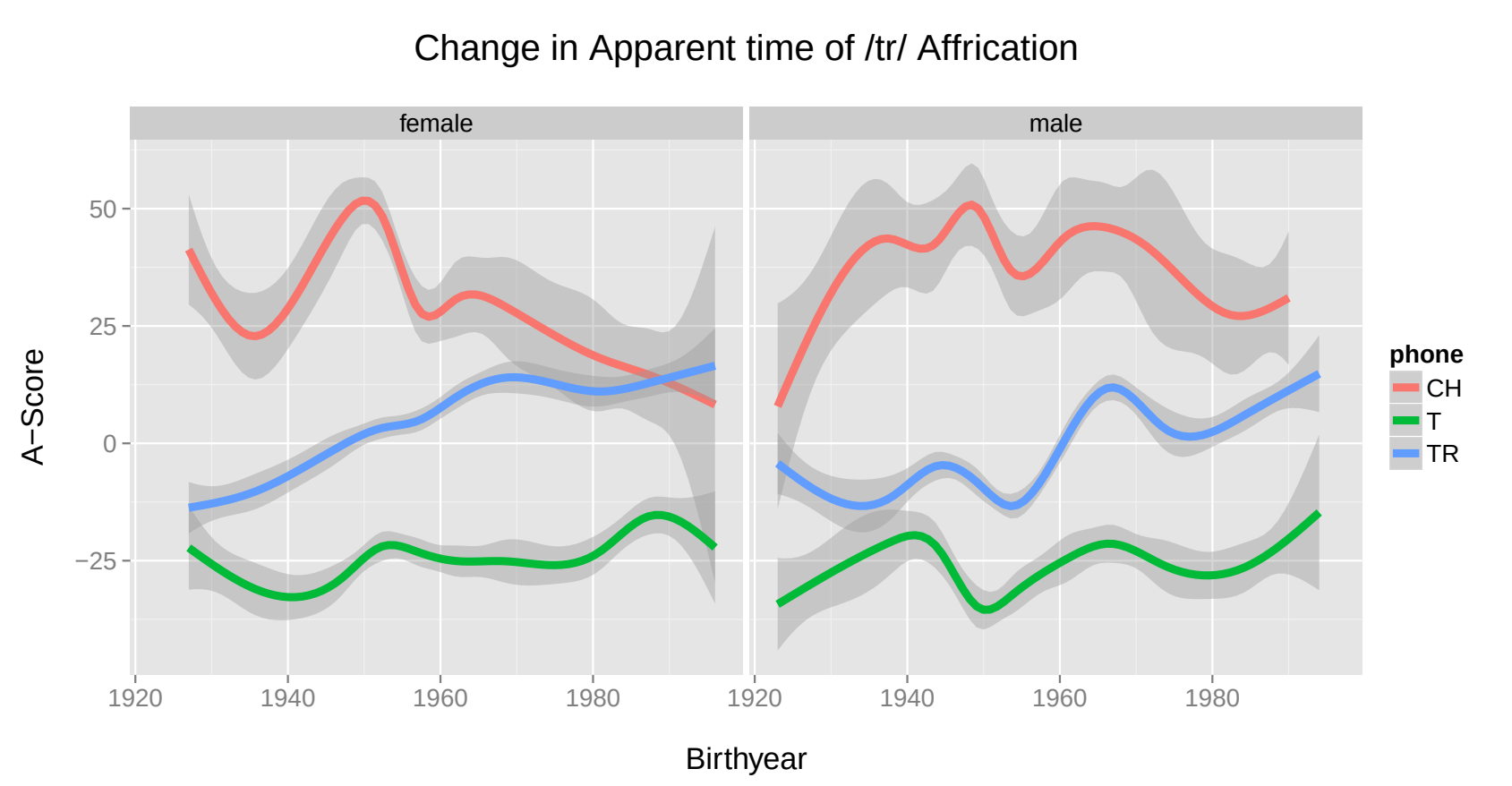
(str) Retraction (Raw data)



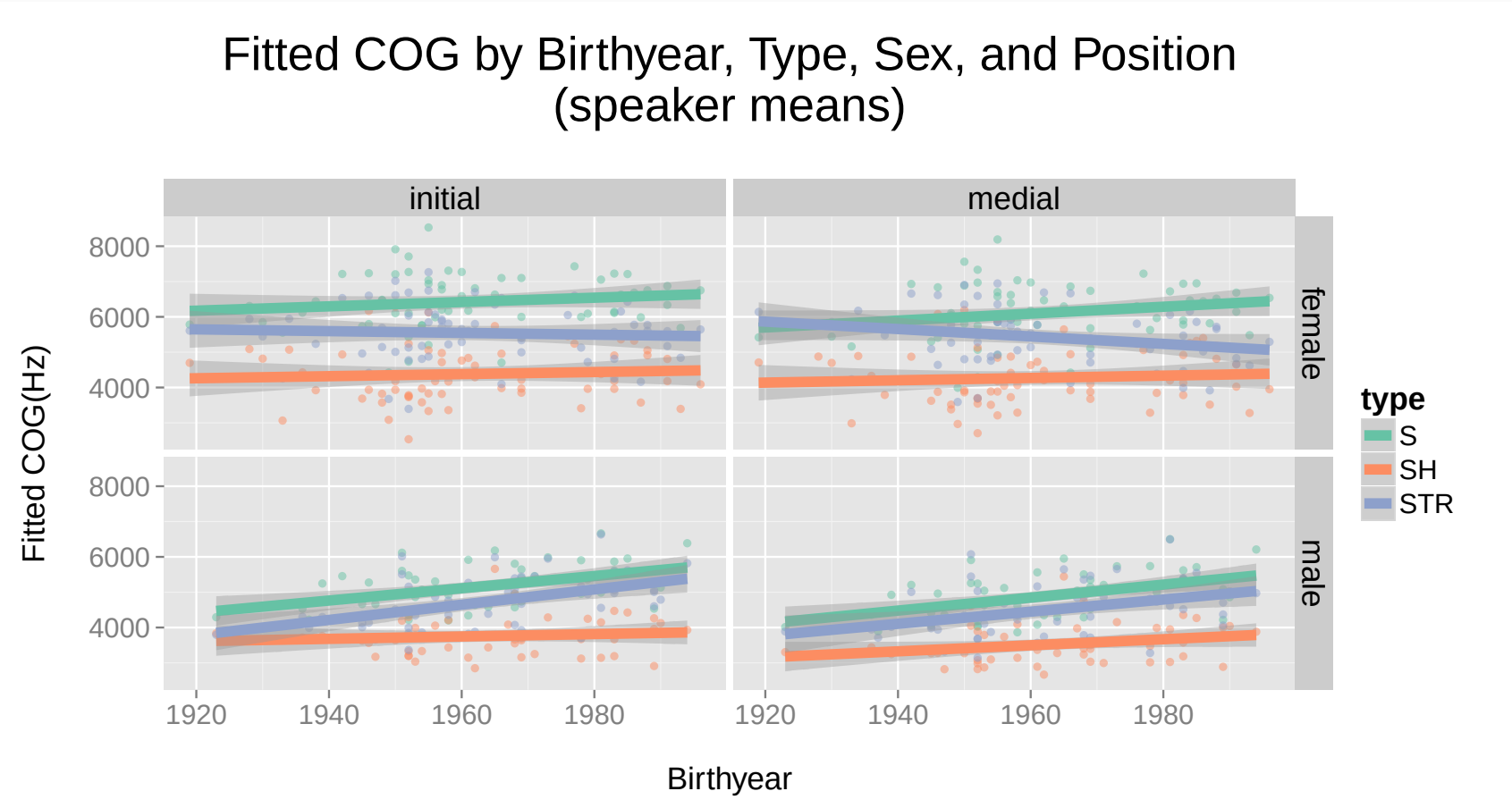
/dr/ Affrication (Raw data)



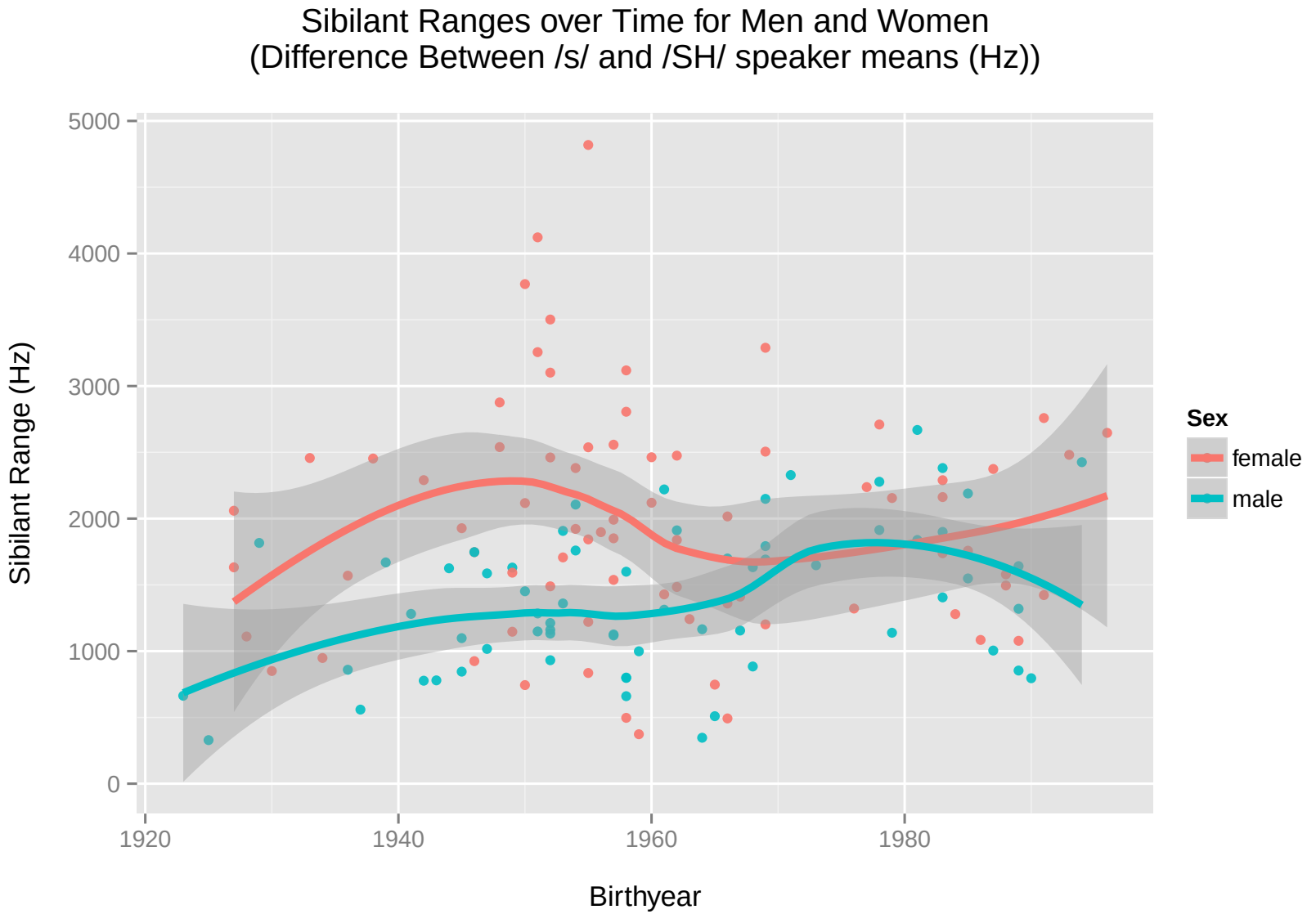
/tr/ Affrication (Raw data)



Center of Gravity Models- (phone|speaker)



Sibilant Space Change (Observed, not Fitted)



AIC model comparisons - All Sibilants

	K	LL	AIC	ΔAIC_{top}	ΔAIC_{each}	Factors Added
M10	160	-110542	221404.6	0	102.0	Sex : Birthyear : Type : Position
M9	149	-110604	221506.6	101.95	54.2	Sex : Birthyear : Type
M8	143	-110637	221560.8	156.16	-1.1	Sex : Birthyear
M7	142	-110638	221559.7	155.08	9.8	Birthyear (scaled)
M6	141	-110644	221569.5	164.89	-0.4	Sex
M5	140	-110644	221569.1	164.52	120.2	Position
M4	139	-110705	221689.3	284.65	909.4	Right Phone
M3	74	-111225	222598.7	1194.04	1529.8	Left Phone
M2	8	-112056	224128.5	2723.83	4948.6	Type (/s/, /ʃ/, or (str))
M1	6	-114533	229077.1	7672.51	NA	Random Effects

Table 2: AIC model comparisons - All Sibilants

AIC model comparisons - only (str)

	K	LL	AIC	ΔAIC_{top}	ΔAIC_{each}	Factors Added
M9e	47	-2335.88	4767.60	-10.68	NA	Sex : Birthyear : Position : Occ.
M9d	33	-2345.90	4758.78	-1.86	NA	Occupation (Occ.)
M9c	39	-2342.60	4764.48	-7.56	NA	Sex : Birthyear : Position : Frequenc
M9b	32	-2346.78	4758.42	-1.50	NA	Frequency
M9a	38	-2343.56	4764.33	-7.41	NA	Sex : Birthyear : Position : Duratio
→ M8 ←	31	-2347.06	4756.92	0	5.26	Sex : Birthyear : Position
M7	28	-2352.76	4762.18	5.26	7.71	Sex : Birthyear
M6	27	-2357.64	4769.89	12.97	12.32	Position
M5	26	-2364.82	4782.21	25.29	-2.04	Birthyear (scaled)
M4	25	-2364.82	4780.17	23.25	-0.48	Sex
M3	24	-2365.60	4779.69	22.77	27.95	Log(Duration)
M2	23	-2380.60	4807.64	50.72	82.37	Previous Phone
M1	6	-2438.99	4890.01	133.10	NA	Random Effects

Table 3: AIC model comparisons

(str) Model Coefficients

	Dependent variable:
	cog.ratio.inv
Log(Duration)	−0.294*** (0.052)
Sex- Male	−0.076 (0.056)
Birthyear (scaled)	0.041 (0.039)
Position- Medial	0.137*** (0.044)
Sex- Male : Birthyear	−0.130** (0.058)
Sex- Male : Position- Medial	0.047 (0.053)
Birthyear : Position- Medial	0.125*** (0.038)
Sex- Male : Birthyear : Position- Medial	−0.139** (0.056)
Constant	−0.337*** (0.120)
Observations	2,499
Log Likelihood	−2,347.057
Akaike Inf. Crit.	4,756.113
Bayesian Inf. Crit.	4,936.646
Note:	*p<0.1; **p<0.05; ***p<0.01

AIC model comparisons - /tɹ/

	K	LL	AIC	ΔAIC_{top}	ΔAIC_{each}	Factors Added
M6	15	-51498.74	103027.5	0.60	-0.06	PHONE:BIRTHYEAR:SEX
→M5←	10	-51503.45	103026.9	0.00	4	SEX
M4	9	-51506.43	103030.9	3.95	7.1	PHONE:BIRTHYEAR
M3	7	-51512.00	103038.0	11.09	6.8	BIRTHYEAR
M2	6	-51516.38	103044.8	17.84	132.7	PHONE
M1	4	-51584.74	103177.5	150.55	NA	Random Effects

Table 4: AIC model comparisons

lmer(a_score ~ phone * birthyear * sex + (1|speaker) + (1|word), REML=F,data=df)

/tɹ/ coefficients

	Dependent variable:
	a_score
phoneT	−449.038 – t = −1.080
phoneTR	−1,061.517 – t = −2.803***
birthyear	−0.154 – t = −0.828
sexmale	−5.869 – t = −2.484**
phoneT:birthyear	0.198 – t = 0.932
phoneTR:birthyear	0.525 – t = 2.719***
Constant	333.661 – t = 0.914
Observations	8,773
Log Likelihood	−51,503.450
Akaike Inf. Crit.	103,026.900
Bayesian Inf. Crit.	103,097.700
Note:	* p<0.1; ** p<0.05; *** p<0.01

AIC model comparisons - /dɹ/

	K	LL	AIC	ΔAIC_{top}	ΔAIC_{each}	Factors Added
→M6←	15	-63277.25	126584.6	0.00	11.5	Phone:Birthyear:Sex
M5	10	-63288.06	126596.1	11.59	8.3	Sex
M4	9	-63293.20	126604.4	19.86	71.9	Phone:Birthyear
M3	7	-63331.14	126676.3	91.75	7.3	Birthyear
M2	6	-63335.78	126683.6	99.02	272.9	Phone
M1	4	-63474.23	126956.5	371.91	NA	Random Effects

Table 5: AIC model comparisons

lmer(a_score ~ phone * birthyear * sex + (1|speaker) + (1|word), REML=F,data=df)

/dɹ/ coefficients

	Dependent variable:
	a_score
phoneDR	−975.579 – t = −4.722***
phoneJH	1,402.403 – t = 5.927***
birthyear	0.134 – t = 1.887*
sexmale	−37.708 – t = −0.190
phoneDR:birthyear	0.520 – t = 4.927***
phoneJH:birthyear	−0.677 – t = −5.604***
phoneDR:sexmale	307.297 – t = 1.024
phoneJH:sexmale	−852.080 – t = −2.380**
birthyear:sexmale	0.018 – t = 0.175
phoneDR:birthyear:sexmale	−0.161 – t = −1.053
phoneJH:birthyear:sexmale	0.436 – t = 2.385**
Constant	−297.541 – t = −2.141**
Observations	11,713
Log Likelihood	−63,277.250
Akaike Inf. Crit.	126,584.500
Bayesian Inf. Crit.	126,695.000
Note:	* p<0.1; ** p<0.05; *** p<0.01