Shtreets of Philadelphia: An Acoustic Study of /str/-retraction in a Naturalistic Speech Corpus

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1 Introduction

Some speakers of English have been reported to palatalize, or retract, /s/ before /tɹ/, leading /s/ in this context to sound similar or identical to a palatal fricative [ʃ] (e.g., pronouncing *street* as [ʃtɹit] or *distract* as [dɪʃtɹækt]). Reports of retracted (str), as I will refer to this variable, have come from studies examining speakers in a range of English-speaking locations. This includes various places in the United States: from Georgia (Phillips 2001), southern Louisiana (Rutter 2011), and Columbus, Ohio (Durian 2007), to Philadelphia (Labov 1984), where it was first mentioned in the sociolinguistic literature. It has also been observed in the U.K. (Glain 2014), in location-specific studies of Estuary English (Bass 2009) and Cockney English (Altendorf 2003), as well as in New Zealand (Lawrence 2000). Most of these studies refer to retracted (str) as an innovative variant, and a few make direct claims about its status as a change in progress toward this pronunciation and away from standard /s/ in this context. Some give good support for this: For example, Glain (2014) uses data from the International Dialects of English Archives corpus to give evidence of change in apparent time in English and Scottish speakers toward more frequent retraction of (str) in unscripted speech. However, no sample of North American speakers with a large age range has been examined with respect to this variable, and most existing studies are based on laboratory speech. The current study aims to fill this gap.

1.1 Possible Causes of (str) Retraction

Several possible mechanisms have been proposed as the source of this phenomenon. Shapiro (1995) analyzes retraction of (str) as a process of long distance assimilation to /ɹ/ across /t/. He describes /ʃ/ as being more similar to /ɹ/ than /s/ in three principal ways. One is tongue position: /ʃ/ and /ɹ/ involve contact between the tongue and the hard palate or just behind the alveolar ridge, while /s/ is alveolar. Another is tongue shape: /ʃ/ and /ɹ/ have a shape that is flatter than the grooved shape used for /s/. The third is lip shape: /ʃ/ and /ɹ/ are canonically round in American English, while /s/ involves at most minimal lip rounding (Rutter 2011). The effect of /ɹ/ on /s/ can be seen more directly in pronunciations of /sɹ/ clusters in foreign borrowings like *Sri Lanka*, which at least some American English speakers pronounce with retracted /s/ (Rutter 2011). In the case of (str), /ɹ/ could be exerting a direct coarticulatory influence on /s/ across /t/, in which case we might expect a similar effect on /s/ in /skɹ/ and /spɹ/. Baker et al. (2011) found this to be the case in their laboratory study with /kɹ/ and /pɹ/ resulting in more /s/-retraction than /k/ and /p/, although /tɹ/ had the strongest retraction effect of the three by a significant margin.

Lawrence (2000) considers a slightly different coarticulatory view. He suggests that /t/ is first affricated (and thus palatalized) before /ɹ/ (producing e.g., [t͡ʃɹɑli] for *trolley*), and that /s/ then assimilates to palatal /t͡ʃ/. This account predicts a direct relationship between (str)-retraction and degree of affrication of /tɹ/, something that is not examined in this study but is a promising avenue for future research.

Finally, some accounts point to /t/ itself as a potential source of retraction: the Baker et al. (2011) study found that although /ɹ/ increased this effect significantly, a following consonant generally (and /t/ especially) depressed the centroid frequency of /s/ (i.e., was associated with more retraction). Janda and Joseph (2001) give impressionistic reports of retraction before simple stops in words like *school* and *still*. In New High German, a historical change eliminated the contrast between /s/ and /ʃ/ in all consonant clusters, beginning with /sl/ turning into [ʃl]. Retraction of /s/ then spread to contexts before following nasals, glides, and finally all stops (Moser et al. 1981). This demonstrates

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that a single following alveolar consonant has the potential to obscure the contrast between /s/ and /ʃ/ (although it was /l/ in that case, rather than /t/). Appeals to the influence of /r/ may thus not be necessary in principle to explain the origin of (str)-retraction in English.

In English (as in modern German), /s/ and /ʃ/ are not contrastive in syllable-initial consonant clusters. As Baker et al. (2011) point out, this might have allowed for greater variation in production and thus a greater probability of reanalysis of coarticulation as being "beyond the phonetic motivation," resulting in the actuation of change. Baker et al. found variability among "non-retracting" speakers as to the degree of retraction that /s/ showed in the /stɹ/ context, and attribute some of this variability to individual differences in /ɹ/ tongue shape. Indeed, the (str) variable seems to be associated with a spectrum of retraction, with multiple forms potentially able to carry social meaning. Labov (2001) documents the occurrence of one or more intermediate forms in Philadelphia. He describes the existence of "a hissing [s], used only by cultivated speakers, to a normal sibilant with considerable hushing quality, to a fully hushing sibilant equivalent to the /ʃ/ in *sheet*, and an even more extreme form with distinct rounding of the fricative" Labov (2001). Binary treatment of (str) variants has the potential to mischaracterize variation of (str) and lose out on potential detail across the course of the change.

Turning to perception, there is some evidence that the lack of contrast of /s/ and /ʃ/ in initial consonant clusters has a direct effect on perceptual discrimination. In a similarity rating task, listeners in Scudieri (2012) found sibilants of different frequencies to be more perceptually similar when they were followed by /tr/ than when they were followed by a vowel. Kraljic et al. (2008) found that perceptual accommodation to a talker's retracted ([ʃ]-like) /s/ did not extend to the (str) context. Subjects adjusted the perceptual boundary between /s/ and /ʃ/ when a talker showed /s/-retraction in many phonological contexts, but did not do so when they only heard retracted /s/ preceding /tɹ/. That is, listeners attributed retracted /s/ to a talker idiosyncrasy and adjusted for it in perception *except* when it was limited to the (str) context.[1] What these findings suggest is that listeners, because of their knowledge of the phonotactics of their language, have a high amount of tolerance for variation in place of articulation of /s/ in this phonological context. This tolerance may be the mechanism that creates the kind of variation hypothesized by Baker et al. (2011) to have led to the actuation of this sound change.

2 Current Study

This study examines 225 speakers from one speech community, the city of Philadelphia. As mentioned above, retracted (str) has been reported in Philadelphia speech: Labov (1984) briefly mentions this variable as a change in progress in Philadelphia, and Labov (2001) discusses a subjective evaluation test whose results showed that retracted (str) was more associated with working-class speech for Philadelphian subjects. This is the extent of published material about (str) in Philadelphia to date, and no large-scale examination of this variable has been done with Philadelphia speakers. To remedy this, I turned to the Philadelphia Neighborhood Corpus (PNC). The PNC is a collection of sociolinguistic interviews conducted in neighborhoods of Philadelphia and the surrounding suburbs between 1972 and 2012, for many of those years as part of a course at the University of Pennsylvania. Using automated methods with a naturalistic corpus allows for the examination of this variable through multiple tokens for each speaker, while avoiding some of the stylistic problems of laboratory speech. The large number of speakers and the considerable time depth of the corpus permits generalizations to be made about the dynamics of this variable over time in the community.

2.1 Speakers

I extracted interview data from the PNC for 136 speakers born from 1888 to 1992. However, only 5 of these speakers were born after 1985, so in order to be able to see the recent development of this variable, I also included data from 89 speakers from a new project, the ongoing Influence of

[1] It can't be ruled out, however, that the subjects assumed that retracted (str) was a dialect feature, rather than an individual feature because they have been exposed to it in speech.

PNC		IHELP	
F	M	F	M
60	76	50	39

Table 1: Speaker breakdown by gender.

Higher Education on Local Phonology (IHELP). This project has conducted 169 interviews with Philadelphia-native college students in the city, and in some cases their families. With the added data of 89 of these interviews, the total apparent time range covered in this study expands to include 225 speakers born from 1888–2004.

2.2 Methods

Automated acoustic measurement was used to quickly and objectively evaluate the degree of retraction for each token in the corpus. Automated measurement has been used prolifically with vowels with some impressive results (see e.g., Labov et al. 2013, Fruehwald 2013), but this kind of technique has not yet been applied to many cases of consonant variation. Sibilant place of articulation is a good test case for this kind of implementation, as it has an acoustic realization that can be captured with a continuous measurement. Specifically, the frequency location of greatest intensity in a sibilant has been found to correlate well with backness in anterior fricatives. The position of the tongue closer to the front of the mouth results in a smaller cavity in front of the constriction, and therefore spectral energy at higher frequencies (Evers et al. 1998). Rutter (2011) notes that "in order to consistently distinguish /s/ from /ʃ/, it is generally acknowledged that spectral analysis is the most reliable approach." I therefore take such an approach in order to evaluate retraction of (str). One complication is lip position: Rutter (2011) notes that lip rounding serves to further lower the spectral energy. This means that a production of (str) could possibly be made with considerable retraction but no lip rounding, and acoustic information would in this case underestimate the degree of retraction. In a corpus with no visual data, this is impossible to account for, but should be kept in mind as a cautionary note.

The transcribed interview data was force-aligned using the Forced Alignment and Vowel Extraction suite (Rosenfelder et al. 2011). I extracted all sibilants from the data. All speakers with less than 5 (str) tokens were excluded, and any sibilants shorter than 40 ms were excluded. A total of 24,157 sibilant tokens were measured, 3,049 of which were tokens of (str). All sibilants were first high-pass filtered with a cutoff at 750 Hz, to avoid interference from any voicing present in that range, following Evers et al. (1998). A 20 ms Hamming windows was placed in the middle 50% of each sibilant. This was done to correct for any parts of neighboring segments that may have been included in the forced alignment. Following Baker et al. (2011), a spectrum was then generated from this window, and a center of gravity measurement was taken from each frame of the spectrum. The mean of those measurements was then recorded.

Rutter (2011) discusses the importance of not directly comparing sibilant frequencies between speakers, as the important information is not the absolute location of the spectral energy of (str), but rather its location relative to a speaker's other sibilant productions. To avoid this, I based my analysis on a standardized measurement: each speaker's mean center of gravity measurement was z-score normalized with reference to all of that speaker's measured non word-final sibilants (see Table 2). As (str) can only occur syllable-initially, word-final /s/ was excluded in order to be able to fairly compare (str) to other instances of /s/. The result is a number that gives a good approximation of where most of the spectral energy was located, on average, in (str) tokens as compared to /s/ in other contexts and /ʃ/. The value of this standardized number is not meaningful in itself except as a comparison.

Z-score Formula

$$\frac{\text{COG of segment - mean COG for speaker across types}}{\text{standard deviation for speaker across types}}$$

Table 2: The formula used to standardize each speaker's sibilant productions. COG = center of gravity.

3 Results

Centroid frequency was successful in distinguishing /s/ and /ʃ/, with the mean measurement of /s/ being higher in every case. Figure 1 also confirms the observation that has been made that (str) is more retracted (has a lower center of gravity) than /s/ in other contexts in Philadelphia. This was confirmed by the results of a linear mixed effects regression model, shown in Table 3, which found following /tr/ to be a highly significant predictor of lowered frequency ($\beta = -24.81$, $p < .001$), with a coefficient more than three times larger than that of any other predictor. To evaluate the degree to which a following stop or stop cluster in general affected /s/, these contexts were included as predictors along with /str/. A following stop, no matter what kind, had a significant effect on /s/ frequency. A following /k/ was associated with a modestly fronter /s/ ($\beta = 5.09$, $p < .05$), and following /p/ was associated with more retracted /s/ ($\beta = -7.80$, $p < .05$). However, a following /ɹ/ did not lead to significantly more or less retraction in the case of /k/ or /p/, but it did in the case of (str), as stated above. Following plain /t/ was associated with a slightly more retracted /s/ ($\beta = -3.86$, $p < .01$), but (str), as stated above, was a larger predictor of retraction.

Moving to the dynamics of (str) in Philadelphia, the results show a clear trend (see Figure 1) of lowering of the normalized spectral energy measurement of (str) over time, which we can analyze as an increase in the relative retraction of (str). This trend is confirmed by the results of a mixed effects regression fitted to the (str) tokens (see Table 4), which found date of birth (DOB) to be a

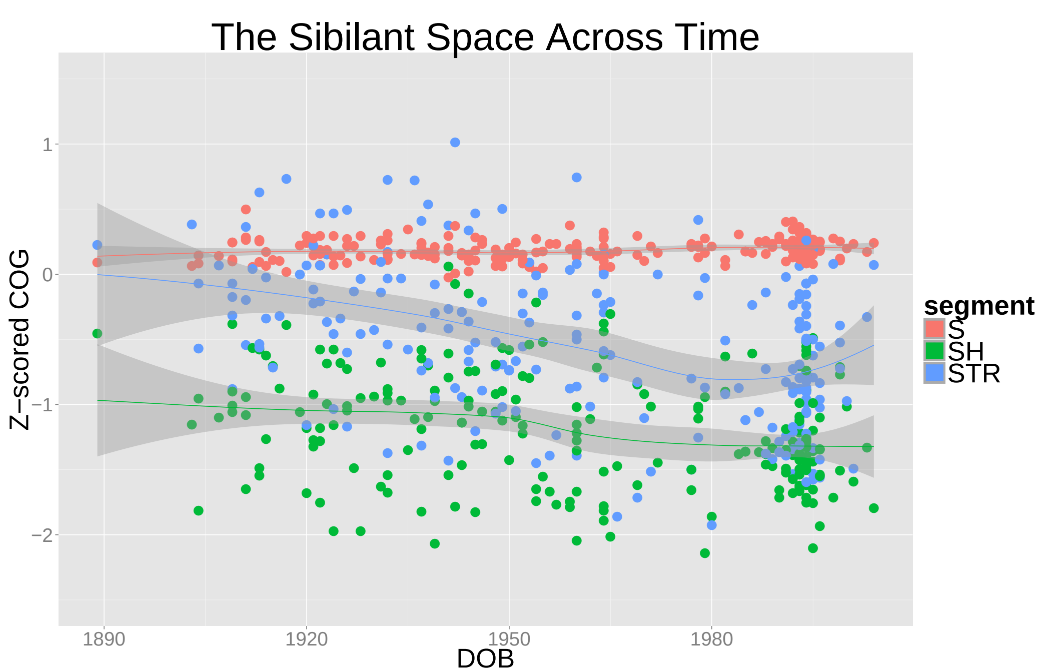

Figure 1: Average normalized COG for all sibilant types for each speaker.

Center of gravity of /s/ in (str) in Z-score normalized Hz					
Fixed effects				Model statistics	
(Intercept)	-0.26	$t = -0.306$	(0.84)	AIC	63305.29
/sk/	5.09^{*}	$t = 2.376$	(2.14)	BIC	63442.86
/sp/	-7.80^{*}	$t = -2.519$	(3.09)	Log Likelihood	-31635.64
/st/	-3.86^{**}	$t = -2.77$	(1.40)	Num. obs.	24157
/str/	-24.811^{***}	$t = 12.18$	(2.04)	Variance: Subject	0.01
Sex = M	-0.07^{***}	$t = -3.60$	(0.02)	Variance: Residual	0.80
DOB: /str/	-0.01^{***}	$t = 12.575$	(0.00)		

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table 3: Mixed effects linear regression model fit to all /s/ values. Only significant coefficients are reported. P-values were generated with a Kenward-Rogers approximation and are reported only with signficance markers.

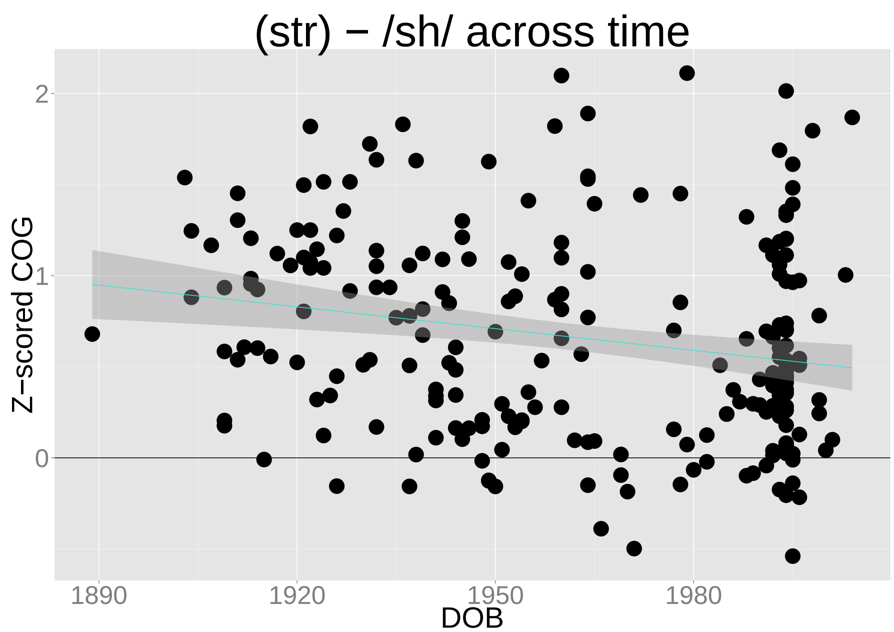

Figure 2: The difference between average normalized COG of (str) and /ʃ/ for each speaker.

highly significant predictor of retraction ($\beta = -0.23$, p < .001). Strikingly, by the end of the time span, the normalized frequencies of (str) for many speakers are well within the distribution of /ʃ/. To examine this more closely, Figure 2 shows the difference between each speakers (str) and /ʃ/ mean standardized frequency measurement. This shows more clearly how the difference between (str) and /ʃ/ has diminished over time, with many more young speakers showing (str) that is equally or even more retracted than /ʃ/. Highly retracted (str) seems to have existed in Philadelphia since the early 20th century, but today it is markedly more common. However, we see a large degree of variability in the entire time scope, and particularly in the younger speakers. In Figure 1, we can see some younger speakers whose (str) productions are very similar to their /s/ productions alongside peers that have a very retracted (str).

Model selection was used to select predictors for the model of centroid frequency of (str) tokens in Table 4. A step-up step-down procedure was used, using BIC as the criterion. A set of internal factors were considered as predictors in the model. Following vowel, position (initial *vs.* medial),

Center of gravity of /s/ in (str) in Z-score normalized Hz					
Fixed effects				Model statistics	
(Intercept)	0.48^{***}	$t = -8.488$	(0.06)	AIC	6608.02
DOB	-0.23^{***}	$t = -6.207$	(0.04)	BIC	6662.22
Medial	-0.03	$t = -0.904$	(0.04)	Log Likelihood	-3295.01
Sex = M	0.03	$t = 0.486$	(0.07)	Num. obs.	3049
Following High Front	-0.05	$t = 1.229$	(0.04)	Variance: Subject	0.24
street = Yes	-0.05	$t = -1.089$	(0.05)	Variance: Residual	0.44
DOB: medial	-0.07^{*}	$t = -2.192$	(0.03)		

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table 4: Mixed effects linear regression model fit to the initial (str) values. All coefficients for predictors in the best model are reported. *P*-values were generated with a Kenward-Rogers approximation and are reported only with signficance markers.

and the specific word *street* (often cited as the stereotypical example of this variant) were included in the best model but not found to be significant. There was a significant interaction of date of birth and medial position, suggesting that younger speakers retract more in medial contexts. A more sophisticated breakdown of following vowel quality did not contribute to the model. Finally, word frequency did not contribute to the model.

In addition to date of birth, gender was included in the model as an external factor.[2] A look at Figure 3 does not show a clear gender difference at any point, as the lack of significance for gender in the model shown in Table 4 confirms. A close examination of the plot suggests a brief lead in retraction by women born in the 50s and 60s, but the difference is not robust enough to make any large claims. The younger speakers look particularly evenly distributed by gender on the retraction spectrum.

Finally, the IHELP speakers were examined to see if (str)-retraction was associated with another phonological innovation that many of them have been found to show; that is, an allophonic split between /æ/ before nasals and non-nasals, a newly emerging system that represents a total reorganization of the traditional Philadelphia short-a system (Labov et al. 2013). A measurement (Pillai's statistic) of the bimodality of their vowels in nasal and non-nasal contexts was included in a separate mixed effect regression and was a significant predictor of retraction ($\beta = .90$, $p < .05$). This means that speakers that have adopted the new nasal short-a system are less likely to show /s/-retraction. In the IHELP data, these tended to be speakers that attended selective middle and/or high schools and went on to attend elite colleges (Fisher et al. 2015). We can hypothesize from this association that both abandonment of the traditional short-a system in favor of the nasal system and lack of (str)-retraction are a result of these students' general orientation away from local Philadelphia norms.

4 Discussion

4.1 Phonological Change?

A few of the older speakers in this corpus and many of the younger speakers have an average (str) production that is closer to their average production of /ʃ/ than their average production of /s/. This points to a likely reanalysis by some speakers of /s/ in (str) as /ʃ/, meaning that their target for the sibilant in words like *street* is actually /ʃ/. A small shift has therefore occurred in their phonological system, with [ʃ] becoming an allophone of /s/ in this context. The time course data presented here do not straightforwardly match an account where gradual phonetic shift leads to sudden widespread

[2]Income and education are not included here due to the incompleteness of that data.

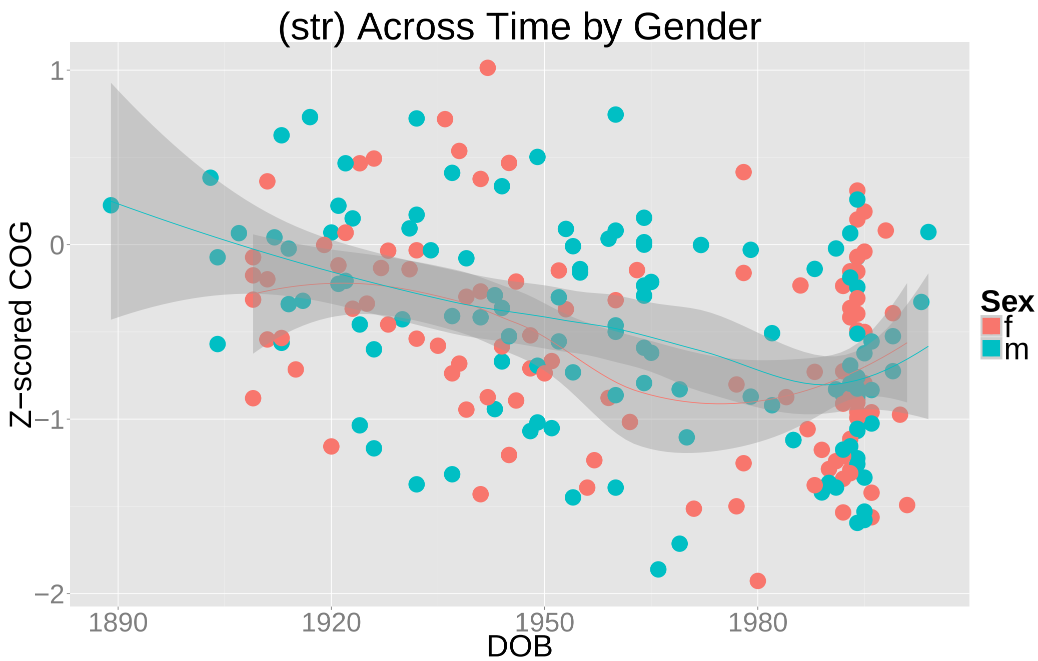

Figure 3: (str) across time by sex.

reanalysis. It does not seem that Philadelphian speakers have moved together slowly toward a more retracted (str). Instead, (str) has been somewhat retracted for many speakers from the beginning of the data, and this variability triggered some of the speakers to reanalyze /s/ in this context. As young speakers receive input from more and more reanalyzed speakers whose average productions are more retracted, more of them end up with allophonic retracted (str).

4.2 Factors Influencing (str)

The results for the internal factors are somewhat unexpected. Although intuitively we might expect following vowel height or backness to have an effect on (str) retraction, there is no significant effect of following phonological context. With two intervening segments, a following vowel may be too distant to have much of an influence. The lack of a frequency effect goes against usage-based theories of sound change beginning in the most frequent words (e.g., Bybee 2003), although this data cannot rule out a frequency effect earlier in time, closer to the very beginning of this change.

The apparent time trend is strong confirmation of the status of the variable (str) as a change that at least was in progress during the 20th century. Again, to our knowledge, no study has demonstrated change in apparent time of this variable in the United States. Most surprising, perhaps, is the lack of a clear gender difference. We expect to see women in the lead, especially at the beginning of this change, but such a pattern does not clearly emerge. It may be that this data does not go back far enough to capture the early female adopters of this change. Other studies have found higher male use of retracted (str) (Bass 2009, Glain 2014), most likely the result of the variable gaining negative social evaluation or covert prestige (Trudgill 1972).

It is not clear whether this variable has reached the level of consciousness in the Philadelphia speech community. Beyond anecdotal accounts of a few Philadelphians expressing their disapproval of the retracted pronunciation (one claiming to be an elementary school speech therapist), we have little evidence of it. For many of the speakers born in the 1990s, (str) is well within the range of /s/, suggesting that some speakers with retracting parents may have moved away from this variable due to growing salience. That is, although evidence in their input should lead them to have /ʃ/ in this context, negative social evaluation has lead them to shift their productions back to something more /s/-like.

4.3 Implication for Theories of Actuation of (str)-retraction

The results of the analysis of contexts before stops generally are not quite in line with the findings in Baker et al. (2011). The data here does not show /ɹ/ in /skɹ/ and /spɹ/ influencing the degree of retraction, whereas it does have an effect after /t/. This is problematic for an account that attributes retraction of (str) as long-distance assimilation, since there is no reason to predict that /ɹ/ would not have, if not to the same degree, at least the same kind of effect across /k/ and /p/ as across /t/. The data also shows no support for /t/ alone being associated with retraction of a preceding /s/. This leaves Lawrence's (2000) affrication analysis, an account which would predict a strong association between retraction of (str) and affrication of /t/ in /tɹ/. As stated earlier, this possibility is not addressed by the current study. The results here do suggest that /t/ is essential for this process in Philadelphia English.

4.4 Further Directions

The automation of an acoustic method to measure the centroid frequency of stop bursts would allow the approach used here to be applied to affrication of /t/. This has a lot of potential as a way to evaluate the affrication hypothesis using the degree of correlation of palatalization of (str) and /tr/.

Some changes might be made to the methodology used here to quantify retraction. Rutter (2011) recommends a spectral peak measurement, rather than a centroid measurement, to evaluate fricative place of articulation. A reanalysis of the data with this technique may lead to clearer results. In addition, as this study is entirely acoustic, coding at least a sample of the data impressionistically for retraction would be instructive in confirming the accuracy of the acoustic methodology and/or exposing any systematic differences between the two.

The effects of social class are not examined here, but an effort to fill in some of the gaps in income data in the PNC would allow for a better description of the social status of (str) by determining its degree of social stratification. The IHELP nasality results may indicate that general adoption of linguistic norms associated with prestigious schools and colleges in Philadelphia includes a move away from retraction of (str).

Finally, a closer look at individual variability between different tokens of (str) in this data, and in particular in different speech styles, has great potential to shed some light on the social and stylistic association of the retraction of /s/ in this context.

5 Conclusion

This study provides evidence of a change over time in the pronunciation of (str) in Philadelphia. This was possible with the innovative application of automatic acoustic analysis to a consonant variable in a large corpus of speech, and has the advantage of representing (str) as it occurs in naturalistic speech in a community. Many questions remain about the cause of this widespread change in English. The results here raise some doubts about a long-distance assimilation account. With regards to social evaluation, a possible link to another linguistic innovation, the move toward a nasal short-a system, helps begin to locate this variable in the sociolinguistic system of Philadelphia. A gender difference was not found, indicating that the initial change most likely began before the time scope of the data, and that social evaluation of the variable is not yet strong enough for women to move away from it. Finally, it shows evidence for phonological reanalysis in the case of (str) by comparing speakers' productions of (str) to variability in the rest of their natural sibilant space.

References

Altendorf, Ulrike. 2003. *Estuary English: Levelling at the Interface of RP and South-eastern British English*. Gunter Narr Verlag.

Baker, Adam, Diana Archangeli, and Jeff Mielke. 2011. Variability in American English s-retraction suggests a solution to the actuation problem. *Language Variation and Change* 23:347–374.

Bass, Michael. 2009. Street or shtreet? Investigating (str-) palatalisation in Colchester english. *Estro: Essex Student Research Online* 1:10–21.

Bybee, Joan. 2003. Mechanisms of change in grammaticization: The role of frequency. In *The Handbook of Historical Linguistics*, ed. R. Janda and B. Joseph, 602–647. Blackwell.

Durian, David. 2007. Getting ʃtronger every day?: More on urbanization and the socio-geographic diffusion of (str) in Columbus, OH. In *U. Penn. Working Papers in Linguistics 13:2: Selected Papers from NWAV 35*, ed. S. Brody, M. Friesner, L. Mackenzie, and J. Tauberer, 65–79.

Evers, Vincent, Henning Reetz, and Aditi Lahiri. 1998. Crosslinguistic acoustic categorization of sibilants independent of phonological status. *Journal of Phonetics* 26:345–370.

Fisher, Sabriya, Hilary Prichard, and Betsy Sneller. 2015. The apple doesn't fall far from the tree: incremental change in Philadelphia families. In *U. Penn. Working Papers in Linguistics 21:2: Selected Papers from NWAV 44*, ed. S. Fisher, 49–58.

Fruehwald, Josef. 2013. The Phonological Influence on Phonetic Change. Doctoral dissertation, University of Pennsylvania.

Glain, Olivier. 2014. Introducing contemporary palatalisation. In *Proceedings of the First Postgraduate and Academic Researchers in Linguistics at York conference*, ed. Theodora Lee.

Influence of Higher Education on Local Phonology. 2012–2015. With support of NSF contract number to W. Labov.

Janda, Richard D., and Brian D. Joseph. 2001. Reconsidering the canons of sound-change: Towards a "big bang" theory. In *Historical Linguistics 2001: Selected Papers from the 15th International Conference on Historical Linguistics*, ed. B. J. Blake, K. Burridge, and J. Taylor.

Kraljic, Tanya, Susan E. Brennan, and Arthur G. Samuel. 2008. Accommodating variation: Dialects, idiolects, and speech processing. *Cognition* 107:54–81.

Labov, William. 1984. Field Methods of the Project on Linguistic Change and Variation. In *Language in Use*, ed. J. Baugh and J. Schezer, 28–53. Englewood Cliffs, NJ: Prentice Hall.

Labov, William. 2001. *Principles of Linguistic Change: Social Factors*. Wiley.

Labov, William, and Ingrid Rosenfelder. 2011. The Philadelphia Neighborhood Corpus.

Labov, William, Ingrid Rosenfelder, and Josef Fruehwald. 2013. One hundred years of sound change in Philadelphia: Linear incrementation, reversal, and reanalysis. *Language* 89:30–65.

Lawrence, Wayne P. 2000. /str/ → /ʃtr/: Assimilation at a distance? *American Speech* 75:82–87.

Moser, Hans, Hans Wellmann, and Norbert Richard Wolf. 1981. *Geschichte der deutschen Sprache*. Utb Fuer Wissenschaft.

Phillips, Betty S. 2001. Lexical diffusion, lexical frequency, and lexical analysis. In *Frequency and the Emergence of Linguistic Structure*, ed. J. L. Bybee and P. Hopper, 123–136. John Benjamins Publishing.

Rosenfelder, Ingrid, Josef Fruehwald, Keelan Evanini, and Jiahong Yuan. 2011. FAVE (Forced Alignment and Vowel Extraction) Program Suite. http://fave.ling.upenn.edu/.

Rutter, Ben. 2011. Acoustic analysis of a sound change in progress: The consonant cluster /st/ in English. *Journal of the International Phonetic Association* 41:27–40.

Scudieri, Kristen. 2012. On the perception of /s/ and /ʃ/: Considering the Effects of Phonotactics. Bachelor's Thesis, The Ohio State University.

Shapiro, Michael. 1995. A case of distant assimilation: /str/ –> /tr/. *American Speech* 70:101–107.

Trudgill, Peter. 1972. Sex, covert prestige and linguistic change in the urban British English of Norwich. *Language in society* 1:179–195.

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