

/t d/ Releases are strengthening among White speakers: Evidence from a large-scale acoustic study of English in Raleigh

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Abstract

The release and aspiration of word-final /t/ and /d/ are important sociolinguistic variables in American English because they have strong, contextually driven indexicality. Word-final /t d/ releases are usually coded impressionistically due to the absence of automated methods for identifying prepausal release bursts or aspiration. This paper introduces an automated method for identifying released tokens prepausally and for measuring phonetic properties of releases. We use the method to code prepausal /t d/ release versus non-release in a corpus of conversational English in Raleigh. We assess the data in relation to internal and social factors in order to validate the automated method, finding that the patterns in the automatically generated distributions match those in previous studies. We next show that among Raleigh White speakers but not Black speakers, /t d/ releases are becoming more frequent and stronger after obstruents across apparent time, a change that reflects Raleigh's changing cultural landscape.

Keywords: Southern American English; apparent-time change; affrication; coronal stop release; release magnitude; language variation

Introduction: previous variationist analyses of word-final /t/ and /d/ release *Released /t/ and /d/: linguistic and social factors*

Word-final American English /t/ and /d/ have several gesturally and auditorily distinct variants (Davidson, 2011; Farrington, 2018; Podesva, Reynolds, Callier, & Baptiste, 2015; Sumner & Samuel, 2005): a released or unreleased alveolar stop, a released alveolar stop with aspiration following the release, an alveolar stop with glottalization on the preceding segment, a glottal stop, and a lenited (e.g., spirantized) alveolar stop. Word-final /t/ and /d/ are often deleted when the word is a monomorpheme, as in *mist*, in contrast with words such as *missed* in which the /t/ or /d/ encodes a past tense morpheme (Baranowski & Turton, 2020; Guy, 1980; Holliday, 2017; MacKenzie & Tamminga, 2021; Smith, Durham, & Fortune, 2009; Wolfram, 1969:49–50). Word-final

/t/ and /d/ are more often released, or have a longer release, in phrase-final position in spontaneous speech, probably because phrase-final position is perceptually salient (Davidson, 2011:1045; Podesva et al., 2015:66). In American politicians' speech, word-final /t/ release is favored by preceding obstruents, following pauses or vowels, past tense verbs versus monomorphemes and semiweak verbs, and low-frequency words (D'Onofrio & Stecker, 2022:15; Podesva et al., 2015:66).

Previous sociolinguistic analyses of released and unreleased word-final /t/ and /d/ in American English reveal complex and strong indexicality. Depending on the social context, released /t/ can index professional competence, articulateness, learnedness, formality, "traditional" femininity, Whiteness, and other qualities (Eckert, 2008:467-470). The ideological link between released /t/ and clear, learned, articulate, "standard" speech is broadly shared across social contexts in which American English is spoken. In fact, sociolinguistic studies of national political speech use this link as a starting point in their investigations of inter- and intra-speaker variation in production and perception (Podesva et al., 2015:62-63; D'Onofrio & Stecker, 2022:3-5). Released /t/ is also ideologically linked to Whiteness. Bucholtz (2010:151-153) found that White self-identified "nerds" in a northern California high school use word-final released /t/ and /d/ as part of a "superstandard English" variety that evokes "the registers of scholarship and science" as well as Whiteness. In Davidson's (2011) study of StoryCorps data, White speakers, relative to Black speakers, produce significantly more /d/ release in phrase-final position (1050).

Methods for coding /t/ and /d/ in previous sociolinguistic studies

In nearly all sociolinguistic studies of English word-final /t/ release, coding is chiefly impressionistic and categorical. The coding process usually combines listening with visual inspection of spectrographic cues (Benor, 2004; D'Onofrio & Stecker, 2022; Podesva et al., 2015), a time-consuming process. In some cases, /t/ is coded as either released or unreleased, and in other cases there are more variants coded but not distinguished in the quantitative analysis. For example, Podesva et al. (2015) coded for released, flapped, glottalized, and deleted variants but subsequently collapsed all of the unreleased variants into one category for quantitative analysis. Some phonetic studies of English stops similarly assess the categorical presence versus absence of a release burst (Zsiga, 2000). While many studies of stop release use VOT as the (continuous) dependent variable rather than categorical presence versus absence (Abramson & Whalen, 2017; Cho, Whalen, & Docherty, 2019; Flege & Hillenbrand, 1987; Fritche, Shattuck-Hufnagel, & Song, 2021; Nagy, 2015; Nodari, Celata, & Nagy, 2019; Ostrand & Chodroff, 2021; Stoehr, Benders, Van Hell, & Fikkert, 2018; Stuart-Smith, Sonderegger, Rathcke, & Macdonald, 2015; Torreira & Ernestus, 2011), VOT is not applicable to prepausal /t/ because there is no immediate following sound.

Research aims

This paper describes a new automated method for reliably collecting acoustic information about coda stops in conversational data. We further describe a process for using the acoustic information to code prepausal /t d/ automatically as released or

unreleased with a random forest classifier. Both tasks are demonstrated with data from a conversational corpus in the Southern U.S. city of Raleigh, North Carolina. The results from the automated classifier are assessed by comparing the internal and social distribution of released versus unreleased /t d/ with their distribution in previous studies of /t/ release. As previous studies have generally not considered /d/ release, the investigation of the distribution of /d/ release in the Raleigh data is exploratory. The /t d/ tokens classified as “released” by the random forest are used to investigate the social and internal factors influencing the *magnitude* of releases in Raleigh. The pragmatic and social functions of /t d/ releases and high-magnitude releases are considered in the context of Raleigh’s changing social environment.

Acoustic analysis of /t/ and /d/ in the Raleigh corpus

Data

The data used in this analysis are drawn from a corpus of conversational interviews with people who grew up in, and mostly still live in, the city of Raleigh, North Carolina, or in Garner, a small town adjacent to Raleigh. Collection of the corpus data began in 2008 and is ongoing. Extensive description of the corpus appears elsewhere, particularly in Dodsworth and Benton (2020:44-59). All of the speakers arrived in Raleigh before age 5, and most were born in Raleigh. Most of the interviews are private conversations between the speaker and the interviewer, usually in the speaker’s home but sometimes in an office on the North Carolina State campus. The speaker wore a lapel microphone while the digital audio recorder sat in full view in front of the interviewer. The speakers were asked to talk about their life experiences including family, school, neighborhoods, and jobs. Because Raleigh has been growing quickly in terms of both land area and population since the mid-20th century, often the conversations turned to Raleigh’s expansion and change. The sample used in the present analysis consists of 233 White and Black speakers born between 1918 and 1996. Table 1 summarizes the demographic information for the sample.

In the present sample, some of the 33 interviews with Black speakers were collected for a related but distinct oral history project in Raleigh’s South Park neighborhood, which lies in the historically African American southeastern quadrant. These speakers are older on average than those in the White sample and were often speaking in a more formal style than other speakers in the Raleigh corpus. In contrast, the youngest Black speakers in the sample, born after 1980, were not part of the oral history project, and most are interviewed by peers.

Table 1. Speakers in the present sample from the Raleigh corpus

Ethnicity	Gender	N	Year of birth
White	Female	113	1919–1996 (mean 1959)
	Male	87	
Black	Female	14	1918–1991 (mean 1948)
	Male	19	
Sample total		233	

Acoustic methods

In order to measure the spectral and temporal properties of stop releases, it was necessary to first locate the release phase (if present) of each prepausal /t/ and /d/. All 233 recordings were force-aligned using the Montreal Forced Aligner (McAuliffe, Socolof, Mihuc, Wagner, & Sonderegger, 2017) and its *english_us_arpa* acoustic models. This applies a single phone interval to each stop phoneme, generally including its closure phase and its release phase, if present, but it does not distinguish the two phases. We extracted all word intervals with prepausal /t d/ (plus a 0.1s pad before and after) using *one_script* (Mielke & Wilbanks, 2015) for *Praat* (Boersma & Weenink, 2018). This yielded 38,071 tokens of prepausal /t/ in 1,343 distinct words and 27,166 tokens of prepausal /d/ in 1,254 distinct words. To help put the magnitude of the noisy stop releases in terms of English affricates and alveolar sibilants, we similarly extracted all prepausal /s/ and /tʃ/, yielding 15,389 tokens of prepausal /s/ in 1,359 distinct words and 1,728 tokens of prepausal /tʃ/ in 69 distinct words.

To find stop (and affricate) releases, we applied a segmentation scheme following Cronenberg, Gubian, Harrington, and Ruch (2020), who used a high-frequency energy signal (along with a voicing measure) to identify pre- and post-aspiration in Andalusian Spanish. Following Cronenberg et al. (2020), we created the high-frequency signal by first applying preemphasis twice to effectively boost the signal 12 dB per octave, then high-pass filtering at 3 kHz using the *wrassp* package (a wrapper for *libassp*, version 1.0.5; Winkelmann & Raess, 2014) in *R* (version 4.1.2, R Core Team, 2000) and calculating the RMS intensity of this high-frequency sound signal. Note that these filters are part of the segmentation procedure but not part of the measurement procedure, which used no preemphasis. Since we are using this signal specifically for segmentation, we diverged from Cronenberg et al. (2020) by using a time step of 1 ms for the intensity signal and not applying a Butterworth filter.

To achieve segmentation, we found the time point of the maximum high-frequency signal value during the stop interval assigned by forced alignment (which should be within the release phase, if a release is present), and the minimum high-frequency signal value between the start of the stop interval and the maximum (which should be within the closure phase). The amplitude difference between the (release) maximum and (closure) minimum is taken as the *release amplitude* (dB). We calculated the difference between frames of the high-frequency signal. The maximum value of this difference represented the steepest rise. The time of the steepest rise of the high-frequency signal between the minimum and maximum was taken as the start of the release. The release end was taken to be the time after the maximum high-frequency signal when the signal first drops down back to half its peak amplitude.¹ This release interval can be understood as a candidate release interval. For intervals with an actual release, the amplitude will be high and the *release duration* (s; the time between the release start and release end) is a meaningful measure of it. If the amplitude is low, as when there is no release, then this duration measure is mostly meaningless. Below we evaluate these candidate release intervals quantitatively, to determine how to distinguish between actual stop releases and non-releases.

Multitaper spectra were extracted from a single 20 ms window beginning 10 ms after the start of each candidate release interval with the *spectRum* package (Reidy, 2013) for *R* (version 4.1.2, R Core Team, 2000), with eight tapers and a bandwidth parameter

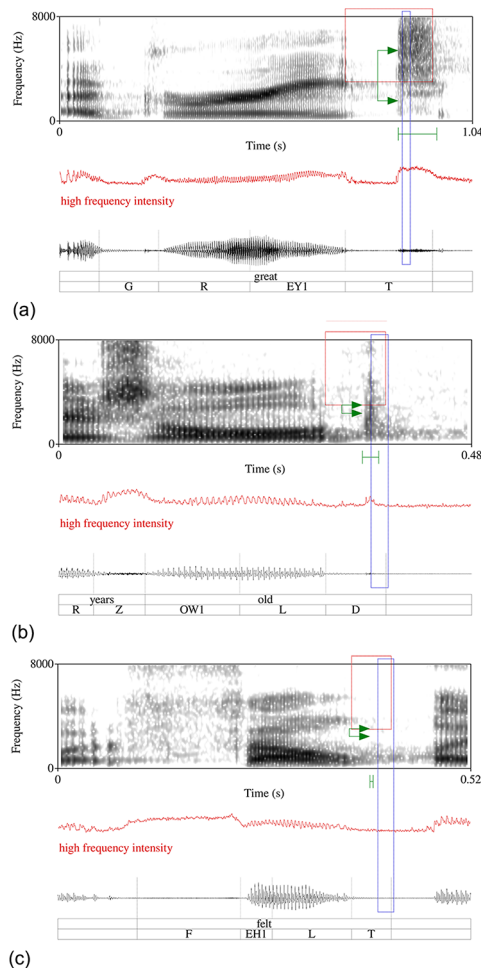


Figure 1. Measurement illustration for three sample tokens. The red high-frequency intensity signal below the spectrogram in each subfigure was used to locate stop releases. The red box indicates the time interval segmented as /t/ or /d/ and the frequency band used to generate the high-frequency intensity signal. The release amplitude is the difference between the greatest high-frequency intensity value during the stop (i.e., the release) and the lowest value before it in the stop interval (i.e., the closure). The green whiskers below the spectrogram show the duration of the release according to the high-frequency intensity signal. The blue box extending below the spectrogram indicates the 20 ms window that was used for the multitaper spectrum analysis. The green arrows indicate the frequencies of the spectral peak and spectral trough that were used to calculate the spectral amplitude difference. Top: affricated /t/ in *great* (release duration = .097 s, release amplitude = 37 dB, spectral amplitude difference = 17 dB, release magnitude = 1.38). Middle: less affricated released /d/ in *old* (release duration = .019 s, release amplitude = 21 dB, spectral amplitude difference = .1 dB, release magnitude = .60). Bottom: unreleased /t/ in *felt* (release duration = .004 s, release amplitude = 0 dB, spectral amplitude difference = 5 dB; release magnitude = .22).

of 4. This analysis was applied to the original waveforms. Preemphasis and high-pass filtering were not applied for the purposes of making spectral measurements. *Spectral*

amplitude difference (dB) was defined as the amplitude difference between the main spectral peak within the 1–22.05 kHz range and the lowest spectral trough between 1 kHz and the spectral peak. This measure is intended to quantify sibilance (following Jesus & Shadle, 2002; Koenig, Shadle, Preston, & Mooshammer, 2013; Shadle, 2023). Figure 1a–c illustrates the measurement scheme for three words ending in /t d/ with different releases or no release, all produced by the same female speaker born in 1988. The top panel shows *great* produced with an affricated /t/. The middle panel shows *old* produced with an unaffricated release. The bottom panel shows *felt* produced with no audible release. The affricated /t/ in *great* has the largest values for release duration (.097 s), release amplitude (37 dB louder than the silence interval) and spectral amplitude difference (a mid-frequency peak 17 dB louder than the low-frequency trough), yielding a release magnitude value of 1.38. The less affricated released /d/ in *old* is shorter in duration (.019 s) and lower in amplitude (21 dB), and it has no prominent mid-frequency peak characteristic of sibilants (a spectral amplitude difference of only .1 dB). The lack of release for the /t/ in *felt* is indicated by its release amplitude of 0 dB (i.e., no discernible noise after the closure. In the absence of a release, the other release measures (.004 s duration and 5 dB spectral amplitude difference) are not meaningful.

Coding prepausal /t d/ as released or unreleased

Data cleaning, impressionistic coding, and acoustic “zones”

The initial dataset consisted of 65,237 tokens of prepausal /t d/. Eleven tokens with erroneous release duration above .3 s were removed. Further data cleaning involved the removal of wordlist and reading passage tokens that only a subset of speakers read, leaving a total of 63,913.

On the basis of graphical inspection of the three acoustic indicators of release (release duration, release amplitude, and spectral amplitude difference), a 460-token sample of the remaining data was selected and coded impressionistically by the first author. In the impressionistic coding, “unreleased” included all tokens without a release burst, including deleted and glottalized tokens. An exploration of the acoustic characteristics of tokens coded as released versus unreleased led to an initial set of acoustic criteria for classifying /t d/ as released or unreleased. For example, all tokens with release amplitude under 2 dB or release duration under .01 s were hypothesized to be unreleased (including deleted /t d/). Tokens with both release amplitude and spectral amplitude difference above 5 dB, for which release duration was also greater than .025 s, were hypothesized to be released. These acoustic criteria were used for grouping all tokens in the corpus into three categorical acoustic “zones”: released ($n = 8096$), undetermined ($n = 18,342$), and unreleased ($n = 37,493$). The large number of “undetermined” tokens results from the fact that the acoustic measurements are noisy; for example, some tokens with high duration values are in fact unreleased. The acoustic “zones” represent a careful but inadequate method for binning acoustic objects that vary greatly along multiple dimensions.

The random forest classifier

In order to avoid ending up with an “undetermined” category, we used an automated classifier to label every token as released or unreleased on the basis of the three acoustic

variables. A random forest was chosen as the automated classifier method in view of evidence that random forests perform well when the token count is high and the number of variables is low (Althnian, AlSaeed, Al-Baity, Samha, Dris, Alzakari, Abou Elwafa, & Kurdi, 2021). Random forests are similar to decision trees, which recursively identify the best feature (acoustic variable, in this case) for splitting tokens in a data frame into groups (in this case, released versus unreleased). A random forest is a collection of decision trees, each using a random subset of the data and a random selection of the features. The importance of each feature for making predictions (in this case, for predicting whether any token is released or unreleased) is determined by aggregating across the individual trees. In this way, the model determines the relative importance of each feature while avoiding the overfitting that often occurs when there are multiple interrelated features.

A random forest model was trained on the 460 tokens that had been coded impressionistically; of these, 209 were impressionistically coded as released and 251 as unreleased. The training dataset included the three acoustic measures (release duration, release amplitude, and spectral amplitude difference) as well as the impressionistic coding. The *train* function in the *R* package *caret* (version 6.0-94, Kuhn, 2008) and the *randomForest* function in the package *randomForest* (version 4.7-1.1, Liaw & Wiener, 2002) were used to train a random forest model on the training data using 10-fold cross-validation. The random forest had 500 trees, each involving a sample of 414 or 415 tokens from the training data and two of the three acoustic variables.

In the random forest model, the mean decrease accuracy, a measure of each variable's importance in classifying tokens, was .07 for release duration, .08 for release amplitude, and .02 for spectral amplitude difference, indicating that spectral amplitude difference contributes the least to the model predictions. The model was overall 76% accurate in classifying the training data as released or unreleased, with an error rate of 25% for unreleased and 33% for released tokens, as derived from the model's confusion matrix. Crucially, checking the model's predictions against the impressionistic coding revealed that the model was better at identifying released tokens relative to the human-generated acoustic zone system described above, which grouped tokens according to acoustic criteria but ended up with many "undetermined" tokens. Accordingly, the trained random forest model was applied to the full data frame, generating a prediction (released or unreleased) for each prepausal /t d/ token in the corpus. The random forest predictions yield a dataset of 50,577 unreleased and 13,336 released tokens.

Figure 2 shows the human-generated acoustic zones and random forest model predictions for all pairs of the three acoustic measures. The human-generated zones (released, undetermined, and unreleased) are represented by shaded rectangular and L-shaped regions. Contour lines show the distributions of tokens labeled as released or unreleased by the random forest model.

Tokens labeled as unreleased by the random forest model generally have very low release amplitude. This is because they lack a silent closure interval followed by a contrastingly noisy release that gives the released tokens their relatively large release amplitude. There is more overlap between unreleased and released tokens with respect to the other two measures. Tokens which are actually unreleased may have a closure followed fairly long interval of not very high-amplitude energy that is not a release. This low-amplitude energy may also have a spectral shape with a mid-frequency peak and

a low-frequency trough similar to some released tokens. What separates these unreleased tokens from released tokens is their low release amplitude, and most unreleased tokens have low values for spectral amplitude difference and release duration as well.

All three measures are useful for distinguishing among released tokens, which range from a minimal audible release of the stop closure to quite a lot of affrication. An affricated /t/ or /d/ is expected to have a release intensity and duration profile similar to the affricate /tʃ/, and a release spectrum similar to the alveolar fricative /s/. The crosshairs in each panel of Figure 2 show expected values for a very affricated /t/ or /d/, based on the means and standard deviations of measurements of prepausal /s/ and /tʃ/. In the top-left panel, we see that the longest and noisiest /t d/ tokens reach the release duration of /tʃ/ and the spectral amplitude difference of /s/. In the top-right panel, we see that they also reach the release amplitude of /tʃ/. The bottom-left panel shows that they reach the release duration and amplitude of /tʃ/.

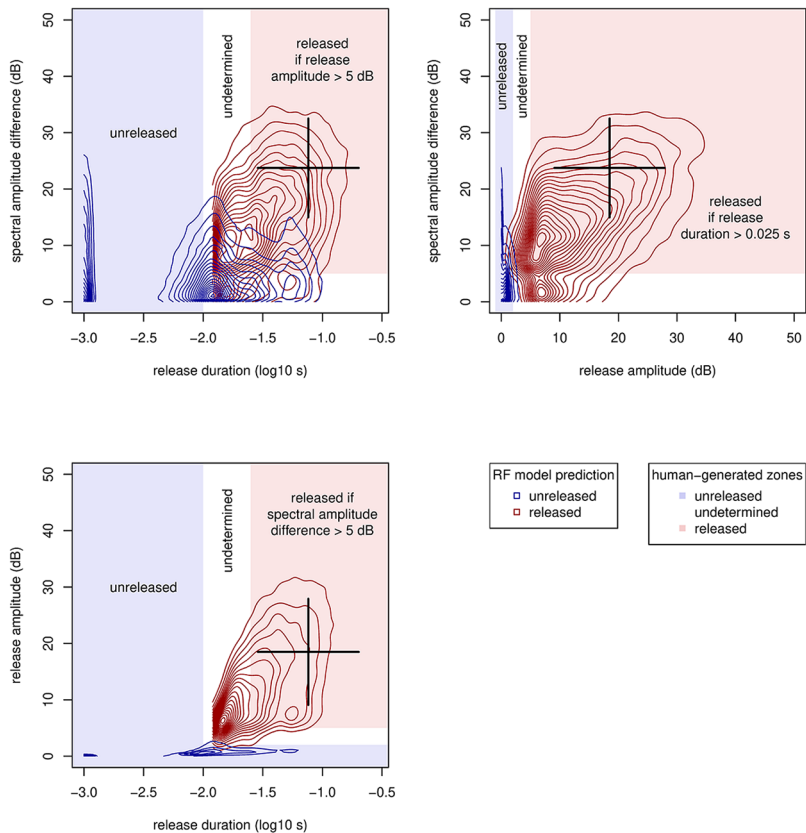


Figure 2. Distribution of all tokens of /t/ and /d/ according to three spectral measures. Shaded areas show initial acoustic criteria. Contour lines illustrate predictions from the random forest model. Cross hairs indicate mean and standard deviation of reference sounds (/tʃ/ for release duration and release amplitude, /s/ for spectral amplitude difference).

Calculating release magnitude

Among tokens classified as released by the random forest, release duration and release amplitude are strongly and positively correlated. We constructed an index of release magnitude using the three acoustic measures shown in [Figure 2](#). A strongly affricated /t d/ resembles an alveolar affricate such as [ts] or [dz]. Since American English does not have alveolar affricate phonemes, we compared /t d/ to an alveolar fricative and a postalveolar affricate. We imagine that a very affricated /t d/ will have a release phase with spectral properties similar to /s/ and that its timing and intensity envelope will resemble /tʃ/, so we scaled the acoustic measures so that a value of 0 will represent the minimum and a value of 1 means a spectral peak as high as in /s/, or a release that is as long or as loud as in /tʃ/.

Accordingly, each of the three measures was normalized so that the mean for the reference sound (/s/ or /tʃ/) has a value of 1 and the minimum value for /t d/ is 0 (the minimum value is 0 for the two amplitude measures and -3.000829 [i.e., slightly less than 1 ms] for the log duration measure).

The three measures were combined by taking the square root of the sum of their squares (i.e., the diagonal of a rectangular prism whose sides are the values of the three normalized acoustic measures), and then dividing this by the square root of 3, so that a token with values identical to the reference sounds will have a value of 1.

Assessing the automated classification: internal and external factors

We examine the distribution of released and unreleased /t d/ in relation to internal (linguistic) and external (social) factors in order to assess the automated method for identifying released and unreleased tokens and for measuring the varying phonetic properties of releases.

/t d/ release versus non-release: internal factors

Previous research has found word-final /t/ release to be promoted by preceding obstruents, following pauses or vowels, and past tense verbs versus monomorphemes and semiweak verbs (D'Onofrio & Stecker, 2022:15; Podesva et al., 2015:66). [Table 2](#) gives the release proportions in the Raleigh data for /t/ and /d/ in relation to each of these three factors.

The sound preceding coda /t/ or /d/ was coded into one of four categories: obstruent, /s/, sonorant, and vowel. As in previous studies, /t/ and /d/ in Raleigh are proportionally more often released after obstruents relative to sonorants and vowels. While a direct comparison of proportions between studies is vulnerable to many factors surrounding data collection, including the social and situational setting, we can compare the release proportions in [Table 2](#) with those in D'Onofrio and Stecker's (2022:18, [Figure 4](#)) analysis of U.S. presidential candidates. The presidential candidates' median /t/ release rates after obstruents range from just over .4 to just below .7, as compared with the Raleigh post-obstruent /t/ release rate of .59. After vowels and sonorants, the presidential candidates' medians range from 0 to about .2, as compared with the Raleigh /t/ release proportions of .17 and .19. The Raleigh proportions are therefore within the ranges defined by the presidential candidates. [Table 2](#) additionally shows that /d/

occurs most often after sonorants while /t/ predominantly occurs after vowels; this is partly because /t/ and /d/ occur in different high-frequency words, especially *that*, *but*, and *it* ($n = 14,493$) versus *and* ($n = 12,479$).

Following sound is more difficult to assess in the context of previous studies because the present study includes only prepausal tokens. In the Raleigh data, /t/ release rates before following consonants versus vowels are identical, and /d/ release rates are higher before vowels (Table 2).²

With respect to morphological status, we follow previous studies in comparing bimorphemic, semiweak, and monomorphemic words, and we additionally distinguish the category of words such as *decided* or *elected* in which schwa plus /d/ constitutes a morpheme. For both /t/ and /d/, the morphological categories pattern as expected insofar as release rates are highest for past tense verbs or past participles. There is very little difference between semiweak verbs and monomorphemes (Table 2).

Table 2. /d/ and /t/ release rates across linguistic factors (rates were calculated on the basis of the random forest classifications)

Sound	Linguistic factor	Release rate	Total <i>N</i>
/d/	Preceding sound		
	Obstruent	.62	947
	Sonorant	.20	16,940
	Vowel	.22	9185
	Following sound (after pause)		
	Consonant	.20	17,091
	Vowel	.26	9981
	Morphological category		
	Bimorphemic (<i>agreed, moved</i>)	.35	4176
	Schwa plus /d/ (<i>decided, elected</i>)	.25	1130
	Semiweak (<i>sold</i>)	.20	1419
	Monomorphemic (<i>good, and</i>)	.20	20,347
/t/	Preceding sound		
	Obstruent	.59	1320
	/s/	.29	3954
	Sonorant	.19	5100
	Vowel	.17	26,447
	Following sound (after pause)		
	Consonant	.20	23,125
	Vowel	.20	13,696

(Continued)

Table 2. (Continued.)

Sound	Linguistic factor	Release rate	Total <i>N</i>
Morphological category			
	Bimorphemic (<i>missed, noticed</i>)	.54	1201
	Semiweak (<i>kept</i>)	.20	597
	Monomorphemic (<i>that, night</i>)	.19	35,023

In previous studies, lexical frequency is negatively correlated with /t/ release. Lexical frequency is defined here as a word's frequency as its number of occurrences in the entire Raleigh corpus (not just the subset of prepausal /t d/ tokens). The most frequent words, including *and*, have relatively low release rates below .25, as shown in Figure 3. Most of the lowest-frequency words have release rate 1 or 0, and middle-frequency words have widely varying release rates. Therefore, the effect of lexical frequency is in the expected direction, but it is noisy.

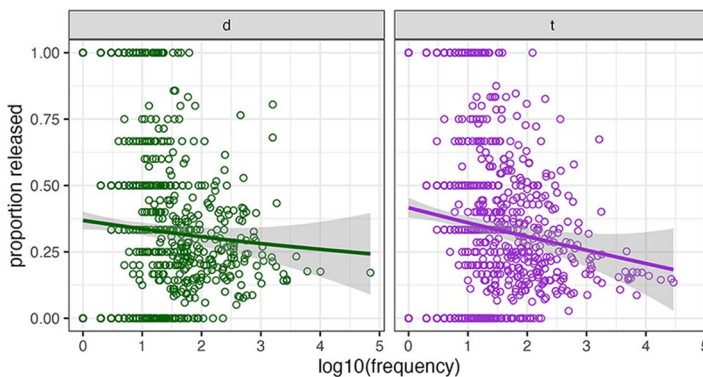


Figure 3. Release rate by word as a function of word frequency in the Raleigh corpus.

The above descriptive account of internal factors takes a step toward legitimizing the automated acoustic method of release detection followed by random forest categorization. Three of the four internal factors pattern as expected on the basis of previous research, and the fourth, following sound, is largely irrelevant here because all tokens are prepausal.

/t d/ release versus non-release: social factors

Our hypotheses concerning social factors are guided by previous findings about /t/ release and about language change in Raleigh. The first social factor is year of birth. Because previous work on the social and apparent-time patterning of linguistic variation in Raleigh has found the ongoing, socially conditioned replacement of Southern linguistic norms with pan-regional norms (Dodsworth & Benton, 2020), we expect apparent-time change toward more frequent /t d/ releases when taking into account internal factors. We further expect female speakers to release /t d/ more frequently

than males in the aggregate, both because female politicians have been found to use more frequent releases (Podesva et al., 2015:66) and because released /t/ has been argued to index a “Good Woman” persona (Davies, 2004; Sclafani, 2009). We expect higher education levels to correspond to higher release rates, given the association between released /t/ and articulateness or learnedness (Benor, 2010; Eckert, 2008:467-470; Podesva, Roberts, & Campbell-Kibler, 2001). Finally, on the basis of previous arguments that /t/ release is linked to Whiteness (Bucholtz, 2001), we expect White speakers in the Raleigh sample to have higher rates of /t d/ release than Black speakers in the aggregate.

Table 3 presents group-level release rates for /t/ and /d/. Because there are only 33 Black speakers in the sample, in contrast with 200 White speakers, and because there is only one Black woman born after 1965 in the sample, we assess Black and White speakers separately. In both groups, and for both /d/ and /t/, women show higher release rates than men in the aggregate. White speakers have higher release rates: White women show a higher /d/ release rate relative to Black women (.26 versus .20), and White men relative to Black men (.19 versus .13). For /t/, the release rates are lower than the /d/ release rates, but the differences between groups are parallel.

An important discrepancy between the Black and White samples has to do with education. Among White speakers, the highest level of education obtained is known for all but one speaker, and the highest overall release rate is observed for speakers who attended graduate school. Among Black speakers, however, education level is known for only 11 out of 33 speakers, and 6 of those 11 were born after 1980. For this reason, we do not show release rates by educational group for the Black sample in Table 3, but we discuss individual speakers (Figure 4).

Table 3. /d/ and /t/ release rates by social group (rates were calculated on the basis of the random forest classifications)

Race	Sound	Social factor	Release rate	Total <i>N</i>
Black	/d/	Gender		
		Female	.20	1654
		Male	.13	1744
	/t/	Gender		
		Female	.19	1990
		Male	.11	2787
White	/d/	Gender		
		Female	.26	13,892
		Male	.19	9782
		Education		
		College	.23	12,305
		Graduate	.26	4393

(Continued)

Table 3. (Continued.)

Race	Sound	Social factor	Release rate	Total <i>N</i>
White	/t/	No college	.20	6840
		Unknown	.14	136
		Gender		
		Female	.24	18,256
		Male	.17	13,788
		Education		
		Graduate	.25	6282
		College	.20	16,617
		No college	.19	8938
		Unknown	.20	207

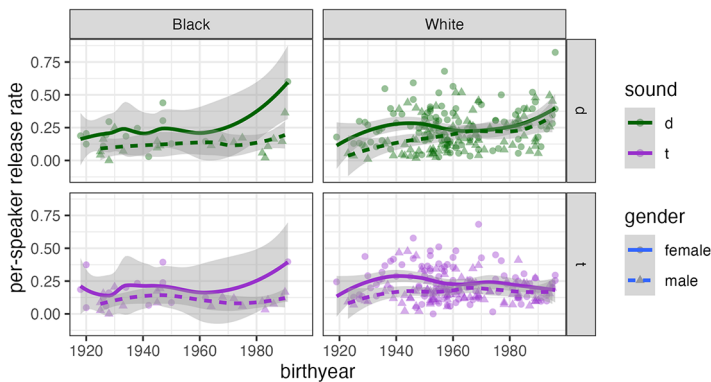


Figure 4. /d/ and /t/ release rate by individual speaker, race, gender, and birthyear. Rates were calculated on the basis of the random forest classifications.

Most individual Black speakers have release rates below .25, with no clear apparent-time rise (Figure 4). Instead, there are a few speakers with unusually high rates. The highest /d/ release rate among Black speakers is observed for a female born in 1991, who also has an unusually high /t/ release rate. This speaker grew up in a predominantly Black neighborhood but recalled being teased as a child for “sounding White”; she dropped out of college but expressed interest in returning; and (crucially, we think) she was interviewed by a White friend. The Black male speaker born in 1990 with an unusually high /d/ release rate (.36) also had a White interviewer, whereas all of the other Black males born in the 1980s were interviewed by a familiar Black male. A college-educated Black woman born in 1947 has release rates for both /t/ and /d/ near .4. We suspect that her high release rates are not simply a product of her education, as the other college-educated speakers born around the same time have lower rates. Instead, we suspect that her high release rates reflect her status as a community

organizer, the most vocal and active champion of the advancement of a historically Black neighborhood.

Among White speakers, Figure 4 shows one particularly striking outlier, a female born in 1996 with a /d/ release rate of .82. We have no explanation for her high /d/ release rate on the basis of social or individual facts. We can note, however, that 29 of her 51 prepausal /d/ tokens occur in the word *and*; of these, 27 are released. The word *and* has an overall release rate of .17 in the corpus and is therefore not exceptional, but as we will argue, one pragmatic function of released /t d/ appears to be holding the floor, and the word *and* comes up often in this context.

/t d/ release versus non-release: mixed effects logistic regression

Generalized linear mixed effects models were fit using the *glmer* function in the R package *lme4* (Bates et al., 2015) to assess the effects of internal and social factors on /t d/ release. Regressions were run separately for /t/ and /d/. Regressions were run for Black and White speakers separately because we lack education data for 21 of the 33 Black speakers. Our model building strategy follows a “holistic” approach (Sonderegger, 2023:142) in which variables and interactions between them are chosen on the basis of substantive reasons, in this case previous findings concerning /t/ release, common sociolinguistic patterns, and the limitations of our data. The fixed effects included in all models were preceding sound, following sound (after the pause), morphological status, lexical frequency, gender, and year of birth. Categorical predictors were treatment coded, and birthyear was standardized.

The models for White speakers have the additional fixed effect of highest education level completed. The models for White speakers include random intercepts for speakers and random intercepts for words. The models for Black speakers have random intercepts for speakers. More complex random effects structures for both groups resulted in singular fits or non-convergence.

Several interactions between fixed effects were tested in accordance with the hypotheses and distribution of data. Among these, only two improved the models for White speakers as determined by model comparison via the *anova* function: preceding sound and year of birth, and gender and year of birth. The interaction between year of birth and gender was motivated by the well-known, though not universal, tendency for women to lead linguistic change in the aggregate (Labov, 2001). The interaction between year of birth and preceding sound was tested chiefly because preceding sound has shown strong effects in prior studies. Moreover, as Raleigh is undergoing dialect change away from Southern linguistic norms and toward pan-regional “standard” norms, it would not be surprising to find that an apparent-time increase in /t d/ release rates was accompanied by a strengthening of pan-regional internal effects.

Full model summaries appear in Appendix A, Tables A1–A4. In the models for both Black and White speakers, the variables of preceding sound, morphological status, and gender pattern in the expected direction on the basis of previous research: /t d/ release is favored by preceding obstruents, past tense morphemes, and females. Speakers who attended graduate school are more likely to release /t/ than others in White speakers’ /t/ model, but the effect does not quite reach significance in the /d/ model. Less frequent words favor release in all models except Black speakers’ /d/ release model. In

the Black speakers' models, birthyear is not significant. In the White speakers' models, however, birthyear shows significant effects: a more positive birthyear slope (meaning, in this case, a greater apparent-time rise in release rates) is associated with men relative to women, and preceding obstruents relative to preceding vowels. Note that in the White speakers' models, the presence of the interactions means that the coefficients for the effects of preceding sound and gender indicate the estimates when standardized birthyear = 0, which is the mean birthyear. Similarly, the simple effect of birthyear gives the estimated birthyear slope for females and when the preceding sound is an obstruent.

Model comparison determined that none of the tested interactions between fixed effects improved the /t/ and /d/ models for Black speakers. The interactions between birthyear and preceding sound, and between birthyear and gender, in the models for White speakers are represented in Figure 5, which shows the mean predicted likelihood of release for all combinations of birthyear, preceding sound, and gender. In the early-20th century, White speakers' release rates were generally low, but women had higher release rates after obstruents. Over time, men acquired the same effect of preceding obstruents, and the effect of preceding sound strengthened among both men and women as indicated by rising release rates after obstruents. In summary, while individual differences remain high, a pan-regional internal factor has strengthened in apparent time among White speakers but not Black speakers.

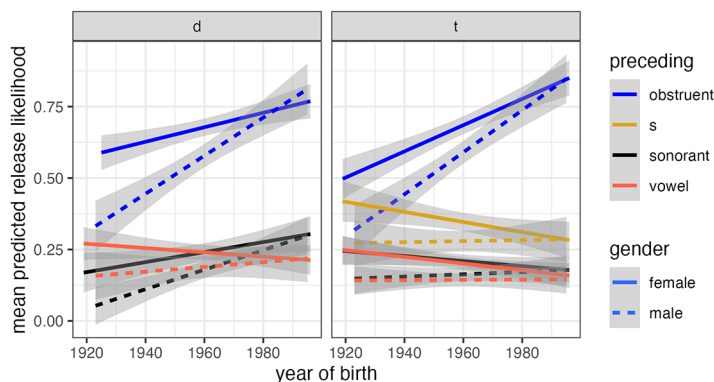


Figure 5. Mean predicted /d/ and /t/ release likelihood, White speakers only.

Neither White nor Black speakers show a significant effect of following vowel versus consonant, but recall that the following interval is actually a pause, and “following sound” here refers to the consonant or vowel after the pause.

Finally, we note that in all of the /t d/ release models, the marginal R^2 , a measure of the variance accounted for by fixed effects, is substantially smaller than the conditional R^2 , indicating that the random effects account for a great deal of variance. Inter-speaker variation is high, even in the presence of significant linguistic effects.

The rising /t d/ release rates likely reflect ongoing dialect contact in Raleigh, which has resulted in the gradual shift from Southern linguistic norms to pan-regional American English norms. The near-identical distribution of /d/ release with respect

to internal and social factors is a new finding that requires further exploration, especially with respect to individual words and their discourse functions. Many speakers release /d/ in the word *and* when holding the floor during a pause, though *and* is not driving the apparent-time change; its release rate is unexceptional in the sample, even among the youngest speakers.

In the /t/ release model for White speakers, the five words with the highest intercepts are *built*, *aunt*, *eight*, *dirt*, and *straight*. Among the 37 prepausal occurrences of *aunt*, 20 are classified as unreleased by the random forest, and 17 are classified as released. We coded the 37 tokens impressionistically in order to check the random forest's predictions. In 31 of the 37 tokens of *aunt*, the impressionistic coding matches the random forest model's prediction. In three of the remaining six cases, there are transcription errors or other obstacles: in one case, *aunts* was incorrectly transcribed as *aunt*; another case was a false start, and in another case, the interviewer was talking over the speaker. The remaining three tokens had short releases but were incorrectly classified as unreleased by the random forest.

When the /t/ in *aunt* is released, it usually corresponds to the introduction of the aunt as a new character in the speaker's narrative, as in (1a-c):

- (1) (a) My uh **aunt** (pause) Joyce who was very prim and proper ...
- (b) Well we still have an **aunt** (pause) who lives in Springmoor.
- (c) My **aunt** (pause) um was a renowned English teacher at [high school].

When *aunt* is unreleased, it usually refers to a person who has been introduced earlier in the narrative as in (2):

- (2) ...[my father] had an older sister named Louise and Louise had four kids, that's the one that lived in Silver Spring, Maryland. So during the sixth grade I would go up ... and stay for a couple weeks with my **aunt**.

It appears that prepausal released /t/ and /d/ can index new information, akin to syntactic and prosodic techniques for presenting new or focal topics (Lambrecht, 1996).

/t d/ release magnitude

Having assessed the social and linguistic factors correlated with /t d/ release, we turn to the release *magnitude* of tokens classified as released by the random forest model. Recall that the release magnitude index combines release duration, release amplitude, and the spectral amplitude difference between the main spectral peak and the lowest spectral trough. A release magnitude value of 1 corresponds to the reference sounds (/tj/ for release duration and release amplitude, /s/ for spectral amplitude difference).

Release magnitude data

The distribution of release magnitude values (Figure 6) is similar for Black and White speakers despite the large difference in number of released tokens (Black: $n = 1253$,

White: $n = 12,077$). Black speakers have lower release rates in the aggregate, but when they do release /t d/, their release magnitude is similar to that of White speakers. A larger sample of Black speakers, especially women born in the 1980s and 1990s, would be needed to confirm this impression. Inter-speaker variability is high in both groups, as in the case of release versus non-release. The appearance of an upward trend for /d/ among Black females is due entirely to one speaker born in 1991 who was interviewed by a White peer, the same speaker who appears as an outlier in Figure 4.

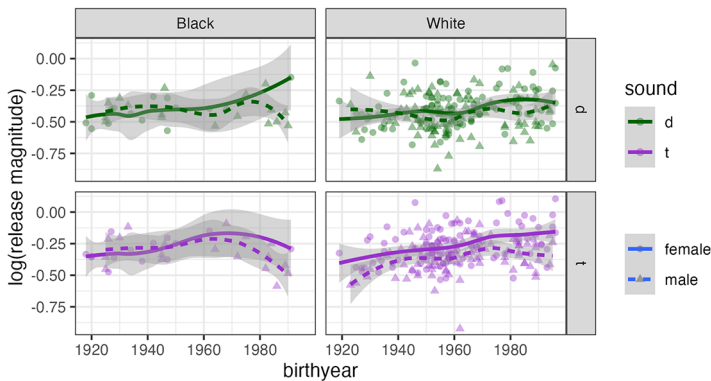


Figure 6. Per-speaker means of log(release magnitude) for /t/ and /d/ among Black ($n = 1253$) and White ($n = 12,077$) speakers.

/t d/ release magnitude: mixed effects linear regression

We investigated the relationship between release magnitude and both internal and social factors using mixed effects linear regression models fit with the *lmerTest* package in R (version 3.1-3, Kuznetsova, Brockhoff, & Christensen, 2017). The dependent variable is the natural log of release magnitude. We began with the most complex random effects structure that allowed for convergence, which was similar to the random effects in the /t d/ release models: for White speakers, the models include random intercepts for speakers and words, plus (in White speakers' /d/ model) by-speaker random slopes for preceding sound. The models for Black speakers include random intercepts for speakers, and the /d/ model for Black speakers additionally has random intercepts for words. The fixed effects in all models are the same as those in the /t d/ release models. Well-motivated interactions among fixed effects were tested via model comparison. A polynomial term for birthyear was tried in the /t/ and /d/ models for White speakers but did not improve the model fits. Model summaries appear in Appendix B, Tables B1-B4.

In both the /t/ and /d/ release magnitude models for White speakers, preceding obstruents are associated with higher-magnitude releases relative to preceding vowels, and relative to preceding /s/ in the /t/ model, and their release magnitude shows greater apparent-time change as indicated by the interaction term (Figure 7). In the case of /t/, predicted release magnitude for preceding obstruents and preceding sonorants is similar. The effect of birthyear in the regression table indicates the birthyear slope for preceding obstruents due to the presence of the interaction. Women have

higher predicted release magnitude than men. In the /t/ model, past tense morphemes have higher predicted release magnitude than monomorphemes. The youngest White speakers in the corpus still commonly produce low-magnitude /t d/ releases, especially after vowels, but they produce high-magnitude releases more frequently than older speakers.

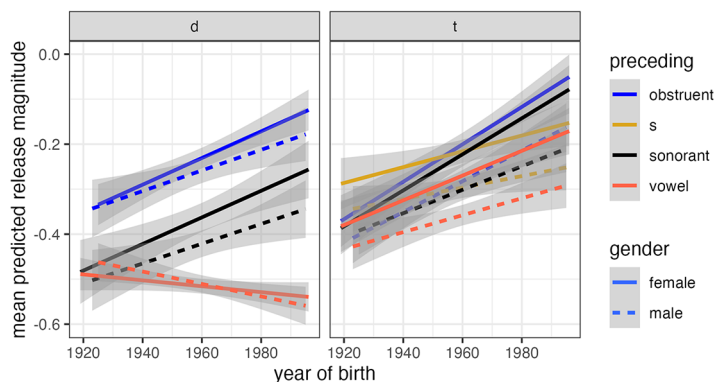


Figure 7. Mean predicted /t d/ release magnitude, White speakers only.

The results for Black speakers are quite different. In the /t/ release magnitude model, only lexical frequency has a significant effect, with high-frequency words predicted to show lower-magnitude releases. In Black speakers' /d/ release magnitude model, the only significant factor is preceding sound: preceding obstruents are associated with higher release magnitude relative to preceding sonorants and vowels. There is no evidence of change across apparent time for Black speakers.

In all of the release magnitude models, comparing the conditional and marginal R^2 values indicates that the random effects account for more of the variance than the fixed effects. Even in the context of the familiar, pan-regional effects of preceding sound, morphological status, and lexical frequency, inter-speaker variation is high and is only partly reducible to gender and birthyear for White speakers, and not significantly for Black speakers.

We argued that one pragmatic use of released /t d/ is to introduce new information in narratives. We investigate the pragmatic function of the increasingly prevalent high-magnitude /t d/ releases by looking at the highest-magnitude releases among the 703 released tokens produced by speakers born in the 1990s. High-magnitude releases appear to be used for holding the floor while pausing to think or slowing down before giving new information. This happens often when speakers are listing events in their lives chronologically. In (3a–f), the bolded words contain strong releases; the examples in (a–b) contain the two highest-magnitude releases in the 1990s sample.

- (3) (a) I never **got** (pause) my um (pause) First Communion and then it's something else, Confirmation.
 (b) You know, Wakefield schools are right in a row together um (pause) **and** (pause) high school except for the Freshman Center is what they call it.

- (c) I think it was just convenience um **and** (pause) the fact that you know I was an in-state student I was paying in-state tuition.
- (d) And then I **worked** (pause) **at** (pause) Chuck E Cheese for one summer.
- (e) And we **moved** (pause) **out** (pause) close to kind of like, it was like North Raleigh.
- (f) Our plan is to get a very large space that can **accommodate** (pause) both a shop, a showroom, um offices and storage.

Discussion

Different trends: Black and White speakers

The distribution of release versus non-release is consistent with previous research: preceding obstruents are associated with higher release rates, as are past tense morphemes, low-frequency words, and women. White speakers' /t d/ release rates are rising after obstruents, and release magnitude is rising for White speakers, especially after obstruents or sonorants. Black speakers, in contrast, show both apparent-time stability and fewer internal constraints. We can attribute some differences between the Black and White regression results to the unequal sample sizes, but we can also recognize Black speakers' stability in the context of other evidence of the stability of African American English (AAE) vowels in Raleigh and in the South even in the context of linguistic change in adjacent dialects (Kohn, 2013, 2018; Smith, Sonderegger, & Dodsworth, 2024; Thomas, 2001, 2007). In Raleigh, one reason for linguistic stability in AAE appears to be racial segregation. The Raleigh-Cary metropolitan area has a very high "Black-White divergence" score (Menendian, Gailes, & Gambhir, 2021), indicating pronounced residential segregation. At the same time, the social and pragmatic functions of released /t d/ likely contribute to the differences between Black and White Raleigh speakers.

The social meaning of /t d/ release in Raleigh

In the context of sociolinguistic interviews, Raleigh speakers use strong /t d/ releases to hold the floor and indicate that new information is coming. But strong /t d/ releases have powerful, multifaceted indexicality in the U.S. and elsewhere. When Raleigh speakers use strong /t d/ releases, they necessarily use not only a discourse pragmatic tool but also a symbol that indexes locally or situationally relevant social meanings. In the context of Raleigh, symbolic choices are made within the changing cultural landscape in which a formerly mid-sized Southern town is becoming a large *urban* center that is only secondarily Southern. For several decades, White speakers in Raleigh have been replacing Southern vocalic variants with pan-regional variants such as diphthongal /ai/ in words such as *tide* or *high* (Dodsworth & Benton, 2017, 2020; Dodsworth & Kohn, 2012; Lundergan, 2024) as educated people from outside the South move to Raleigh for jobs in the technology industry, universities, and other sectors. We expect that the increasing use of /t d/ release is part of the general linguistic turn away from traditional Southern identities and toward urban Southern, or just urban, self-presentation. The ideological link between released /t d/ and personal qualities

such as educated, professional, or White allow Raleigh speakers to distance themselves from longstanding negative stereotypes about Southerners and Southern speech (Cramer, 2016; Preston, 1997, 2015) without letting go of what they see as positive elements of Southern culture.

The excerpt in (4) is from an interview with a White male Raleigh speaker born in 1994. The interviewer is a White male from the large Southern city of Charlotte, North Carolina. The final /d/ release in *raised* in the excerpt is in the top 5.4% of releases, by magnitude, among speakers born in the 1990s, and sounds similar to [ts].

- (11) Interviewer: So do you feel like you're Southern?
 Speaker: I don't know. {laughs} Uh I was **raised** (pause) in Raleigh which I do and don't consider the South. See, my take is, it's North Carolina. It's got the word *north* in it. {laughs} But uh it's the South, no doubt. You'll find a lot of people from the South down here, a lot of people that call it the South. Everyone does, actually, except for me. But uh, my mom's from the South, my dad's from the North, I don't know how to really answer that. ... I try to be polite. I let people in when I'm driving. Go up to Maryland and they won't let you do that, uh Maryland, Pennsylvania. You sit at the stoplight after it turns green for half a second, everyone's laying on their horn, and you're like what did I do? ... Not down here, you've got five minutes. {laughs} ... They just sit there patiently.

The speaker echoes others in the Raleigh corpus in expressing ambivalence about his own, and Raleigh's, status as Southern or not Southern. Like many others, he embraces what he understands to be the characteristic friendliness of Southern people, in opposition to (perceived) Northern impatience, but he nevertheless does not straightforwardly identify as Southern. The increasing prevalence of aregional or pan-regional linguistic features, including high-magnitude /t d/ releases, does not specifically index non-Southern identity but is rather one of many linguistic elements that mark the ongoing shift away from a regionally based cultural identity.

Conclusion

Our acoustic method for assessing prepausal /t d/ release finds validation in the effects of preceding sound, morphological status, and lexical frequency, which closely resemble effects found in previous studies. The method additionally allowed us to consider social effects in a large corpus, at a scale that would have been unrealistic for impressionistic analysis. We found that /t d/ release is conditioned by gender for both Black and White speakers in Raleigh and is changing in apparent time for White speakers. The magnitude of /t d/ release also shows apparent-time change for White speakers, strengthening across time as Raleigh's transition away from Southern linguistic norms continues.

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Competing interests. The authors declare none.

Notes

1. We chose half as a threshold because we found this to be stable across a wide range of tokens. When there is a strong release followed by relative silence, the choice of threshold does not make a big difference, because the signal is falling quickly through the middle range. When there is a weaker release and/or background noise, we found that half the peak amplitude was a good threshold for separating the release from what we considered to not be the release.
2. In conversational data, the potential influence of the first sound of the following word after a pause is difficult to assess for several reasons, including the fact that the pause may occur either at the end of an utterance or mid-utterance, or in response to an interruption. A fuller investigation of the effect of following sound would require a detailed assessment of each pause in relation to surrounding discourse.

References

- Abramson, Arthur S., & Whalen, D. H. (2017). Voice Onset Time (VOT) at 50: Theoretical and practical issues in measuring voicing distinctions. *Journal of Phonetics* 63:75–86. doi: [10.1016/j.wocn.2017.05.002](https://doi.org/10.1016/j.wocn.2017.05.002)
- Althnian, Alhanoof, AlSaeed, Duaa, Al-Baity, Heyam, Samha, Amani, Dris, Alanhoud Bin, Alzakari, Najla, Abou Elwafa, Afnan, & Kurdi, Heba (2021). Impact of dataset size on classification performance: An empirical evaluation in the medical domain. *Applied Sciences* 11(2):796. doi: [10.3390/app11020796](https://doi.org/10.3390/app11020796)
- Baranowski, Maciej, & Turton, Danielle (2020). TD-deletion in British English: New evidence for the long-lost morphological effect. *Language Variation and Change* 32(1):1–23. doi: [10.1017/S0954394520000034](https://doi.org/10.1017/S0954394520000034)
- Bates, Douglas, Mächler, Martin, Bolker, Ben, & Walker, Steve (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software* 67(1):1–48. doi: [10.18637/jss.v067.i01](https://doi.org/10.18637/jss.v067.i01)
- Benor, Sarah (2004). Talmid Chachams and Tsedekes: Language, learnedness, and masculinity among Orthodox Jews. *Jewish Social Studies* 11(1):147–170. doi: [10.1353/jss.2005.0001](https://doi.org/10.1353/jss.2005.0001)
- Benor, Sarah (2010). Ethnolinguistic repertoire: Shifting the analytic focus in language and ethnicity. *Journal of Sociolinguistics* 14(2):159–183. doi: [10.1111/j.1467-9841.2010.00440.x](https://doi.org/10.1111/j.1467-9841.2010.00440.x)
- Boersma, Paul, & Weenink, David (2018). Praat: Doing phonetics by computer (Version 6.0. 37). *Computer Program*. Available online: <http://www.fon.hum.uva.nl/praat>.
- Bucholtz, Mary (2001). The Whiteness of Nerds: Superstandard English and racial markedness. *Journal of Linguistic Anthropology* 11(1):84–100. doi: [10.1525/jlin.2001.11.1.84](https://doi.org/10.1525/jlin.2001.11.1.84)
- Bucholtz, Mary (2010). *White Kids: Language, Race, and Styles of Youth Identity*. Cambridge University Press.
- Cho, Taehong, Whalen, D. H., & Docherty, Gerard (2019). Voice onset time and beyond: Exploring laryngeal contrast in 19 languages. *Journal of Phonetics* 72:52–65. doi: [10.1016/j.wocn.2018.11.002](https://doi.org/10.1016/j.wocn.2018.11.002)
- Cramer, Jennifer (2016). Rural vs. urban: Perception and production of identity in a border city. In J. Cramer & C. Montgomery (Eds.), *Cityscapes and perceptual dialectology*. De Gruyter Mouton. 27–54.
- Cronenberg, Johanna, Gubian, Michele, Harrington, Jonathan, & Ruch, Hanna (2020). A dynamic model of the change from pre-to post-aspiration in Andalusian Spanish. *Journal of Phonetics* 83:101016. doi: [10.1016/j.wocn.2020.101016](https://doi.org/10.1016/j.wocn.2020.101016)
- Davidson, Lisa (2011). Characteristics of stop releases in American English spontaneous speech. *Speech Communication* 53(8):1042–1058. doi: [10.1016/j.specom.2011.05.010](https://doi.org/10.1016/j.specom.2011.05.010)
- Davies, Catherine E. (2004). Woman's language and Martha Stewart: From a room of one's own to a home of one's own to a corporation of one's own. In R. T. Lakoff & M. Bucholtz (Eds.), *Language and woman's place: Text and commentaries*. Oxford University Press. 187–194.
- Dodsworth, Robin, & Benton, Richard (2017). Social network cohesion and the retreat from Southern vowels in Raleigh. *Language in Society* 46:371–405. doi: [10.1017/S0047404517000185](https://doi.org/10.1017/S0047404517000185)
- Dodsworth, Robin, & Benton, Richard (2020). *Language variation and change in social networks: A bipartite approach*. Routledge.
- Dodsworth, Robin, & Kohn, Mary (2012). Urban rejection of the vernacular: The SVS undone. *Language Variation and Change* 24:221–245. doi: [10.1017/S0954394512000105](https://doi.org/10.1017/S0954394512000105)

- D'Onofrio, Annette, & Stecker, Amelia (2022). The social meaning of stylistic variability: Sociophonetic (in)variance in United States presidential candidates' campaign rallies. *Language in Society* 51(1):1–28. doi: [10.1017/S0047404520000718](https://doi.org/10.1017/S0047404520000718)
- Eckert, Penelope (2008). Variation and the indexical field 1. *Journal of Sociolinguistics* 12(4):453–476. doi: [10.1111/j.1467-9841.2008.00374.x](https://doi.org/10.1111/j.1467-9841.2008.00374.x)
- Farrington, Charlie (2018). Incomplete neutralization in African American English: The case of final consonant voicing. *Language Variation and Change* 30(3):361–383. doi: [10.1017/S0954394518000145](https://doi.org/10.1017/S0954394518000145)
- Flege, James E., & Hillenbrand, James (1987). A differential effect of release bursts on the stop voicing judgments of native French and English listeners. *Journal of Phonetics* 15(2):203–208. doi: [10.1016/S0095-4470\(19\)30548-0](https://doi.org/10.1016/S0095-4470(19)30548-0)
- Fritche, Robin, Shattuck-hufnagel, Stefanie, & Song, Jae Y. (2021). Do adults produce phonetic variants of /t/ less often in speech to children? *Journal of Phonetics* 87:101056. doi: [10.1016/j.wocn.2021.101056](https://doi.org/10.1016/j.wocn.2021.101056)
- Guy, Gregory (1980). Variation in the group and the individual: The case of final stop deletion. In W. Labov (Ed.), *Locating Language in Time and Space*. Academic Press. 1–36.
- Holliday, Nicole (2017). My Presiden(t) and firs(t) lady Were Black. *American Speech* 92(4):459–486. doi: [10.1215/00031283-6903954](https://doi.org/10.1215/00031283-6903954)
- Jesus, Luis M. T., & Shadle, Christine H. (2002). A parametric study of the spectral characteristics of European Portuguese fricatives. *Journal of Phonetics* 30(3):437–464. doi: [10.1006/jpho.2002.0169](https://doi.org/10.1006/jpho.2002.0169)
- Koenig, Laura L., Shadle, Christine H., Preston, Jonathan L., & Mooshammer, Christine R. (2013). Toward improved spectral measures of /s/: Results from adolescents. *Journal of Speech, Language, and Hearing Research* 56(4):1175–1189. doi: [10.1044/1092-4388\(2012/12-0038\)](https://doi.org/10.1044/1092-4388(2012/12-0038))
- Kohn, Mary (2018). (De)Segregation: The impact of de facto and de jure segregation on African American English in the New South. In J. Reaser, E. Wilbanks, K. Wojcik & W. Wolfram (Eds.), *Language Variety in the New South*. University of North Carolina Press. 223–240.
- Kohn, Mary E. (2013). *Adolescent ethnolinguistic stability and change: A longitudinal study*. Doctoral dissertation, The University of North Carolina at Chapel Hill. <https://www.proquest.com/docview/1439144429/abstract/A8A4B9D7B3694C35PQ/1>
- Kuhn, Max (2008). Building predictive models in R using the caret package. *Journal of Statistical Software* 28(5):1–26. doi: [10.18637/jss.v028.i05](https://doi.org/10.18637/jss.v028.i05)
- Kuznetsova, Alexandra, Brockhoff, Per B., & Christensen, Rune H. B. (2017). lmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software* 82(13):1–26. doi: [10.18637/jss.v082.i13](https://doi.org/10.18637/jss.v082.i13)
- Labov, William (2001). *Principles of Linguistic change* (Vol. 2), *Social factors*. Blackwell.
- Lambrecht, Knud (1996). *Information structure and sentence form: Topic, focus, and the mental representations of discourse referents*. Cambridge University Press.
- Liaw, Andy, & Wiener, Matthew (2002). Classification and Regression by randomForest. *R News* 2(3):18–22. <https://CRAN.R-project.org/doc/Rnews/>
- Lundergan, Sean (2024). What kind of fronting? Leveling of /o/ in Raleigh. *Publication of the American Dialect Society* 109:88–111. doi: [10.1215/00031283-11587943](https://doi.org/10.1215/00031283-11587943)
- MacKenzie, Laurel, & Tamminga, Meredith (2021). New and old puzzles in the morphological conditioning of coronal stop deletion. *Language Variation and Change* 33(2):217–244. doi: [10.1017/S0954394521000119](https://doi.org/10.1017/S0954394521000119)
- McAuliffe, Michael, Socolof, Michaela, Mihuc, Sarah, Wagner, Michael, & Sonderegger, Morgan (2017). Montreal forced aligner: Trainable text-speech alignment using kald. *Interspeech 2017*, Stockholm, Sweden. 498–502. doi: [10.21437/Interspeech.2017-1386](https://doi.org/10.21437/Interspeech.2017-1386).
- Menendian, Stephen, Gales, Arthur, & Gambhir, Samir (2021). *The roots of structural racism: Twenty-first century racial residential segregation in the United States*. Berkeley: University of California, Othering and Belonging Institute. <https://belonging.berkeley.edu/roots-structural-racism>.
- Mielke, Jeff, & Wilbanks, Eric (2015). *One script to rule them all (Software)*. Praat Script NCSU Phonetics Lab.
- Nagy, Naomi (2015). A sociolinguistic view of null subjects and VOT in Toronto heritage languages. *Lingua* 164:309–327. doi: [10.1016/j.lingua.2014.04.012](https://doi.org/10.1016/j.lingua.2014.04.012)
- Nodari, R., Celata, C., & Nagy, N. (2019). Socio-indexical phonetic features in the heritage language context: Voiceless stop aspiration in the Calabrian community in Toronto. *Journal of Phonetics* 73:91–112. doi: [10.1016/j.wocn.2018.12.005](https://doi.org/10.1016/j.wocn.2018.12.005)

- Ostrand, Rachel, & Chodroff, Eleanor (2021). It's alignment all the way down, but not all the way up: Speakers align on some features but not others within a dialogue. *Journal of Phonetics* 88:101074. doi: [10.1016/j.wocn.2021.101074](https://doi.org/10.1016/j.wocn.2021.101074)
- Podesva, Robert J., Reynolds, Jermay, Callier, Patrick, & Baptiste, Jessica (2015). Constraints on the social meaning of released /t/: A production and perception study of U.S. politicians. *Language Variation and Change* 27(1):59–87. doi: [10.1017/S0954394514000192](https://doi.org/10.1017/S0954394514000192)
- Podesva, Robert J., Roberts, Sarah J., & Campbell-Kibler, Kathryn (2001). Sharing resources and indexing meanings in the production of gay styles. In K. Campbell-Kibler, R. J. Podesva, S. J. Roberts & A. Wong (Eds.), *Language and Sexuality: Contesting Meanings in Theory and Practice*. CSLI Publications. 175–189.
- Preston, Dennis (1997). The South: The touchstone. In C. Bernstein, T. Nunnally & R. Sabino (Eds.), *Language variety in the South Revisited*. University of Alabama Press. 311–351.
- Preston, Dennis (2015). The South: Still different. In M. D. Picone & C. E. Davies (Eds.), *New perspectives on language variety in the south: Historical and contemporary approaches*. University of Alabama Press. 311–326.
- R Core Team. (2000). *R language definition*. Vienna, Austria: R Foundation for Statistical Computing 3(1).
- Reidy, Patrick (2013). spectRum R package. <https://github.com/patrickreidy/spectRum>.
- Sclafani, Jennifer (2009). Martha Stewart behaving Badly: Parody and the symbolic meaning of style 1. *Journal of Sociolinguistics* 13(5):613–633. doi: [10.1111/j.1467-9841.2009.00427.x](https://doi.org/10.1111/j.1467-9841.2009.00427.x)
- Shadle, Christine H. (2023). Alternatives to moments for characterizing fricatives: Reconsidering Forrest et al. (1988). *Journal of the Acoustical Society of America* 153(2):1412–1426. doi: [10.1121/10.0017231](https://doi.org/10.1121/10.0017231)
- Smith, Irene, Sonderegger, Morgan, & Dodsworth, Robin (2024). Pin-Pen in Raleigh: Socially conditioned unmerger. Paper presented at the American Dialect Society meeting, New York City, January 4.
- Smith, Jennifer, Durham, Mercedes, & Fortune, Liane (2009). Universal and dialect-specific pathways of acquisition: Caregivers, children, and t/d deletion. *Language Variation and Change* 21(1):69–95. doi: [10.1017/S0954394509000039](https://doi.org/10.1017/S0954394509000039)
- Sonderegger, Morgan (2023). *Regression modeling for linguistic data*. MIT Press.
- Stoehr, Antje, Benders, Titia, Van Hell, Janet G., & Fikkert, Fikkert (2018). Heritage language exposure impacts voice onset time of Dutch–German simultaneous bilingual preschoolers. *Bilingualism: Language and Cognition* 21(3):598–617. doi: [10.1017/S1366728917000116](https://doi.org/10.1017/S1366728917000116)
- Stuart-Smith, Jane, Sonderegger, Morgan, Rathcke, Tamara, & Macdonald, Rachel (2015). The private life of stops: VOT in a real-time corpus of spontaneous Glaswegian. *Laboratory Phonology* 6(3–4):505–549. doi: [10.1515/lp-2015-0015](https://doi.org/10.1515/lp-2015-0015)
- Sumner, Mehan, & Samuel, Arthur G. (2005). Perception and representation of regular variation: The case of final /t/. *Journal of Memory and Language* 52(3):322–338. doi: [10.1016/j.jml.2004.11.004](https://doi.org/10.1016/j.jml.2004.11.004)
- Thomas, Erik R. (2001). An acoustic analysis of vowel variation in New World English. *Publication of the American Dialect Society* 85(1). doi: [10.1215/-85-1-1](https://doi.org/10.1215/-85-1-1)
- Thomas, Erik R. (2007). Phonological and phonetic characteristics of African American vernacular English. *Language and Linguistics Compass* 1(5):450–475. doi: [10.1111/j.1749-818X.2007.00029.x](https://doi.org/10.1111/j.1749-818X.2007.00029.x)
- Torreira, Francisco, & Ernestus, Mirjam (2011). Realization of voiceless stops and vowels in conversational French and Spanish. *Laboratory Phonology* 2(2):331–353. doi: [10.1515/labphon.2011.012](https://doi.org/10.1515/labphon.2011.012)
- Winkelmann, Raphael, & Raess, Georg (2014). Introducing a web application for labeling, visualizing speech and correcting derived speech signals. In *Proceedings of the Ninth International Conference on Language Resources and Evaluation (LREC'14)*. European Language Resources Association (ELRA). 4129–4133.
- Wolfram, Walter A. (1969). *A sociolinguistic description of Detroit Negro Speech*. Urban Language Series, No. 5. Center for Applied Linguistics.
- Zsiga, Elizabeth C. (2000). Phonetic alignment constraints: Consonant overlap and palatalization in English and Russian. *Journal of Phonetics* 28(1):69–102. doi: [10.1006/jpho.2000.0109](https://doi.org/10.1006/jpho.2000.0109)

Appendix A

Mixed effects logistic regression summaries for /t/ release and /d/ release

The reference level for the dependent variable is *unreleased*. Reference levels for the independent variables are as follows: preceding sound: *obstruent*; following sound: *consonant*; morphological status: *past tense*; gender: *female*; education: *graduate*.

Table A1. Black speakers, /t/ release

Predictors	Released			
	Odds ratio	SE	Z	p
(Intercept)	1.02	.32	.07	.943
preceding [s]	.60	.15	−2.05	.040
preceding [sonorant]	.60	.14	−2.24	.025
preceding [vowel]	.67	.15	−1.81	.071
following [vowel]	1.09	.09	.99	.324
morph [monomorpheme]	.57	.13	−2.38	.017
morph [semiweak]	.49	.21	−1.66	.097
Birthyear	1.11	.14	.84	.401
gender [male]	.46	.12	−2.91	.004
frequency [log10]	.83	.04	−4.40	<.001
Random effects				
σ^2	3.29			
$\tau^2_{00 \text{ speaker}}$	.39			
ICC	.11			
N_{speaker}	33			
Observations	4777			
Marginal R^2 /Conditional R^2	.049/.151			

Table A2. Black speakers, /d/ release

Predictors	Released			
	Odds ratio	SE	Z	p
(Intercept)	.96	.29	−.15	.884
preceding [sonorant]	.26	.07	−5.26	<.001
preceding [vowel]	.37	.09	−4.13	<.001
following [vowel]	1.64	.16	4.93	<.001
morph [handed]	.77	.18	−1.13	.258
morph [monomorpheme]	.74	.11	−2.06	.040
morph [semiweak]	.82	.19	−.85	.396
Birthyear	1.27	.17	1.75	.079
gender [male]	.45	.14	−2.67	.008

(Continued)

Table A2. (Continued.)

Released				
Predictors	Odds ratio	SE	Z	p
frequency [log10]	.94	.04	-1.39	.163
Random effects				
σ^2	3.29			
$\tau_{00 \text{ speaker}}$	.51			
ICC	.13			
N_{speaker}	33			
Observations	3398			
Marginal R^2 /Conditional R^2	.091/.212			

Table A3. White speakers, /t/ release

Released				
Predictors	Odds ratio	SE	Z	p
(Intercept)	4.61	.71	9.96	<.001
preceding [s]	.61	.08	-3.98	<.001
preceding [sonorant]	.15	.02	-15.41	<.001
preceding [vowel]	.19	.02	-13.98	<.001
birthyear	1.44	.15	3.57	<.001
following [vowel]	1.02	.03	0.62	.534
morph [monomorpheme]	.60	.07	-4.25	<.001
morph [semiweak]	.62	.14	-2.05	.040
gender [male]	.62	.07	-4.44	<.001
education [graduate]	1.31	.18	1.95	.051
education [no_college]	.84	.11	-1.32	.188
education [unknown]	.71	.53	0.46	.646
frequency [log10]	.79	.03	-6.99	<.001
preceding [s] $\times$ birthyear	.63	.05	-5.32	<.001
preceding [sonorant] $\times$ birthyear	.63	.06	-5.29	<.001
preceding [vowel] $\times$ birthyear	.59	.05	-6.76	<.001
birthyear $\times$ gender [male]	1.28	.14	2.28	.023
Random effects				
σ^2	3.29			
$\tau_{00 \text{ word}}$	.19			
$\tau_{00 \text{ speaker}}$	.49			
ICC	.17			
N_{speaker}	200			
N_{word}	1236			

(Continued)

Table A3. (Continued.)

		Released		
Predictors	Odds ratio	SE	Z	p
Observations	32,021			
Marginal R^2 /Conditional R^2	.109/.261			

Table A4. White speakers, /d/ release

		Released		
Predictors	Odds Ratio	SE	Z	p
(Intercept)	2.71	.58	4.62	<.001
preceding [sonorant]	.39	.06	-5.78	<.001
preceding [vowel]	.29	.05	-7.28	<.001
birthyear	1.26	.14	2.04	.041
following [vowel]	1.44	.05	10.20	<.001
morph [monomorpheme]	.65	.06	-4.45	<.001
morph [handed]	.65	.09	-3.05	.002
morph [semiweak]	.78	.21	-0.92	.356
gender [male]	.55	.07	-4.62	<.001
education [college]	.75	.12	-1.75	.079
education [no_college]	.70	.13	-1.88	.060
education [unknown]	.57	.50	0.65	.517
frequency [log10]	.82	.04	-4.64	<.001
preceding [sonorant] × birthyear	.98	.09	-0.24	.813
preceding [vowel] × birthyear	.71	.07	-3.48	.001
birthyear × gender [male]	1.39	.18	2.55	.011
Random effects				
σ^2	3.29			
$\tau_{00 \text{ word}}$	.25			
$\tau_{00 \text{ speaker}}$	.44			
$\tau_{11 \text{ speaker.precedingsonorant}}$	.06			
$\tau_{11 \text{ speaker.precedingvowel}}$	.19			
$\rho_{01 \text{ speaker.precedingsonorant}}$	.83			
$\rho_{01 \text{ speaker.precedingvowel}}$	.34			
ICC	.24			
N_{speaker}	200			
N_{word}	1148			
Observations	23,674			
Marginal R^2 /Conditional R^2	.083/.301			

Appendix B

Mixed effects linear regression summaries for /t/ and /d/ release magnitude

Reference levels for the independent variables are as follows: preceding sound: *obstruent*; following sound: *consonant*; morphological status: *past tense*; gender: *female*; education: *graduate*.

Table B1. Black speakers, /t/ release magnitude

Predictors	log(release_magnitude)			
	Estimate	SE	t	p
(Intercept)	-.09	.07	-1.31	.192
preceding [s]	-.02	.06	-0.34	.737
preceding [sonorant]	-.04	.06	-0.66	.507
preceding [vowel]	-.09	.06	-1.56	.118
following [vowel]	.00	.02	0.06	.955
morph [monomorpheme]	-.09	.06	-1.54	.125
morph [semiweak]	-.03	.11	-0.30	.767
birthyear	-.01	.02	-0.73	.466
gender [male]	.01	.04	0.17	.863
frequency [log10]	-.02	.01	-2.11	.035
Random effects				
σ^2	.08			
$\tau_{00 \text{ speaker}}$	.01			
ICC	.08			
N_{speaker}	32			
Observations	688			
Marginal R^2 /Conditional R^2	.042/.118			

Table B2. Black speakers, /d/ release magnitude

Predictors	log(release_magnitude)			
	Estimate	SE	t	p
(Intercept)	-.22	.05	-4.38	<.001
preceding [sonorant]	-.11	.05	-2.42	.016
preceding [vowel]	-.16	.04	-3.66	<.001
following [vowel]	-.00	.02	-0.18	.859
morph [handed]	.04	.05	0.92	.356
morph [monomorpheme]	-.01	.03	-0.17	.864
morph [semiweak]	-.05	.05	-0.93	.353
birthyear	.02	.02	1.16	.247
gender [male]	-.01	.04	-0.21	.837

(Continued)

Table B2. (Continued.)

log(release_magnitude)				
Predictors	Estimate	SE	t	p
frequency [log10]	-.02	.01	-1.73	.084
Random effects				
σ^2	.06			
$\tau_{00 \text{ word}}$	.00			
$\tau_{00 \text{ speaker}}$	.01			
ICC	.12			
N_{speaker}	32			
N_{word}	161			
Observations	565			
Marginal R^2 / Conditional R^2	.053 / .170			

Table B3. White speakers, /t/ release magnitude

log(release_magnitude)				
Predictors	Estimate	SE	t	p
(Intercept)	-.15	.03	-5.57	<.001
preceding [s]	.00	.02	.23	.819
preceding [sonorant]	-.01	.02	-.41	.682
preceding [vowel]	-.03	.02	-1.61	.108
birthyear	.06	.01	4.48	<.001
following [vowel]	-.02	.01	-2.80	.005
morph [monomorpheme]	-.05	.02	-2.59	.010
morph [semiweak]	-.03	.04	-.81	.416
education [college]	-.02	.02	-.89	.376
education [no_college]	-.05	.03	-1.82	.068
education [unknown]	-.11	.12	-.93	.353
gender [male]	-.09	.02	-4.92	<.001
frequency [log10]	-.00	.01	-.46	.642
preceding [s] × birthyear	-.04	.01	-2.90	.004
preceding [sonorant] × birthyear	-.00	.01	-.24	.813
preceding [vowel] × birthyear	-.03	.01	-2.13	.033

(Continued)

Table B3. (Continued.)

log(release_magnitude)				
Predictors	Estimate	SE	t	p
Random effects				
σ^2	.08			
τ_{00} word	.00			
τ_{00} speaker	.01			
ICC	.15			
N_{speaker}	199			
N_{word}	782			
Observations	6659			
Marginal R^2 /Conditional R^2	.043/.186			

Table B4. White speakers, /d/ release magnitude

log(release_magnitude)				
Predictors	Estimate	SE	t	p
(Intercept)	-.27	.03	-9.61	<.001
preceding [sonorant]	-.18	.02	-8.49	<.001
preceding [vowel]	-.25	.02	-11.49	<.001
birthyear	.04	.01	2.57	.010
following [vowel]	-.01	.01	-.90	.367
morph [monomorpheme]	-.01	.01	-.40	.687
morph [handed]	.04	.02	1.91	.056
morph [semiweak]	-.02	.03	-.73	.463
gender [male]	-.01	.02	-.66	.509
education [college]	-.00	.02	-.02	.985
education [no_college]	-.01	.02	-.55	.580
education [unknown]	-.14	.12	-1.19	.233
frequency [log10]	.01	.01	1.76	.078
preceding [sonorant] $\times$ birthyear	.00	.01	.16	.874
preceding [vowel] $\times$ birthyear	-.06	.02	-3.59	<.001
Random effects				
σ^2	.06			
τ_{00} word	.00			
τ_{00} speaker	.01			

(Continued)

Table B4. (Continued.)

Predictors	log(release_magnitude)			
	Estimate	SE	t	p
τ ₁₁ speaker.precedingsonorant	.01			
τ ₁₁ speaker.precedingvowel	.01			
ρ ₀₁ speaker.precedingsonorant	.17			
ρ ₀₁ speaker.precedingvowel	−.57			
ICC	.21			
N _{speaker}	200			
N _{word}	679			
Observations	5418			
Marginal R ² /Conditional R ²	.075/.273			

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