Title page

Full title: Each p[ɚ]son does it th[ɛː] way: Rhoticity variation and the community grammar

Short title: Rhoticity variation and the community grammar

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ABSTRACT

This paper examines individual differences in constraints on linguistic variation in light of Labov's (2007) proposal that adult change (diffusion) disrupts systems of constraints and Tamminga, MacKenzie, and Embick's (2016) typology of constraints. It is shown that in pooling data from multiple speakers, some of the complexity in structured community variation may be overlooked. Data on rhoticity from speakers of Bristol English are compared to 34 previous studies of rhoticity in varieties of English around the world. Constraints found to be consistent across varieties are also found to be consistent across speakers of Bristol English, whereas those that differ between varieties also differ between individuals, implying that only those which differ are truly part of the grammar, and that these are indeed disrupted by diffusion.

ACKNOWLEDGEMENTS

Acknowledgements are made to the Bristol Centre for Linguistics (BCL) at the University of the West of England, which funded and coordinated this project. Thanks go to Sali Tagliamonte and to the audience at Language Variation and Change in the South of England 2017 for helpful comments on earlier versions of this paper.

INTRODUCTION

The community grammar and individual grammars

This paper uses data from rhoticity variation in Bristol English to investigate the nature of constraints on sociolinguistic variables and the relationship between the grammars of individuals and the community grammar. The identification of the community grammar as the object of study and the relationship between community grammar and individual grammars allow a number of interpretations. Firstly, we might *define* the speech community as a community of individuals who share the same variable grammar (i.e., a system of constraints) and evaluative norms. Under this understanding, studying the grammar of the speech community is equivalent in definition to studying the grammars of individuals within it; this is probably the most common understanding (Tamminga, MacKenzie, & Embick, 2016:307; cf. Labov, 1966). Secondly, we might define the speech community independently (by shared location, overlapping social networks, other shared cultural practices, etc.) but *assume* that all individuals within it share the same grammar. In this case, studying the grammar of the speech community is assumed to be a good proxy for studying the grammar of individuals. This is implicit, for example, in work which attempts to determine a formal representation for variation in historical data reflecting multiple speakers (e.g., Abramowicz, 2008; Nevins & Parrott, 2010; Santorini, 1992, 1994). Thirdly, we could avoid the question by asserting that the grammars of individuals are entirely outside the scope of study, as Labov did when he wrote that “the individual does not exist as a unit of linguistic analysis” (2014:18). Under this conception, individual grammars could be largely uniform and identical to the community grammar (as is Labov’s position: “The end result [of native acquisition] is a high degree of uniformity in both the categorical and variable aspects of language production, where individual variation is reduced below the level of linguistic significance” [Labov, 2014:17]), or could vary substantially and arbitrarily relative to it.

The assumption that groups of individuals in a given location whose social networks overlap share near-identical grammars has been tested. Guy (1980) investigated t/d deletion in Philadelphia and New York speakers, concluding that individual deviations from the overall constraint hierarchy merely reflected statistical noise with two exceptions to prove the rule: the effect of a following pause, which differed systematically between New York and Philadelphia speakers, demonstrating that these represented different speech communities; and a morphological condition that differed between middle-class adults and others. Meyerhoff & Walker (2007:353–359), investigating variable zero copula in Caribbean English, found no differences between the community grammar and the grammars of speakers who had spent a significant time away from the community as adults.

However, Horvath & Horvath (2003), in a study of l-vocalisation in New Zealand and Australian English datasets, found individual deviations in sizes, relative orders and even directions of effects, although they pointed out that "the percentage of individuals was quite small and statistical fluctuation cannot be ruled out" (Horvath & Horvath, 2003:167). Forrest (2015), investigating (ing) in the English of Raleigh, North Carolina, with the caveat that "a reorganization of the hierarchy of internal constraints never truly occurs" (2015:400), went so far as to say that "it would be overstating the case to say that an aggregate representation of constraint weight values accurately represents all members of the community; rather, they seem to represent a central tendency of speakers, given enough speakers in a corpus." (2015:401)

Beyond the empirical findings, there is a particular conceptual problem with features undergoing change due to contact. The transmission-diffusion distinction (Labov, 2007) suggests that, due to the degraded language-learning ability of adults, when features are transferred among adult speakers (diffusion) rather than from adults to children (transmission), the grammatical detail of those features is disrupted and their complexity reduced. This is proposed to give rise to a distinction between features which have spread into communities from the outside, and therefore show the disrupted signature of diffusion, and undisrupted features with a long history of community-internal transfer. The argument is that the agents of transfer between communities must be mobile adults and so the mechanism must be diffusion. Inter-community contact will often involve many independent agents travelling in both directions and be spread over a longer time; such agents will undergo different degrees of contact-induced adult change (diffusion) at different times. Thus, we must assume that both undisrupted grammars and many grammars with differently disrupted systems of constraints enter such speech communities.

Additionally, longitudinal studies of various ongoing changes have found that a subset of speakers participate in changes during their adulthoods (lifespan change) (e.g., Buchstaller, 2006; Raumolin-Brunberg, 2009; Sankoff & Blondeau, 2007). Some studies (such as Blondeau, 2006; Bowie, 2005; Sankoff & Wagner, 2006; Wagner & Sankoff, 2011) even find retrograde lifespan change–perhaps a sign of advanced changes of which speakers are highly conscious (Sankoff, 2013:10). The point here is that adults do participate in change, including changing their underlying vernacular grammar (Sankoff & Blondeaum 2010:15–17; Sankoff & Blondeau, 2013; contra Meyerhoff & Walker, 2007). This must be understood in at least some cases as diffusion, and so we should expect those adults who have undertaken large enough lifespan change to exhibit disrupted grammars for their newly acquired features.

The question then is: if we have a change spreading into a speech community from outside (diffusion) in which some adults are participating (lifespan change), is the end result still somehow a variable grammar that is consistent across individuals? Do learners manage to settle on a common core of constraints which they then reproduce faithfully (koinéisation?), or is input variation from the diffusers so great that our transmitters, too, end up with disagreeing grammars?

Mechanisms behind statistical effects

There is good reason to think that not all statistical effects on variable linguistic phenomena reflect constraints in the grammar. Guy (1997) distinguished between articulatory universals, which reflect physiological properties of the articulators, functional universals, and the truly linguistic, variety-specific constraints that can evolve from these two types. Horvath & Horvath (2003), investigating l-vocalisation, aimed to discover which effects are constant across varieties (‘scale-independent’, in their vocabulary) and which are variety-specific (‘scale-dependent’) on the assumption that effects which are constant may reflect universal phonetic processes, whereas those which are specific must be “open to social intervention” (Horvath & Horvath, 2003:148). Nagy & Irwin (2010) compared constraints from past studies of rhoticity to identify which can and cannot vary between varieties, suggesting that only those which can vary should be used as metrics for relatedness. Tamminga et al. (2016) distinguished three types of effects:

1. ‘s-conditioning’ = sociostylistic factors
2. ‘i-conditioning’ = internal linguistic factors
3. ‘p-conditioning’ = physical and cognitive factors

These types differ in their relationship to the grammar: i-conditioning is clearly part of the grammar; s-conditioning might fall inside or outside the grammar, depending on your theoretical orientation and whether we’re talking about the community grammar or the individual grammar; p-conditioning is clearly outside the grammar. A necessary caveat here is that over time, p-conditioning can give rise to s- and i-conditioning (see also Janda & Joseph, 2003). They also differ in their universality: p-conditioning is universal (even if factors such as short-term memory capacity vary between speakers, they don’t vary between populations) whereas i-conditioning and s-conditioning are variety- and/or community-specific. There are potential exceptions to this. It is perfectly conceivable that a variable i- or s-conditioning factor might counteract an invariant p-conditioning factor, giving the appearance of an inconsistent p-conditioning factor. Likewise, it is perfectly conceivable that within a given set of varieties an s- or i-conditioning factor might happen to be universal, especially if the varieties in question are related. Nevertheless, we can expect these broad tendencies to hold. Note also that they seem to hold at the level of individuals: in Horvath & Horvath’s study (2003:160–161) it appeared that an effect which was more consistent across communities was also more consistent across individuals within a community.

The problem

If there is considerable inter-individual disagreement in variable grammars (constraint hierarchy variation), then effects which have conflicting directions for different speakers will tend to cancel each other out in pooled data. With pooled data, we will most consistently be able to identify effects which reflect universal physical and cognitive factors (i.e., p-conditioning) since these will usually be invariable across individuals: but these effects are precisely those which are not part of the grammar. Effects which are part of the grammar (i-conditioning) will only emerge from analyses of pooled data if they are shared by most speakers or are very strong for the subset of speakers to whom they apply. What is more, the exact composition of the sample from the speech community may have a decisive effect on what effects we find.

This problem is most acute for studies which compare constraint hierarchies identified from different populations of speakers to make arguments about community identities and histories. Examples are studies that compare constraint hierarchies for variable phenomena in AAVE to the grammars of English-lexifier creoles to interrogate the possibility that AAVE is the descendent of such a creole (e.g., Cukor-Avila, 1999; Poplack & Sankoff, 1987; Tagliamonte, 2013). Other examples include studies that use shared constraint hierarchies in different ethnic groups (e.g., Becker, 2014; Hoffman & Walker, 2010) or generations (e.g., Blondeau, 2006) to demonstrate membership of a larger speech community or, indeed, studies which use differences in constraint hierarchies to argue for a history of diffusion (Buchstaller, & D'Arcy 2009; Labov, 2007). These approaches assume that findings of effects in pooled data are findings of constraints in grammars; they are weakened if their methodology is most effective at discovering those effects which are *not* parts of grammars. They also rely on the assumption that individuals share the grammar of their group. Should we assume, for example, that speakers of AAVE with certain constraints speak a variety descended from a creole and others with different constraints do not?

BACKGROUND ON RHOTICITY

Rhoticity in Bristol English

Loss of rhoticity in Bristol English offers us an excellent case study to explore these issues. The realisation of non-prevocalic /r/ is undergoing change in many English varieties: rhoticity is declining in many previously rhotic British English varieties, but being gained in traditionally non-rhotic varieties in North America. The loss of rhoticity in West Country Englishes like Bristol English is a change in which adults participate, and one triggered by an external norm: Standard Southern British English (SSBE) has categorical non-rhoticity in nonprevocalic contexts. Variable rhoticity in other English varieties has been extremely widely studied. Thus, effects found to be universal across previous studies of rhoticity are potential candidates for p-conditioning, whereas variable effects are more likely to reflect i- or s-conditioning. If the above discussion is on the mark, we will find that older Bristol speakers (who were agents of diffusion and/or participated in community-internal lifespan change) vary in the effects of such i- and s-conditioning factors. For younger speakers, we might find that a consistent consensus system has emerged, or we might find yet more constraint hierarchy variation, the result of acquiring the variable from a mixed input. Since the external standard has categorical non-rhoticity, there should be no external standard constraint hierarchy which could play a role.

This study is based on the use of rhoticity by 30 speakers of Bristol English in unstructured sociolinguistic interviews. The sample population was made up of 15 speakers born between 1920 and 1947, 4 speakers born between 1983 and 1989, and 11 speakers born between 2000 and 2003. A minimum of 20 tokens were collected per speaker for each preceding vowel context, except where fewer occurred in the interview; there were insufficient tokens following certain vowels (exemplified by the lexical sets CURE, FIRE, and HOUR) and so these were excluded. Tokens were judged by ear as rhotic or non-rhotic and the spectrogram for each token examined; where tokens were perceptually indeterminate, they were classified as rhotic if the spectrogram showed a discernible drop in f3 across the vowel segment. These judgements were made by a single coder, Blaxter. Four speakers with (near-)categorical non-rhoticity (b1, b2, 9, 11) were excluded from the analysis (although they are included in Table 1 and Figure 1). The remaining dataset consists of 5817 tokens.

Ongoing change, with traditional rhoticity declining under the influence of the non-rhotic standard, is visible in these data as change in apparent time (Blaxter et al., forthcoming)[1]. Table 1 and Figure 1 show the number of observations and proportion of rhoticity per speaker against speaker age (the line is the linear trend line; points for female speakers are squares and male speakers diamonds)[2]. As is also clear from this figure, there is a high degree of within-group variability: there are speakers with less than 30% rhoticity born before 1950 and speakers with greater than 70% rhoticity born after 2000. The Survey of English Dialects (SED) suggests that the traditional variety when these oldest speakers were children was fully rhotic. Instructively, Piercy (2012: 79) found that 97% of tokens produced by five SED speakers in Dorset were rhotic, a figure similar to the most conservative speakers in this study (b5, b7, and b8 all have over 95% rhoticity). Taken together, these observations suggest that much of the change away from rhoticity has taken place over the course of these speakers' lifetimes. We might guess, then, that the older speakers with the highest rates of rhoticity reflect community usage at the time of their childhoods, whereas the adults who exhibit low rates of rhoticity (such as speakers 26, 28, 20, and 22) have undergone substantial lifespan change.

TABLE 1. *Observations and rhoticity rates per speaker, listed by year of birth*

speaker	year of birth	gender	observations	overall % rhoticty
24	1920	F	102	63.73%
25	1924	F	91	60.44%
26	1925	F	128	52.34%
b5	1927	F	877	95.67%
23	1932	F	113	64.60%
b6	1932	F	375	89.60%
27	1934	M	132	78.03%
28	1935	F	140	12.14%
29	1935	M	113	1.77%
b7	1939	M	453	96.47%
b3	1940	F	388	83.76%
19	1941	M	122	74.59%
b8	1942	M	595	96.47%
20	1946	F	143	20.28%
22	1947	F	143	20.98%
21	1947	M	120	92.50%
b1	1983	F	558	0.00%
b2	1984	M	427	1.41%
b13	1986	M	646	60.37%
b12	1989	F	559	85.69%
11	2000	F	136	0.74%
3	2000	M	108	69.44%
7	2000	M	99	16.16%
4	2001	F	131	11.45%
8	2001	F	130	32.31%
6	2001	M	104	11.54%
10	2001	M	130	38.46%
1	2002	F	261	22.61%
5	2002	F	125	62.40%
2	2003	F	125	60.80%
9	2003	M	109	0.92%

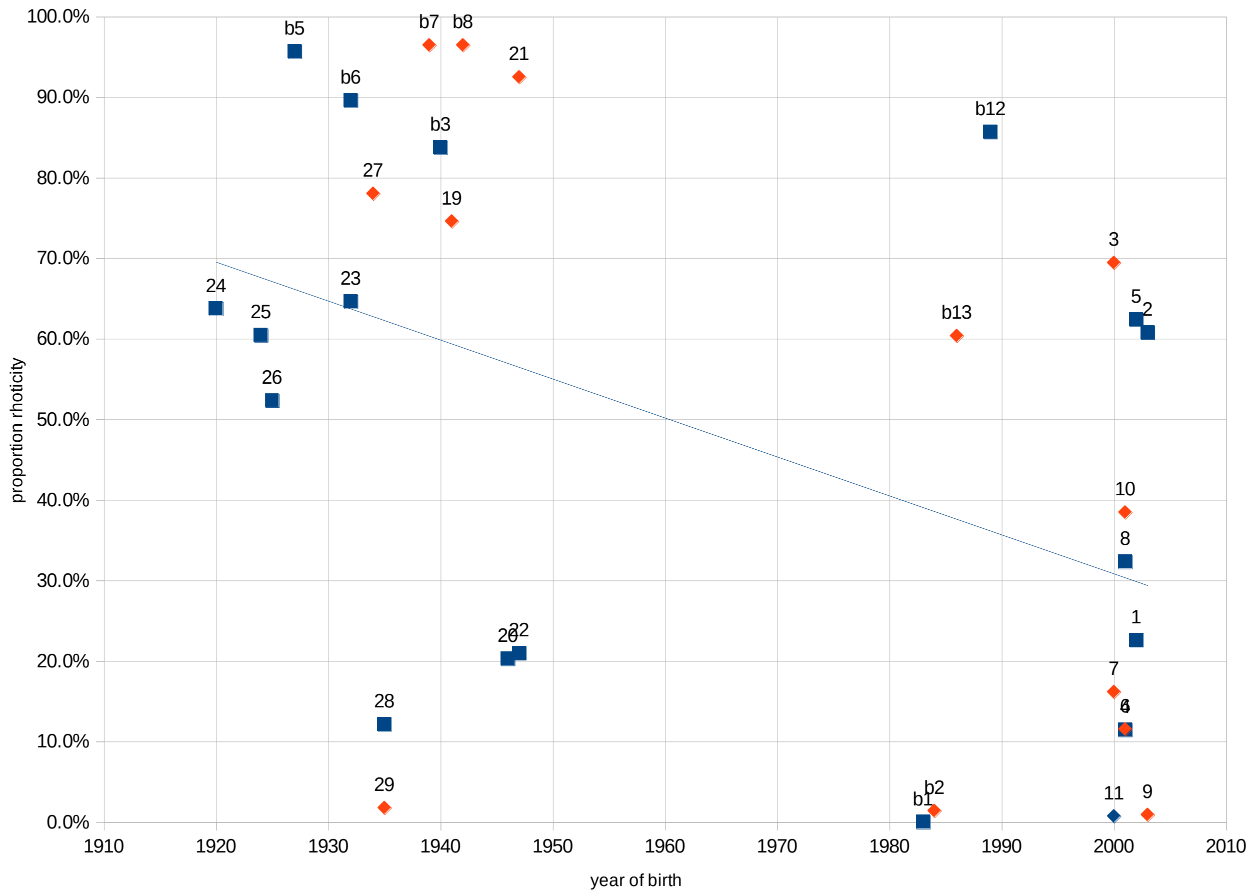

FIGURE 1. Rates of rhoticity by speaker for the sample population.

Independent variables

To identify the relevant independent variables 34 studies of rhoticity were surveyed. These include seven studies of other West Country varieties (Dudman, 2000; Hollitzer, 2013; Jones, 1998; Piercy, 2006; Piercy, 2007; Piercy, 2012; Sullivan, 1992), seven of varieties elsewhere in the UK (Barras, 2010; French, 1988; Schützler, 2010; Simpson, 1996; Vivian, 2000; Watt, Llamas, & Johnson, 2014; Williams, 1991), 16 studies of North American varieties (Baxter, 2008; Becker, 2014; Cychosz & Johnson 2017; Elliott, 2000; Ellis, Groff, & Mead, 2006; Feagin, 1990; Hinton & Pollock, 2000; Irwin & Nagy, 2007; Labov, 1972; Miller, 1998; Myhill, 1988; Nagy & Irwin, 2010; Parslow, 1967; Parslow, 1971; Pollock & Bernie, 1997; Villard, 2009), and four studies of English varieties elsewhere (Hartmann & Zerbian, 2010; Sharbawi & Deterding, 2010; Sudbury & Hay, 2002; Trudgill & Gordon, 2006). Table summaries showing the independent variables and their effects in each study are given in the appendix. Here, we will concentrate on generalisations across studies. Since even coefficients from similarly designed regression models are not strictly comparable the findings have been simplified to whether a variable was found to favour, disfavour or be neutral for rhoticity.

One of the most striking findings of this review is the high degree of inter-variety agreement. Especially if we do not consider findings of no effect as strong evidence, most factors either consistently disfavour rhoticity:

- higher word frequency (disfavouring in 3/3 studies),
- another /r/ in the word (disfavouring in 3/4 studies, no effect in 1),
- function words (disfavouring in 2/3 studies, no effect in 1)

or consistently favour it:

- stress (favouring in 10/10 studies),
- a following tautosyllabic consonant (favouring in 7/10 studies, no effect in 2, mixed in 1).

Thus, the only factors for which we find substantial inter-variety disagreement are:

- word-final position (disfavouring in 8/12 studies, favouring in 3 and no effect in 1),
- prepausal position (favouring in 6/7 studies, disfavouring in 1),
- and morpheme-final (word-internal) position (disfavouring in 3/5 studies, no effect in 1, mixed in 1).

There is some slight evidence that direction of change (or perhaps dialect family) determines the effect of word-final position: all three studies which found word-final position favoured rhoticity were studies of North American varieties with increasing rhoticity.

The effects of preceding vowel are more heterogenous. Where studies have simply compared back and front vowels, they have usually found that back vowels favour rhoticity compared with front vowels (Barras, 2010; Baxter, 2008; Labov, 1972; Sudbury & Hay, 2002), although there are contradictory findings (Pollock & Bernie, 1997). Where studies have distinguished vowel phonemes (generally denoted by lexical sets), we find considerable variation. Table 2 shows the proportion of studies in which the vowel in the row was found to favour rhoticity compared with the vowel in the column, excluding those in which the vowel was not included or the two were found to have equal effect. Studies that grouped vowels have been coded as finding an identical effect for all of them. On the one hand, certain vowels stand out as having consistent effects: preceding NURSE is almost always one of the most favourable contexts (an exception is Nagy & Irwin's (2010) findings for younger speakers); preceding lettER, NORTH, and FORCE are usually among the most disfavouring contexts (exceptions include Asprey [2007] and Trudgill & Gordon [2006]). On the other, there is no pair of vowels with totally consistent relative effects across previous studies.

TABLE 2. *Proportion of previous studies finding that the vowel in the row favoured rhoticity compared with the vowel in the column*

	NURSE	START	CURE	NEAR	SQUARE	FORCE	NORTH	lettER
NURSE		80%	83%	95%	95%	84%	90%	95%
START			67%	47%	73%	86%	87%	83%
CURE				71%	71%	83%	83%	73%
NEAR					50%	64%	67%	82%
SQUARE						71%	73%	71%
FORCE							67%	87%
NORTH								75%
lettER								

These findings offer us some evidence for the classification of these factors in terms of the typology proposed by Tamminga et al. (2016). Since, barring interactions with other factors, p-conditioning should be universal whereas i-conditioning need not be, factors which were found to have a consistent effect across previous studies are more likely to reflect p-conditioning and factors found to have inconsistent effects across previous studies are more likely to reflect i-conditioning. This classification can be further informed by other properties of the factors in question. Factors which are cross-linguistically observed never to have categorical effects (such as lexical frequency) must be p-conditioning; in any case, we should be able to posit a plausible mechanism of effect in the relevant domain. Suggested classifications are summarised in Table 3.

TABLE 3. *Classification of internal effects on rhoticity according to the typology proposed by Tamminga, MacKenzie, & Embick (2016)*

Effect(s)	Class	Comments
word length	p-conditioning	never involved in categorical alternations cross-linguistically
word frequency		
emphasis, stress, lettER, function word	p-conditioning	these four effects probably reduce to the effect of stress, with r-lessness as a form of lenition in unstressed contexts
another /r/ in the same word	p-conditioning	we can see this as an example of dissimilation at a distance, the result of overlapping perceptual cues to rhoticity (cf. Ohala, 1981:188-196)
following tautosyllabic consonant	p-conditioning	the effect across previous studies is extremely consistent and in terms of mechanism we might suggest that segments in syllable-final position are more susceptible to lenition processes; nevertheless, this is not a strongly evidenced classification
prepausal	p-conditioning / i-conditioning	there is a coherent mechanism for prepausal position as yet another indirect effect of stress (phrase-final lengthening), but since the effect varies among past studies this suggests it might instead (sometimes) reflect i-conditioning
morpheme-final position	p-conditioning / i-conditioning	appears to have a consistent effect across previous studies, but there is no especially obvious mechanism for p-conditioning
preceding NURSE	p-conditiong / i-conditioning	
word-final position	i-conditioning	
preceding START, CURE, NEAR, SQUARE, NORTH/FORCE	i-conditioning	

This typology guides variable selection for this study. We want to include all potential i-conditioning effects (which are of most interest for our research questions), as well as some of the strongest and best-studied p-conditioning effects. The independent variables included are:

- preceding vowel,
- morphological position (morpheme-internal versus word-internal morpheme-final versus word-final),
- prepausal position,
- function word versus content word,

- frequency (on the basis of the spoken BNC (Leech, Rayson, & Wilson, 2001))
- and time during the interview measured in seconds (which gives a very crude measure of shifting style).

Finally, note that past studies also identified external effects on rhoticity, which are summarised in Appendix 1, Table 5A; we can assume that all of these reflect static s-conditioning.

METHODOLOGICAL ISSUES WITH STUDYING INDIVIDUALS

Investigating variation between individuals in conditioning systems is methodologically tricky. We can fit a separate regression model to the data from each speaker and compare them (e.g., Guy, 1980). However, from a purely practical standpoint, we normally do not have enough data per speaker. Moreoever, although we can identify differences in the strengths, directions, and relative orders of coefficients by comparing our models, we do not have a measure of whether those differences were significant. In order to reach his conclusion that individuals agree with the community grammar Guy had to write off a number of disagreeing individuals as the results of statistical noise in small samples, and he noted that at least one reported effect was from a model which did not converge (Guy, 1980:22).

Simply comparing raw rates in different contexts (as was done in several past studies: Horvath & Horvath, 2003; Meyerhoff & Walker, 2007; Poplack & Sankoff, 1987; Tagliamonte, 2013:137-142) creates some of the same problems as using regression analysis (i.e., we don't know whether differences in constraints between different individuals are significant), without the benefits (i.e., we also don't know whether apparent effects are secondary). Tagliamonte (2013:148-149) also used conditional inference trees to compare speakers, but again this offers us no way of deciding whether differences are significant or just the result of small sample sizes.

Returning to regression analysis, we can fit a single model to the whole dataset but add a means to identify individual deviations from the community constraint hierarchy. This can be done by adding fixed interaction terms between speaker and each of our internal predictors or by examining random slopes for speaker/predictor combinations in a mixed effects model (see Forrest, 2015). This gives us a test of whether *at least one* speaker differs from the baseline model for a given predictor (whether the model fit is significantly improved by adding the interaction or by adding random slopes), but does not give us a significance test per speaker/predictor combination or any other way to undertake feature-selection on a per speaker/predictor combination basis. It still potentially suffers from the problems of small data.

Another alternative is elastic net regression (Zou & Hastie, 2005), a method that combines ridge regression with lasso regression. These are methods of fitting regression models which 'penalise' large coefficients in order to avoid overfitting. Like ridge regression, elastic net regression is robust when predictors are highly or even perfectly correlated (as is likely when dealing with a large number of predictors), and shrinks highly inflated coefficients (which sometimes arise when dealing with small datasets). Like lasso regression, it can deal with large numbers of predictors (even where $p > n$) and incorporates a form of automatic feature selection, tending to reduce small coefficients to zero and thus effectively removing them from the model. Thus, an elastic net regression model including interaction terms between speaker and all internal predictors offers us a solution to the problems laid out above:

- the method achieves a parsimonius model by reducing as many coefficients as possible to zero;
- although we have no measure of significance per se for elastic net regression, since it automatically performs variable selection on a per-coefficient basis we can confidently interpret the results for each coefficient that remains in the model;
- the model offers interpretable results with small per-speaker datasets and can converge under perfect separation;
- it is able to deal with highly correlated predictors, which are often a problem with linguistic data.

A fuller explanation of this and related methods is given in the appendix. Here, the implementation of penalised logistic regression from the R package 'penalized' (Goeman. 2009; Goeman et al., 2017) was used to fit a single model for the whole dataset. The model included all of the linguistic variables listed at the end of the 'Independent variables' section above, plus interaction terms between speaker and each of these predictors. The coefficients for non-interaction terms will be described as the 'baseline model': these represent the average constraint ranking for the whole community. The sums of non-interaction and interaction coefficients then give us our models for each speaker (these are given rather than giving the interaction coefficients directly so as to be able to give a constraint ranking for each speaker).[3]

RESULTS

Figure 2 gives the model coefficients[4] for different preceding vowels and Figure 3 for all other predictors (raw cell values on which all coefficients are based are reported in Appendix 1). These figures show roughly the expected picture: preceding vowels favour rhoticity in a hierarchy NURSE > NEAR > START > SQUARE > lettER > NORTH/FORCE. Among other predictors, the largest effects are the favouring effect of prepausal position and the disfavouring effect of being a function word. The magnitudes of other effects are relatively small. All effects except word frequency are in the same directions as identified in the majority of previous studies.

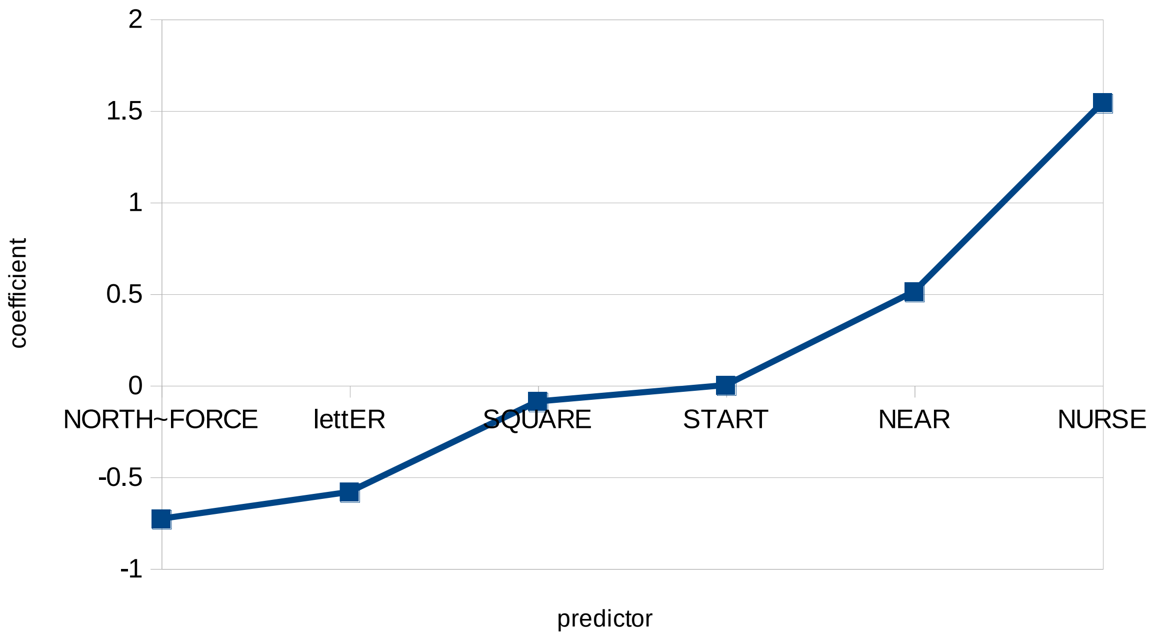

FIGURE 2. Coefficients for preceding vowels (baseline model).

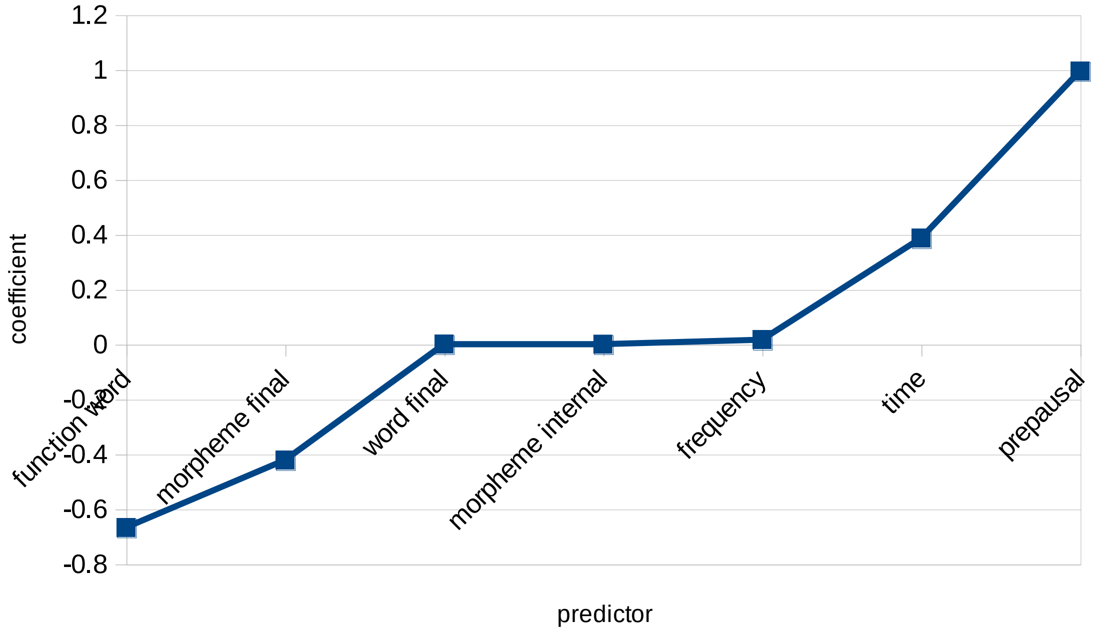

FIGURE 3. Coefficients for other predictors (baseline model).

The interesting results, however, are in individual speaker deviations from this baseline model. Of the 338 possible interactions in the model, 212 had non-zero coefficients. Figure 4 shows the sums of the coefficients of the interaction terms between speaker and preceding vowels and the coefficients of preceding vowels in the baseline model, and Figure 5 shows the same for other predictors; the orders of predictors are the same as in Figure 2 and Figure 3.

At one end of the spectrum, we find speakers whose systems are basically in complete agreement with the community system, cf. the preceding vowel coefficients for speaker b8 (Figure 6[5]) or the coefficients for other predictors for speaker 1 (Figure 7). Most speakers, however, have at least some significant deviations from the common system. At the other extreme, we find highly divergent systems, such as the preceding vowel system of speaker b12 in which NORTH/FORCE and SQUARE slightly favour rhoticity (Figure 8), or the system of other predictors for speaker 24, where prepausal position slightly disfavours rhoticity and most influence comes from morphological position and time (Figure 9).

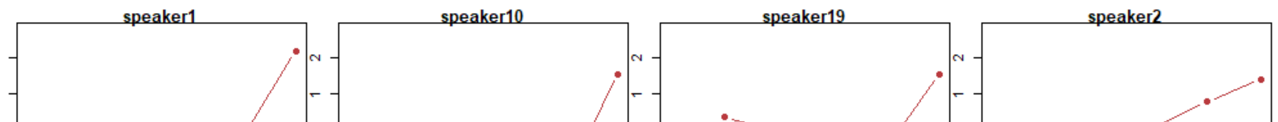
speaker1
speaker10
speaker19
speaker2

FIGURE 4. Coefficients for interactions between speaker and preceding vowel (ordered by speaker number).

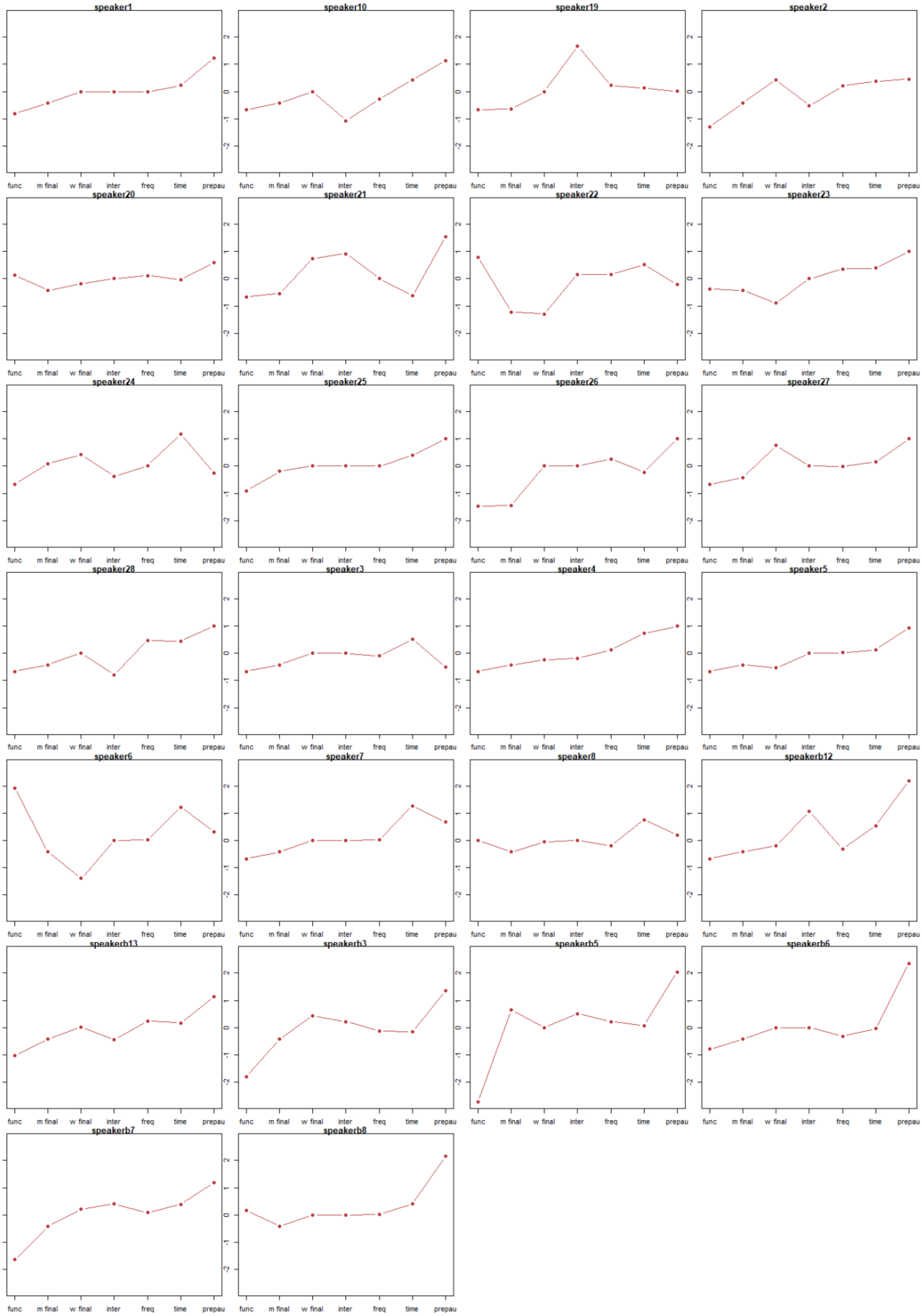

FIGURE 5. Coefficients for interactions between speaker and word class, morphological position, frequency, time and prepausal position (ordered by speaker number).

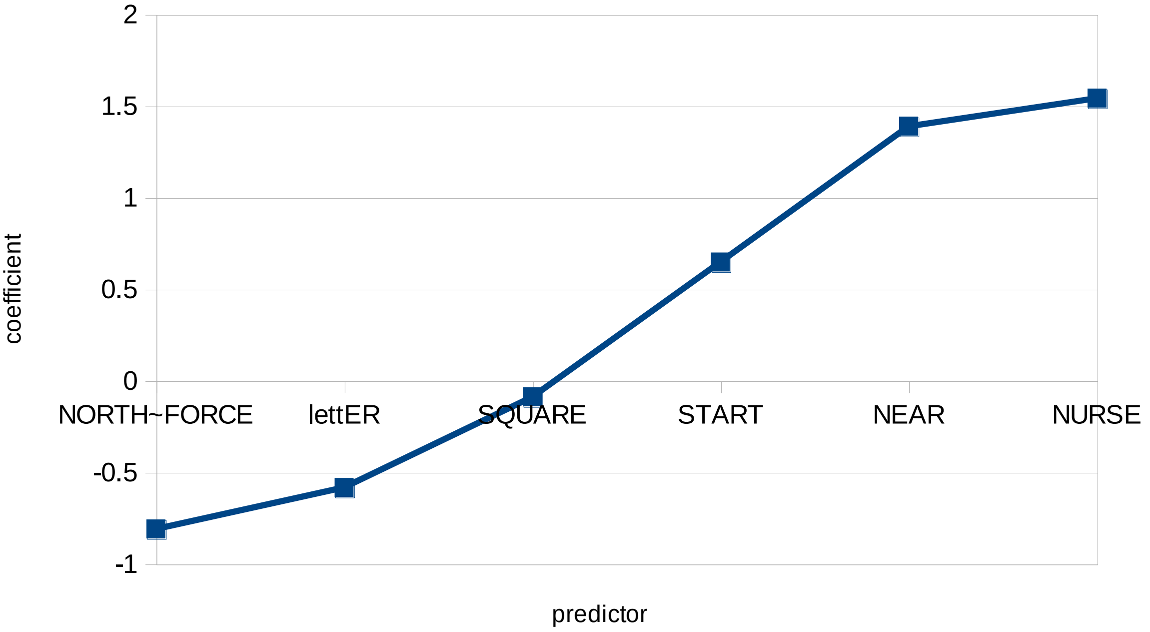

FIGURE 6. Coefficients for preceding vowels (speaker b8).

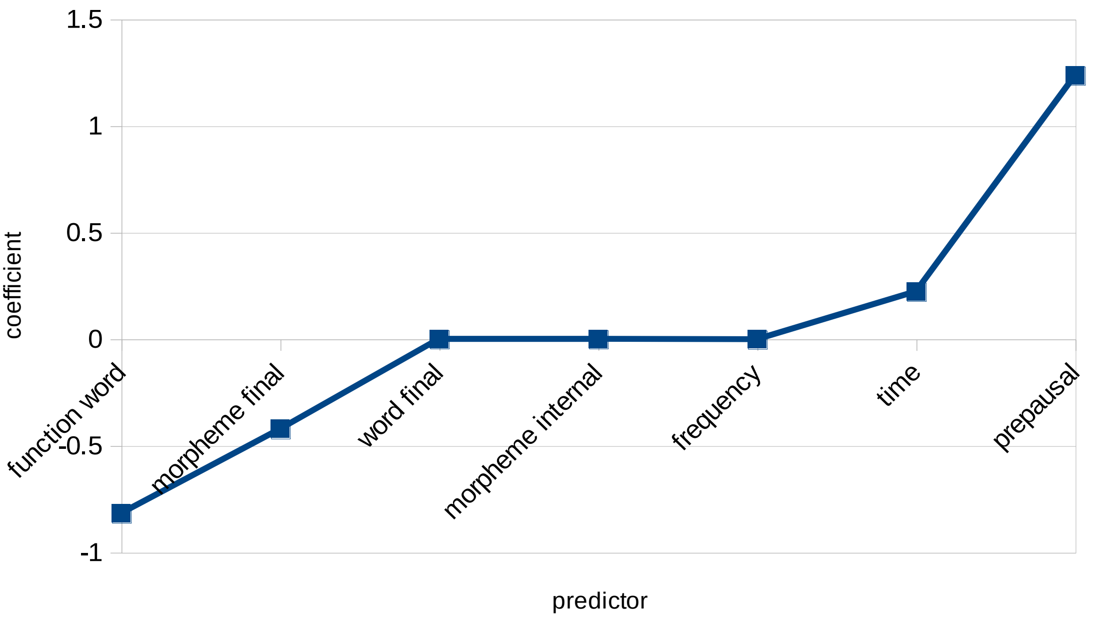

FIGURE 7. Coefficients for other predictors (speaker 1).

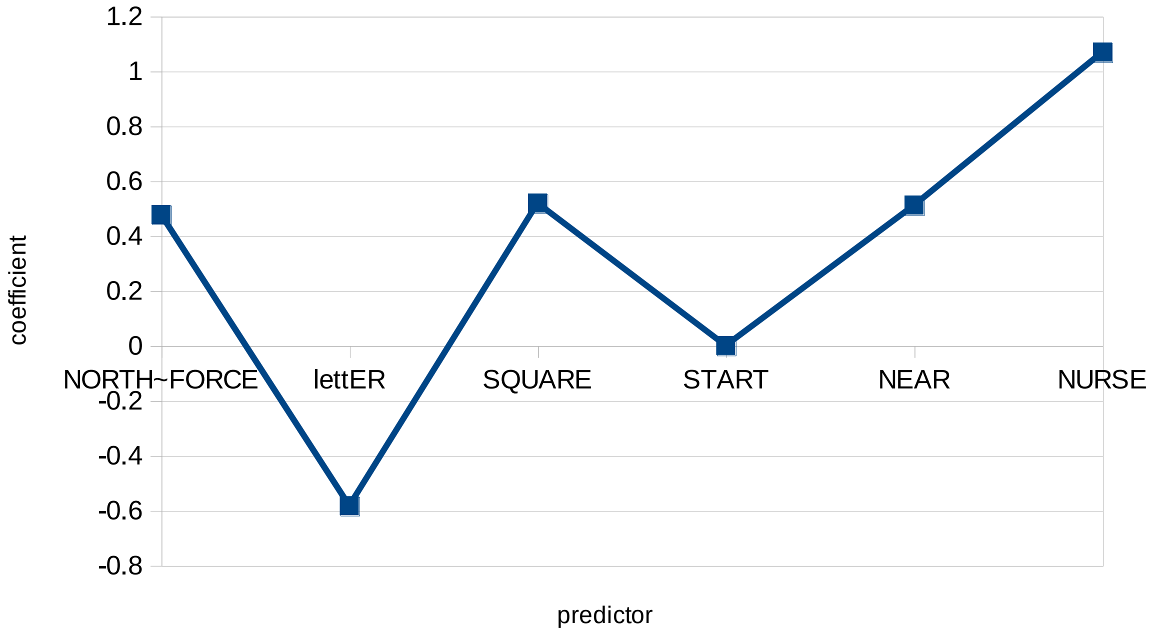

FIGURE 8. Coefficients for preceding vowels (speaker b12).

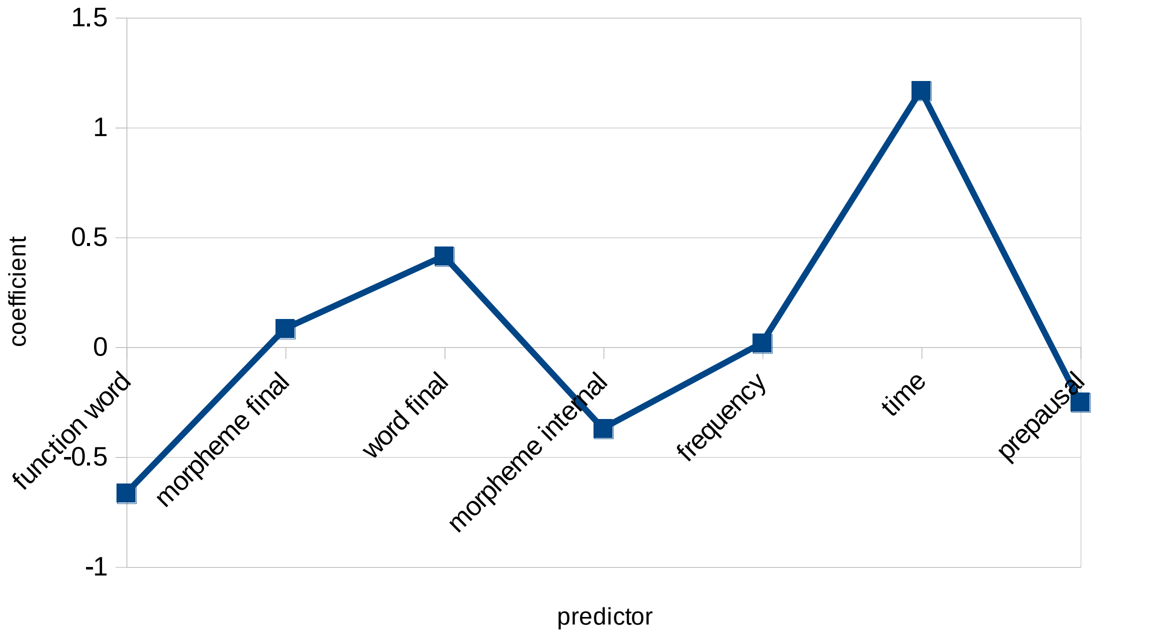

FIGURE 9. Coefficients for other predictors (speaker 24).

One way of measuring speakers' levels of agreement with the community norms is to look at rank correlations between the coefficients of the baseline model and coefficients from individual speaker models (i.e., sums of baseline coefficients and interaction coefficients): a perfect rank correlation would imply that, even if a speaker's system differs from the community norm in details, the overall constraint hierarchy is the same; a correlation coefficient of zero would imply that a speaker's system bore no relation to the community norm. Figure 10 visualises these rank correlation coefficients for vowels and for other predictors. There are no obvious patterns by age or gender: highly agreeing and highly disagreeing speakers are found in the young and old, male and female groups. Note too that there is no significant correlation between these two measures: having a vowel system that deviates from the community norm is not a good predictor of having other effects which deviate from the community norm, and vice versa.

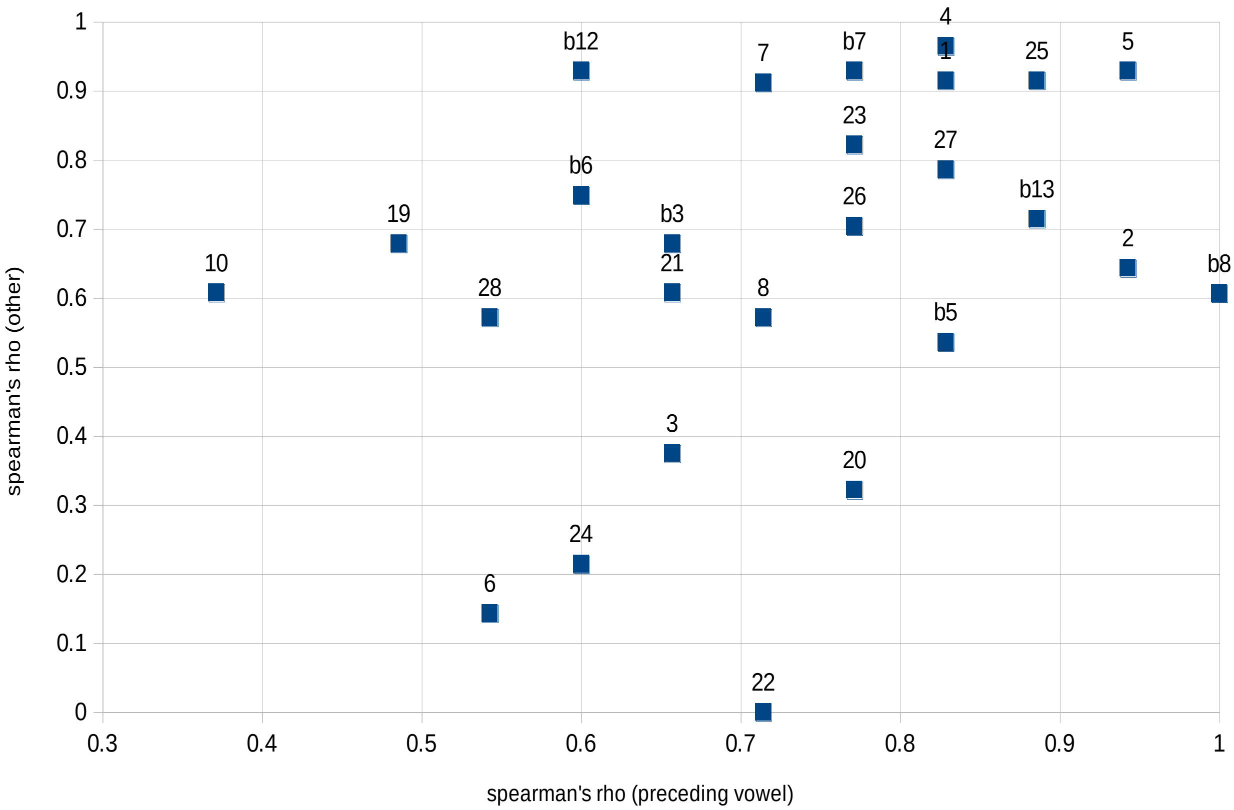

FIGURE 10. Rank correlation coefficients between speaker coefficients and global coefficients.

Turning from speakers to variables, we find some highly consistent predictors. The strongest example is preceding vowel NURSE, which is the most favouring vowel for all but six speakers (and for five of those it is the second most favouring). However, we also find some highly variable predictors such as word final position, which varies from being one of the most favouring contexts for rhoticity (speakers 2, 3, 24, 27, and b8) to the most disfavouring (speakers 6, 22, and 23).

Figure 11 visualises the ranges of coefficients across speakers. In summary, we can say that the following relatively consistently favour rhoticity:

- preceding NURSE (weak reversed effect for speaker 6),
- prepausal position (reversed effect for speakers 3, 22, and 24),
- time in the interview (reversed effect for speakers 21, 26, b3, and b6);

the following relatively consistently disfavour rhoticity:

- function words (with a clearly reversed effect for speakers 6 and 22, and very weakly reversed effects for speakers 8, 20, and b8),
- preceding NORTH/FORCE (reversed effect for speakers 23 and b12),
- preceding lettER (reversed effect for speakers 3, 19, 21, and 26),
- morpheme-final position (reversed effect for speakers b5 and 24);

and the following have inconsistent effects:

- preceding NEAR (favours for 19 speakers but disfavours for speakers 1, 6, 8, 10, 19, 20, and 22),
- word frequency (disfavours for 9 speakers, favours for 18 speakers of which 6 only very weakly),
- morpheme-internal position (disfavours for 6 speakers, neutral for 13 speakers, favours for 7 speakers),
- preceding START (disfavours for 8 speakers, neutral for 10 speakers, favours for 8 speakers),
- word-final position (disfavours for 8 speakers, neutral for 11 speakers, favours for 7 speakers),
- and preceding SQUARE (disfavours for 21 speakers of which 11 only very weakly, favours for speakers 24, 25, b7, b12, and b13).

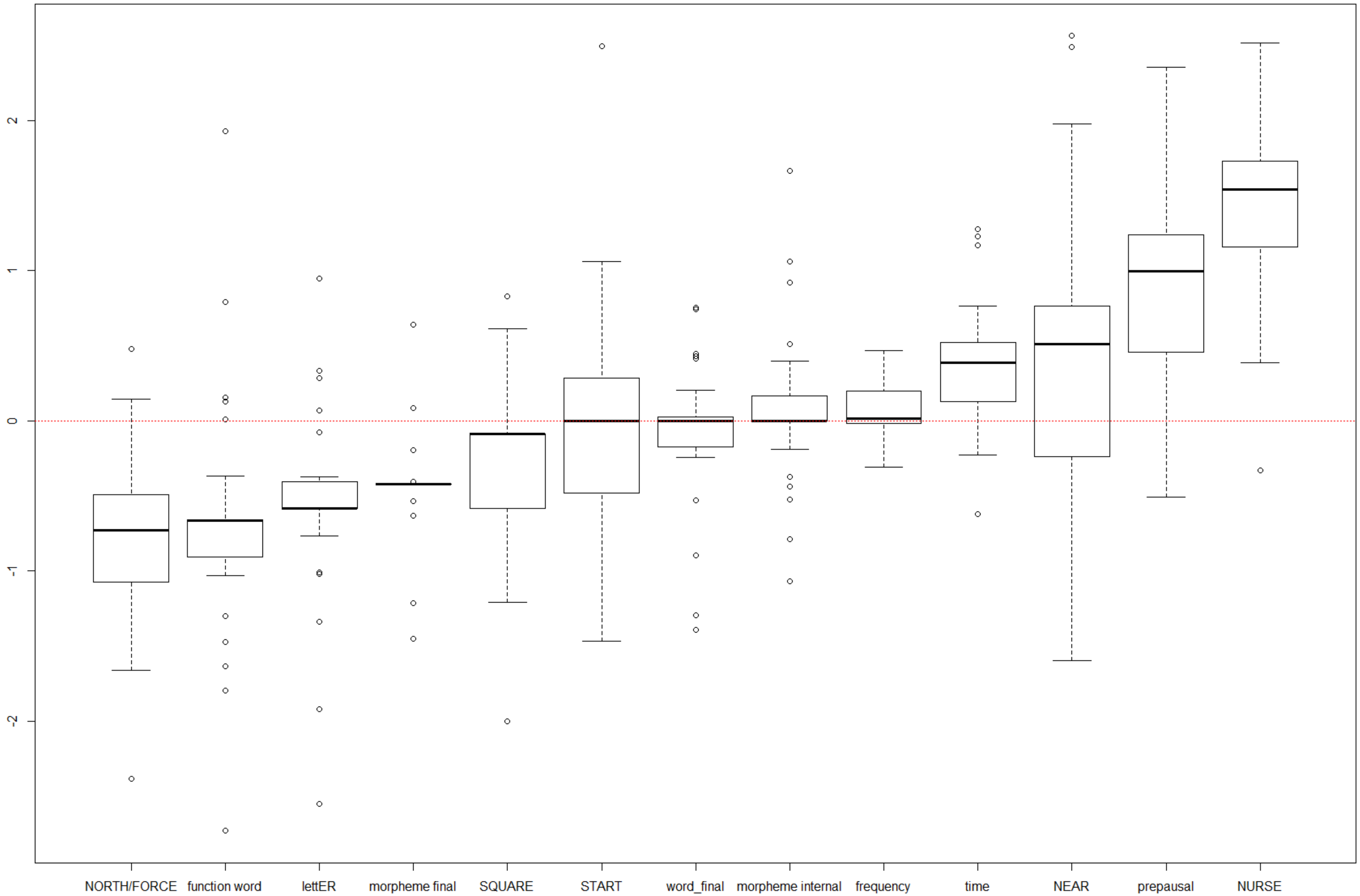
2
1
0
-1
-2
NORTH/FORCE
function word
lettER
morpheme final
SQUARE
START
word_final
morpheme internal
frequency
time
NEAR
prepausal
NURSE

FIGURE 11. Ranges of coefficients across speakers.

DISCUSSION

In the discussion above, we sketched the following scenario:

- following Tamminga et al. (2016), influences on the occurrence of rhoticity fall into three categories, i-conditioning, p-conditioning, and s-conditioning;
- p-conditioning reflects universal physical and psychological factors: excepting interactions with other factors, it should be found to be consistent across studies of different speech communities and (for direction if not necessarily for degree) across individuals within speech communities;
- s- and i-conditioning are community-specific: they should be found to vary across studies of different communities;
- in speech communities undergoing external change (diffusion), s- and i-conditioning should be disrupted and so vary across individuals.

On the basis of these observations, and given that Bristol English is a variety undergoing just such external change, we predicted that:

1. variation across individuals in this study should be substantial, with true reorganisations of systems of constraints;
2. there might be greater consistency for younger speakers, who have koinéised the mixed community input to settle on a common system of constraints;
3. certain factors should recur across all past studies and all individuals within this study; these should otherwise fit the profile of p-conditioning factors;
4. whereas factors which differ across past studies and between individuals in this study should have plausible s- and i-conditioning mechanisms.

Considering the first of these predictions, we find that this is clearly borne out by the data. There are three highly consistent findings across all speakers: preceding NURSE is almost always one of the strongest favouring contexts for rhoticity (the only real exception is speaker b6); preceding NORTH/FORCE always has a disfavouring effect; word frequency is always one of the weakest effects. In every other respect, we find variation across speakers. Comparing the magnitude of coefficients, we find speakers (6, b5, b7) for whom function word status has the largest effect, speakers (21, b6, b8, b12) for whom prepausal position has the largest effect, and many speakers for whom the largest effect is from preceding vowel. There are speakers (7 and 24) for whom the predictor with the third largest magnitude is the time in the interview, suggesting that these speakers showed a particularly high degree of style shifting[6]. Among preceding vowels, there is substantial variation: preceding START ranges from most favouring to least favouring context; preceding NEAR ranges from the most favouring to second most disfavouring; preceding SQUARE and lettER from the second most favouring to most disfavouring. All in all, we find such substantial differences between systems exhibited by different speakers that we cannot describe these as merely minor variations in strengths or reorderings of otherwise-similar effects: it is only reasonable to describe these as true reorganisations of systems of constraints.

Our second prediction fares much more poorly. There are younger speakers (such as speaker 5) whose systems agree relatively well with the global model, but there are also younger speakers with highly divergent systems (such as speaker 6, whose function word constraint is reversed); the same is true of older speakers. Overall, there is no evidence that inter-individual variation is lessening with successive generations of speakers.

Turning to the third prediction, we do find some convincing examples. Function words consistently disfavour rhoticity across past studies and across all but two speakers in this study. An obvious mechanism for this effect is that function words are chronically understressed and so more subject to lenition and fast-speech processes: this is a mechanical consequence of the nature of function words and so qualifies as p-conditioning. There is no reason to think this constraint is part of competence for these speakers (although hypothetically it could easily give rise to a truly linguistic constraint, such as by developing into a lexical split where function words lose underlying rhoticity but content words do not).

Likewise, the preceding vowel lettER seems a good candidate for p-conditioning. This disfavours rhoticity across a large majority of previous studies, and it disfavours rhoticity for a large majority of speakers in this study. Again, the mechanism here would be to do with stress: lettER is the only fully unstressed rhotic vowel.

The influence of prepausal position on rhoticity may also reflect p-conditioning: it favours rhoticity for all but three speakers in this study, and favours rhoticity in all but one previous study. Here, the mechanism is presumably derived from phrase-final lengthening, with rhoticity more likely to be preserved in lengthened syllables and words; since this phrase-final lengthening is a common phenomenon across languages, there is no reason to imagine this effect would be part of learnt competence. The varying size of this effect across speakers in this study might reflect individual differences in speech-rate or propensity for phrase-final lengthening.

Turning to our fourth prediction, we find several effects which fit well into our account. The inclusion of time in the model can give us a (very crude) measure of style shifting—dynamic s-conditioning in the terms of Tamminga et al. (2016)—and as expected for s-conditioning, we see variation across individuals. Some speakers (such as 7 or 24) substantially increase their rate of rhoticity over the course of the interview, whilst others (such as speaker 20 or b5) show close to no change and a few (21, 26 and b3) *de*crease their rate of rhoticity over the course of the interview.

In terms of i-conditioning, the preceding vowels SQUARE, START, and NEAR clearly behave as predicted for i-conditioning factors: the effects of these contexts vary both between past studies and between individuals in this study, implying that they are learnt effects which can be disrupted by diffusion. Likewise, the effects of morphological context (a following word boundary versus a following word-internal morpheme boundary versus neither) are inconsistent across previous studies and inconsistent across Bristol English speakers, suggesting that these are arbitrary, learnt effects that are part of the grammar and can be disrupted by diffusion.

Three effects are a problem for our account and deserve closer comment. The favouring effect of preceding vowel NURSE on rhoticity is very consistent across speakers in this study and one of the most consistent across past studies, suggesting that it might reflect p-conditioning, yet there is no immediately obvious universal mechanical or psychological mechanism to account for it. Similarly, the disfavouring effect of preceding NORTH/FORCE on rhoticity is quite consistent across previous studies and very consistent across speakers in this study. It is, of course, possible that these reflect i-conditioning factors that simply happen to be consistent across all varieties of English studied. If this were the case, we might hypothesise that they would be less liable to disruption by diffusion, since they would be a constant across all varieties a potential diffuser was exposed to, explaining their inter-speaker consistency in this study.

A different possibility is that these are explained by structural phonological factors. Considering the loss of rhoticity, we could classify words by whether the change is a merger—that is, the phonological transfer of the word from one class into another existing class—or involves the creation of a new vowel phoneme. By this classification, NORTH/FORCE words are at one end of the spectrum (the THOUGHT vowel and for some speakers the CLOTH vowel are large, well-established lexical sets into which NORTH/FORCE words are transferred) whereas NURSE words are at the other (there is no other source of /ɜː/). Other lexical sets fall between these extremes, with the loss of rhoticity involving transfer into marginal existing sets (IDEA for NEAR, YEAH for SQUARE) or sets which only exist in certain varieties (BATH for START only in varieties with the TRAP/BATH split, a phenomenon discussed more extensively in Blaxter & Coates [forthcoming]). The one other preceding vowel for which loss of rhoticity involves merger into a large, well-established lexical set is lettER, which merges with commA, and this vowel, like NORTH/FORCE, consistently disfavours rhoticity across speakers and past studies. This implies that there may be a universal psychological mechanism at work here: that it is easier to transfer a word into an existing phonemic class than it is to create a new phoneme.

Finally, word frequency fails to fit our predicted picture: more frequent words consistently disfavoured rhoticity in (admittedly only three) past studies, but had a small and inconsistent *positive* influence on rhoticity for Bristol English speakers. Here, we have two possibilities. Firstly, it is possible that this reflects i-conditioning and that the sample of previous studies is simply too small to have identified the fact that the direction of this effect can differ between varieties. However, the problem would then be that it seems very unlikely *a priori* that word frequency is a variable that can be involved in i-conditioning, since it is not a variable that can be involved in categorical grammatical rules (no language, for example, has one allomorph which is used on stems above a certain threshold frequency in connected discourse and a different allomorph for other stems). We must turn, then, to the second possibility, which is that there is some methodological problem in the approach to frequency in this study or in past studies: either the source of frequency data used here (the spoken component of the British National Corpus) is not a good measure of frequency for these speakers, the effect is too small to capture accurately in the datasets used, or an interaction with other predictors interferes with the effect. There is, in fact, good evidence for this last conclusion: the three studies which found that higher word frequency disfavoured rhoticity did not investigate the effect of function versus content word status, and the one past study which investigated both found no effect of frequency. As the most frequent words are typically function words, it is likely that past findings that frequency favours rhoticity are due to the status of function words, explaining the disagreement with the findings of this study.

TABLE 4: *Comparison of effects across previous studies and across Bristol English speakers*

Variable	**Previous studies**	**Bristol speakers**
preceding NORTH/FORCE	consistently disfavour	consistently disfavour
preceding lettER	consistently disfavour	consistently disfavour
preceding SQUARE	inconsistent	inconsistent
preceding START	inconsistent	inconsistent
preceding NEAR	inconsistent	inconsistent
preceding NURSE	consistently favour	consistently favour
function word	consistently disfavour	consistently disfavour
morpheme final	inconsistent	inconsistently disfavour
word final	inconsistent	inconsistent
word frequency	consistently disfavour	inconsistent
morpheme internal		inconsistent
time		inconsistently favour
prepausal	consistently favour	consistently favour

CONCLUSIONS

This study has proposed that, in light of Labov's (2007) transmission-diffusion distinction and the work of Tamminga et al. (2016) on the nature of constraints on variation, more attention must be paid to individual differences in the conditioning of variables within speech communities. What is more, it has proposed that the standard variationist methodology of pooling data from multiple speakers in order to investigate variable conditioning may be flawed in some cases: if there is substantial individual variation in conditioning systems, which may be typical of cases of ongoing diffusion, the pooling method may miss this variation; in such cases it may also be less effective at identifying precisely those effects in which variationists are usually most interested, effects which are part of the grammar (i-conditioning). In order to investigate these claims, data on rhoticity variation from speakers of Bristol English were compared to 34 previous studies of rhoticity in varieties of English around the world.

In keeping with predictions, it was observed that certain factors have highly consistent effects across different varieties studied and across speakers in Bristol English. This is taken as suggestive that these effects reflect universal physical (in the case of function word, prepausal position and preceding lettER) or structural-psychological (in the case of NURSE/NORTH/FORCE) factors; this suggests that these effects may not be learnt and encoded in the grammar. Other factors had variable effects both across past studies and across speakers in this study, offering evidence that they are part of the grammar and so subject to disruption through imperfect learning when undergoing external change.

Contrary to predictions, there was no indication that younger speakers had more consistent variable grammars than older speakers. This implies that no process of koinéisation, in which new generations of speakers systematise and simplify unstructured variation in the input generated by contact and diffusion, has taken place. This is perhaps unsurprising in light of the fact that the external pressure to change (knowledge of prestigious SSBE/RP) has remained a constant for the entire trajectory of the change. There was no defined period of contact and diffusion after which disrupted grammars could be transmitted and koinéised: rather, contact, adult change, and accordingly new disruption have presumably continued to take place throughout.

These findings problematise both the notion of the community grammar and the method of pooling data from multiple speakers when studying certain communities. From a conceptual standpoint, it is not clear that a notion of speech community as defined by shared grammar is tenable for data like those presented here (although by the definition of shared evaluative norms, it might still be). If the idea that individuals in the speech community share underlying production norms is understood as an assumption rather than as definitional, these data suggest that it should instead be seen as a hypothesis that must be confirmed for any given dataset. Either way, the rich individual variation in these data suggest that we should be wary of investigating variable conditioning in data pooled from multiple speakers without first investigating how much those speakers' grammars differ from one another. Not only does this give us a better chance of identifying real grammatical constraints that can vary between speakers, it also provides us with evidence for the nature and interpretation of the effects we find.

NOTES

1. Female speakers probably lead the change, as expected for an ongoing change from above (Labov, 1990), but interaction with effects of social class and occupation make this difficult to demonstrate for this small sample population (see Blaxter et al., forthcoming).
2. Token counts broken down by speaker and by linguistic variables are given in Appendix 1 Table 1A and 2A.
3. The optimal values for the penalty terms were set using a combination of grid- and random-search to minimise the Aikaike information criterion (AIC): $\lambda 1$ was set at 0.62497 and $\lambda 2$ at 0.00101. Of 378 possible coefficients, 242 were non-zero; the coefficients reduced to zero are effectively removed from the model. The (near-)categorical speakers b1, b2, 9, and 11 were not included in the model. Categorical predictors (morphological position, preceding vowel) were sum-coded. Word frequency and time in the interview were scaled and centred such that they had mean 0 and standard deviation 1. There is currently no equivalent of a random effect in elastic net models and so no control for lexical item was included in this study.
4. Coefficients from a logistic elastic net model can be interpreted just as coefficients from a normal logistic regression model (given here in log odds).
5. This and other individual speaker figures simply reproduce and enlarge panels from the composites Figure 4 and Figure 5.
6. It is impossible to tell from these data alone whether this indicates that style is a particularly important control of rhoticity for these speakers or whether these were particularly stylistically dynamic interviews.

APPENDIX 1: CELL VALUES AND SUMMARIES OF PREVIOUS STUDIES

TABLE 1A. *Rhotic tokens out of total tokens per speaker / vowel combination*

speaker	lettER	NEAR	NORTH/FORCE	NURSE	SQUARE	START
1	2/20 (10%)	2/15 (13.33%)	1/20 (5%)	16/20 (80%)	4/20 (20%)	6/20 (30%)
10	10/20 (50%)	2/10 (20%)	6/20 (30%)	16/20 (80%)	2/20 (10%)	9/20 (45%)
19	15/20 (75%)	7/15 (46.67%)	9/20 (45%)	20/20 (100%)	13/20 (65%)	18/20 (90%)
2	10/20 (50%)	14/17 (82.35%)	11/20 (55%)	16/20 (80%)	9/20 (45%)	12/20 (60%)
20	2/20 (10%)	2/20 (10%)	3/20 (15%)	6/20 (30%)	2/20 (10%)	7/20 (35%)
21	20/20 (100%)	12/13 (92.31%)	15/20 (75%)	20/20 (100%)	19/20 (95%)	19/20 (95%)
22	2/20 (10%)	1/20 (5%)	0/20 (0%)	14/20 (70%)	4/20 (20%)	2/20 (10%)
23	8/20 (40%)	8/12 (66.67%)	15/20 (75%)	17/20 (85%)	8/20 (40%)	13/16 (81.25%)
24	10/20 (50%)	14/14 (100%)	8/20 (40%)	19/20 (95%)	8/11 (72.73%)	5/16 (31.25%)
25	9/20 (45%)	8/10 (80%)	8/20 (40%)	17/19 (89.47%)	9/14 (64.29%)	4/8 (50%)
26	13/20 (65%)	7/20 (35%)	8/20 (40%)	19/20 (95%)	5/20 (25%)	9/20 (45%)
27	16/20 (80%)	15/17 (88.24%)	12/20 (60%)	20/20 (100%)	14/20 (70%)	13/20 (65%)
28	0/20 (0%)	6/20 (30%)	1/20 (5%)	1/20 (5%)	4/20 (20%)	0/20 (0%)
3	14/20 (70%)	15/20 (75%)	13/20 (65%)	16/20 (80%)	6/13 (46.15%)	11/12 (91.67%)
4	1/19 (5.26%)	5/20 (25%)	1/20 (5%)	4/20 (20%)	0/20 (0%)	3/20 (15%)
5	11/20 (55%)	11/16 (68.75%)	6/20 (30%)	18/20 (90%)	8/20 (40%)	18/20 (90%)
6	1/20 (5%)	0/9 (0%)	0/20 (0%)	7/20 (35%)	3/20 (15%)	0/12 (0%)
7	1/20 (5%)	3/6 (50%)	0/20 (0%)	11/20 (55%)	0/17 (0%)	0/12 (0%)
8	7/20 (35%)	3/15 (20%)	2/20 (10%)	14/20 (70%)	2/20 (10%)	9/20 (45%)
b12	91/118 (77.12%)	23/26 (88.46%)	108/128 (84.38%)	135/141 (95.74%)	76/92 (82.61%)	50/61 (81.97%)
b13	77/143 (53.85%)	41/42 (97.62%)	51/170 (30%)	112/135 (82.96%)	70/91 (76.92%)	34/53 (64.15%)
b3	98/118 (83.05%)	33/37 (89.19%)	49/65 (75.38%)	72/74 (97.3%)	33/51 (64.71%)	27/27 (100%)

speaker	lettER	NEAR	NORTH/FORCE	NURSE	SQUARE	START
b5	184/213 (86.38%)	43/43 (100%)	166/171 (97.08%)	133/133 (100%)	102/108 (94.44%)	90/90 (100%)
b6	71/87 (81.61%)	29/29 (100%)	69/77 (89.61%)	50/54 (92.59%)	60/68 (88.24%)	24/25 (96%)
b7	108/115 (93.91%)	18/18 (100%)	94/101 (93.07%)	68/69 (98.55%)	95/98 (96.94%)	54/54 (100%)
b8	141/149 (94.63%)	67/67 (100%)	128/138 (92.75%)	72/72 (100%)	105/108 (97.22%)	40/40 (100%)

TABLE 2A. *Rhotic tokens out of total tokens per speaker and other context*

speaker	morpheme final	morpheme internal	word final	non-prepausal	prepausal	content word	function word
1	8/24 (33.33%)	16/45 (35.56%)	7/46 (15.22%)	26/103 (25.24%)	5/12 (41.67%)	28/84 (33.33%)	3/31 (9.68%)
10	7/23 (30.43%)	23/44 (52.27%)	15/43 (34.88%)	35/94 (37.23%)	10/16 (62.5%)	38/80 (47.5%)	7/30 (23.33%)
19	10/21 (47.62%)	49/54 (90.74%)	23/40 (57.5%)	72/99 (72.73%)	10/16 (62.5%)	67/87 (77.01%)	15/28 (53.57%)
2	10/21 (47.62%)	30/46 (65.22%)	32/50 (64%)	59/98 (60.2%)	13/19 (68.42%)	56/83 (67.47%)	16/34 (47.06%)
20	3/24 (12.5%)	12/45 (26.67%)	7/51 (13.73%)	18/99 (18.18%)	4/21 (19.05%)	16/85 (18.82%)	6/35 (17.14%)
21	18/21 (85.71%)	38/39 (97.44%)	49/53 (92.45%)	90/98 (91.84%)	15/15 (100%)	74/79 (93.67%)	31/34 (91.18%)
22	2/25 (8%)	14/37 (37.84%)	7/58 (12.07%)	21/102 (20.59%)	2/18 (11.11%)	16/85 (18.82%)	7/35 (20%)
23	14/23 (60.87%)	31/37 (83.78%)	24/48 (50%)	45/75 (60%)	24/33 (72.73%)	49/71 (69.01%)	20/37 (54.05%)
24	19/23 (82.61%)	25/44 (56.82%)	20/34 (58.82%)	53/83 (63.86%)	11/18 (61.11%)	51/77 (66.23%)	13/24 (54.17%)
25	14/20 (70%)	22/30 (73.33%)	19/41 (46.34%)	41/72 (56.94%)	14/19 (73.68%)	45/66 (68.18%)	10/25 (40%)
26	11/31 (35.48%)	21/32 (65.63%)	29/57 (50.88%)	58/116 (50%)	3/4 (75%)	43/72 (59.72%)	18/48 (37.5%)
27	22/30 (73.33%)	29/38 (76.32%)	39/49 (79.59%)	87/114 (76.32%)	3/3 (100%)	62/78 (79.49%)	28/39 (71.79%)
28	4/20 (20%)	1/45 (2.22%)	7/55 (12.73%)	9/103 (8.74%)	3/17 (17.65%)	7/84 (8.33%)	5/36 (13.89%)
3	9/16 (56.25%)	36/44 (81.82%)	30/45 (66.67%)	63/84 (75%)	12/21 (57.14%)	59/76 (77.63%)	16/29 (55.17%)
4	3/19 (15.79%)	6/42 (14.29%)	5/58 (8.62%)	11/110 (10%)	3/9 (33.33%)	13/87 (14.94%)	1/32 (3.13%)
5	13/22 (59.09%)	35/43 (81.4%)	24/51 (47.06%)	64/103 (62.14%)	8/13 (61.54%)	58/80 (72.5%)	14/36 (38.89%)
6	2/15 (13.33%)	7/41 (17.07%)	2/45 (4.44%)	7/72 (9.72%)	4/29 (13.79%)	7/73 (9.59%)	4/28 (14.29%)
7	1/18 (5.56%)	10/33 (30.3%)	4/44 (9.09%)	11/76 (14.47%)	4/19 (21.05%)	13/67 (19.4%)	2/28 (7.14%)
8	6/19 (31.58%)	18/40 (45%)	13/56 (23.21%)	31/95 (32.63%)	6/20 (30%)	28/78 (35.9%)	9/37 (24.32%)
b12	46/57 (80.7%)	186/191 (97.38%)	251/318 (78.93%)	403/484 (83.26%)	80/82 (97.56%)	297/323 (91.95%)	186/243 (76.54%)
b13	58/88 (65.91%)	125/208 (60.1%)	202/338 (59.76%)	266/482 (55.19%)	119/152 (78.29%)	247/377 (65.52%)	138/257 (53.7%)

speaker	morpheme final	morpheme internal	word final	non-prepausal	prepausal	content word	function word
b3	51/69 (73.91%)	80/83 (96.39%)	181/220 (82.27%)	200/251 (79.68%)	112/121 (92.56%)	200/218 (91.74%)	112/154 (72.73%)
b5	94/95 (98.95%)	229/229 (100%)	395/434 (91.01%)	496/535 (92.71%)	222/223 (99.55%)	471/476 (98.95%)	247/282 (87.59%)
b6	41/46 (89.13%)	82/87 (94.25%)	180/207 (86.96%)	185/220 (84.09%)	118/120 (98.33%)	186/203 (91.63%)	117/137 (85.4%)
b7	62/67 (92.54%)	127/128 (99.22%)	248/260 (95.38%)	325/342 (95.03%)	112/113 (99.12%)	275/280 (98.21%)	162/175 (92.57%)
b8	95/100 (95%)	144/149 (96.64%)	314/325 (96.62%)	426/447 (95.3%)	127/127 (100%)	325/338 (96.15%)	228/236 (96.61%)

TABLE 3A. *Internal effects on rhoticity reported in previous studies*

Study	variety/ies	direction	preceding vowel	tautosyllabic C	other /r/	prepausal	morpheme-final	word-final	stress	emphasis	functionword	word length	word frequency
Asprey, 2007	Black Country	non-rhoticity	*	+									
Barras, 2010	Lancashire	non-rhoticity	back vowels > front vowels*			+	-	-	+				
Baxter, 2008	Quebec	rhoticity	*					+					
Becker, 2014	New York City	rhoticity	*	+		+	-	-	+		-		
Dudman, 2000	Cornwall	non-rhoticity	*					-	+				
Elliott, 2000	American films	rhoticity											
Ellis, Groff, & Mead, 2006	Philadelphia	rhoticity			-								
Feagin, 1990	Alabama	rhoticity	*	+									
French, 1988	Yorkshire	non-rhoticity				+							
Hartmann & Zerbian, 2010	South Africa	rhoticity		0						+			
Hinton & Pollock, 2000	Iowa	*	0						+				
Hollitzer, 2013	Berkshire, Wiltshire, Somerset	non-rhoticity	*	+									
Irwin & Nagy, 2007	Boston	rhoticity	back vowels > front vowels*	+			0	+			-	-	0
Jones, 1998	Devon; West Somerset	non-rhoticity	*										
Labov, 1966 [1972]	New York City	rhoticity	*					+					
Miller, 1998	Philadelphia	rhoticity	*		-								
Myhill, 1988	Philadelphia	non-rhoticity	*	0	-	-		0	+				

Study	variety/ies	direction	preceding vowel	tautosyllabic C	other /r/	prepausal	morpheme-final	word-final	stress	emphasis	functionword	word length	word frequency
Nagy & Irwin, 2010	Boston; New Hampshire	rhoticity		+	0	+	-	-					-
Parslow, 1967, 1971	Boston	rhoticity	NURSE > other vowels										
Piercy, 2006, 2007, 2012	Dorset	non-rhoticity	*	+		+	*	-	+		0		-
Pollock & Berni, 1997	Tennessee	*	*										
Schützler, 2010	Edinburgh	non-rhoticity				+			+				
Sharbawi & Deterding, 2010	Brunei; Singapore	rhoticity	0										
Simpson, 1996	Shropshire	non-rhoticity						-	+				
Sudbury & Hay, 2002[1]	New Zealand	non-rhoticity	back vowels > front vowels						+				-
Sullivan, 1992	Devon	non-rhoticity						-					
Trudgill & Gordon, 2006	Australia	non-rhoticity	*										
Villard, 2009	New Hampshire; Vermont	rhoticity	*										
Vivian, 2000	Lancashire	non-rhoticity	*					-	+				
Watt, Llamas, & Johnson, 2014	Scottish-English Border	non-rhoticity		*									
Williams, 1991	Isle of Wight	non-rhoticity											

Note: Key: + = favours rhoticity, - = disfavours rhoticity, 0 = no effect, * = mixed or multiple effects

TABLE 4A. *Effects of preceding vowel on rhoticity reported in previous studies*

Study	**Variety**	**Effect of preceding vowel**
Asprey, 2007:96-98	Black Country	NURSE > lettER > SQUARE > NEAR > NORTH > START
Barras, 2010:115, 175	Lancashire	back vowels > front vowels FORCE > NURSE > START > NORTH > SQUARE > NEAR > lettER
Baxter, 2008	Stanstead (Quebec)	NURSE > back vowels > front vowels > lettER
Becker, 2014:155-156	New York City	NURSE > NEAR > START > SQUARE > NORTH/FORCE[2]
Dudman, 2000:36	Cornwall	CURE > START (f) > NURSE > NEAR > SQUARE > NORTH/FORCE > START (b) > lettER (?)
Feagin, 1990:132	Alabama	NURSE > NEAR > SQUARE > START > NORTH > FORCE > lettER
Hinton & Pollock, 2000	Davenport (Iowa)	no effect[3]
Hollitzer, 2013	Berkshire, Wiltshire, Somerset	NURSE > lettER > other vowels (?NURSE > NEAR > lettER > START > SQUARE > NORTH/ FORCE)[4]
Irwin & Nagy, 2007:140-142; Nagy & Irwin, 2010:256-257	Boston & New Hampshire	NURSE > START > SQUARE > CURE > NEAR > NORTH/ FORCE > lettER
Jones, 1998	Devon, West Somerset	START > FUR > 'farmer, darning', NORTH/ FORCE > FIR
Labov, 1972	New York City	NURSE > lettER back vowels > front vowels
Miller, 1998	Philadelphia	NURSE > all other vowels > lettER
Myhill, 1988	Philadelphia	NURSE > all other vowels > lettER (more integrated into white community) NURSE > START > all other vowels (less integrated into white community)
Nagy & Irwin, 2010:258-259, 277	Boston	NURSE > START > CURE > FUR > NORTH/ FORCE > NEAR > lettER > SQUARE (older speakers) CURE > START > NURSE > SQUARE > NEAR > NORTH/ FORCE > lettER (younger speakers)
Nagy & Irwin, 2010:260, 277-278	New Hampshire	NURSE > SQUARE > NEAR > START > NORTH/ FORCE > lettER (older speakers) START > SQUARE > NORTH/ FORCE > NURSE > NEAR > lettER (younger speakers)[5]

Study	Variety	Effect of preceding vowel
Parslow, 1967; 1971	Boston	NURSE > other vowels
Piercy, 2012:81-82[6]	Dorset	NURSE > NEAR > START > lettER > CURE > SQUARE > NORTH/ FORCE
Pollock & Bernie, 1997	Memphis (Tennessee)	NURSE > front vowels > back vowels > lettER
Sharbawi & Deterding, 2010	Brunei, Singapore	no effect[7]
Sudbury & Hay, 2002:289-290	New Zealand	back vowels > front vowels[8]
Sullivan, 1992:82-83	Exeter	(NEAR) > NURSE >START > SQUARE > FORCE > lettER > NORTH
Trudgill & Gordon, 2006:240	Austalian English	NORTH/ FORCE, lettER > others[9]
Villard, 2009	Upper Valley (New Hampshire, Vermont)	NURSE > lettER

TABLE 5A1: External effects on rhoticity reported in previous studies (cells report the social group found to favour rhoticity)

Study	Variety	gender	class	ethnicity	locality	style	exposure
Elliott, 2000	American films	female					
Becker, 2014	New York	female	middle-class	change only for white & Jewish		formal	
Feagin, 1990	Alabama	female	workin-class				
Irwin & Nagy, 2007	Boston	*	middle-class				
Nagy & Irwin, 2010	Boston, New Hampshire	*	*	0			
Ellis, Groff, & Mead, 2006	Philadelphia	*		disfavoured by African Americans			
Villard, 2009	Upper Valley (New Hampshire, Vermont)	female	middle-class				
Baxter, 2008	Stanstead (Quebec)	female	middle-class				
Parslow, 1967, 1971	Boston (Massachusetts)						
Labov, 1966 [1972]	New York	female		favoured by whites		formal	
Myhill, 1988	Philadelphia			0 (but favoured by speakers more integrated into the white community)			
Miller, 1998	Philadelphia			favoured by African Americans			
Hinton & Pollock, 2000	Davenport (Iowa)					0	
Pollock & Berni, 1997	Memphis					0	
Cychosz & Johnson, 2017	American English (Buckeye Corpus)	female					

Study	Variety	gender	class	ethnicity	locality	style	exposure
Hartmann & Zerbian, 2010	South Africa	female	affluent				
Sharbawi & Deterding, 2010	Brunei; Singapore						
Asprey, 2007	Black Country				rural		
Barras, 2010	Lancashire				rural		
Vivian, 2000	Lancashire	male			*		
Jones, 1998	Devon; West Somerset						
Piercy, 2007	Dorset	male			rural		
Williams, 1991	Isle of Wight					minimal pairs wordlist > casual speech > wordlist	
Sudbury & Hay, 2002	New Zealand				*		
Trudgill & Gordon, 2006	Australia						
Watt, Llamas, & Johnson, 2014	Scottish-English Border				*		
Schützler, 2010	Edinburgh	male				wordlist	more exposed to SSBE
Sullivan, 1992	Devon	male	working-class			casual speech	
Simpson, 1996	Shropshire						
Dudman, 2000	Cornwall					casual speech	
French, 1988	Yorkshire						
Hollitzer, 2013	Newbury, Swindon, Taunton				western		

Appendix 2: Penalised regression

Elastic net regression is not widely used in linguistics. Since it is best understood through the matrix approach to regression, we start by describing ordinary least squares regression for context, before describing the different forms of penalised regression: ridge, lasso, and elastic net regression.[10]

Least squares regression

In normal linear regression, we have a set of p predictor variables $x_1, x_2 ... x_p$ and a response variable y. We aim to estimate the values of coefficients $\beta_1, \beta_2 ... \beta_p$ such that:

$$y = \beta_1 x_1 + \beta_2 x_2 + ... + \epsilon$$

where ϵ is Gaussian white noise. We have t observations of our predictor and response variables, so that we actually have a vector$y$responses of length t, a t by p matrix of predictors X called the design matrix, a vector of random noise ϵ, and a vector of coefficients β. We can then express our model as:

$$y = X\beta + \epsilon$$

We estimate the best possible values ofβusing a method called least squares, which minimises the sum of squared residuals:

$$\sum |y - X\beta|^2$$

The solution to this is the matrix equation is:

$$\beta = (X^T X)^{-1} X^T y$$

where X^T is the transpose of the design matrix X and $(X^T X)^{-1}$ is the inverse of $X^T X$. This gives us an estimation of β which is unbiased and as precise as possible.

Ridge regression

This procedure fails when some of the predictors are highly correlated. From a conceptual standpoint, this is easy to understand. If two predictors rise and fall in tandem, and these rises and falls are linearly related to changes in the response variable, it is difficult or impossible to determine which of the two predictors is responsible for the changes in the response. The 'best' result we can achieve will be coefficient estimates with very large errors, representing the fact that either predictor might actually be irrelevant if all of the observed effects is assigned to the other predictor. From the point of view of our least squares method, if two predictors (two columns of our design matrix) are perfectly correlated then $X^T X$ has a determinant equal to zero and so has no inverse. If two predictors are nearly perfectly correlated, the determinant of $X^T X$ is close to zero and so it is difficult to find the inversion precisely.

In ridge regression, we solve this problem by using a different method of estimating our coefficients. Instead of minimising the sum of squared residuals, we minimise the following:

$$\sum ||y - X\beta||^2 + ||\lambda\beta||^2$$

As a result, in addition to minimising the residuals, we are also minimising the coefficients. The solution to this is the following equation:

$$\beta = (X^T X + \lambda^2)^{-1} X^T y$$

Because we have added λ^2 to $X^T X$, we can now find an inverse even if our design matrix contains columns which are perfectly correlated. The result is no longer a truly unbiased estimate and will tend to underestimate the coefficients, but does give better results in cases of collinearity. The difference between the results of this method and the ordinary least squares method depends on the λ parameter. As we increase λ, we increase the penalty for large coefficients and so increase the degree to which coefficients are minimised: if $\lambda = 0$ then the result is identical to the least squares method; if $\lambda = \infty$ then all of our coefficient estimates will be zero. Because we are minimising the sum of the *square* of the coefficients, this penalty is stronger for larger coefficients. The result is that large coefficients are shrunk to a 'reasonable' size while small coefficients are affected relatively little.

Lasso regression

A different approach is Lasso regression (standing for Least Absolute Shrinkage and Selection Operator). Here, instead of minimising the following:

$$\sum ||y - X\beta||^2 + ||\lambda\beta||^2$$

we minimise:

$$\sum ||y - X\beta||^2 + ||\lambda\beta||$$

Again, we are penalising large coefficients: if $\lambda = 0$ then the result is identical to the least squares method, and if $\lambda = \infty$ then all of our coefficient estimates will be zero.

However, penalising the coefficient estimates themselves rather than the squared coefficient estimates gives lasso regression some quite different behaviours to ridge regression. Unlike ridge regression, shrinkage is not greater for larger coefficients, so lasso regression does not offer us a tool to deal with individual inflated coefficient estimates. However, at reasonable values of λ, lasso regression tends to reduce all small coefficients to zero, leaving only the larger coefficients in the model. Thus, lasso regression builds in a form of feature selection: because only the larger coefficients are retained, it tends to give us as simple a model as possible.

Elastic net regression

In cases with a very large number of predictors, neither of these options may suffice. With a sufficiently large number of possible predictors, some are likely to be highly correlated, making ridge regression an attractive option. However, variable selection is difficult with ridge regression: with normal regression we might use a stepwise procedure where we use significance tests to progressively add or remove predictors to the model; since there is no straightforward significance test for ridge regression, we cannot follow this approach and are left with a maximally complex model with all the potential predictors.

To solve this problem, we can use elastic net regression, combining the advantages of ridge regression (robust with highly correlated predictors) with lasso regression (automated variable selection). In elastic net regression, we include both the ℓ_1- and ℓ_2- penalty, minimising the following:

$$\sum \|y - X\beta\|^2 + \|\lambda_2\beta\|^2 + \|\lambda_1\beta\|$$

Elastic net regression has some of the properties of ridge and lasso regression: increasing either λ_1 or λ_2 sufficiently high will shrink all coefficient estimates to zero; if both λ_1 and λ_2 are equal to zero, the model is the same as the ordinary least squares; the model performs well with highly correlated predictors; very high coefficient estimates are shrunk towards reasonable values; small coefficients are reduced to zero, leaving us with a relatively simple model.

Parameter setting

We then have to determine the values of λ_1 and λ_2. There are two broad approaches to this. One is cross-validation. The idea here is to use the existing data to find the model which best predicts some new dataset. Because we generally can't acquire a whole new dataset easily, we instead split our existing dataset into a training set and a test set. To avoid some accidental properties of the data we assign to the test set having disproportionate influence over the final model, we can use *k*-fold cross validation: we divide the dataset into *k* equally-sized subsets each of which is treated as the test set in turn; we then select the values λ_1 and λ_2 that perform best on average across all the test sets.

An alternative approach is to select an 'information criterion' measure, a statistic which measures of model goodness-of-fit offset by model complexity, such as the Aikaike Information Criterion (AIC). By setting λ_1 and λ_2 so as to minimise the AIC of the model, we find the model with the optimal trade-off between complexity and fit.

APPENDIX NOTES

1. Internal factors only investigated for linking r.

2. However, Becker states that when the data is broken down into ethnic groups only the effect of NURSE is consistent and that "no overall pattern for preceding full vowels is evident" (2014:158-159).

3. As with Trudgill & Gordon's (2006) study of Australian English and Nagy & Irwin's (2010) of New Hampshire English, we might hypothesise that the lack of effect here is due to the fact that the change had almost gone to completion: either because conditioning systems tend to disappear in the final stages of change, or because the very low frequency of one variant inevitably makes it hard to detect significant effects without an extremely large sample.

4. Hollitzer's analysis divides the data up into three towns: Newbury, Swindon, and Tauton; although rates of rhoticity per vowel are calculated for each town (2013:34-35), several categorically non-rhotic speakers are included in these calculations for Newbury and Swindon, making the hierarchies suspect. Hollitzer's only strong conclusion is that NURSE and lettER favour rhoticity, since this is consistent across the three towns (2013:35).

5. Nagy & Irwin point out that disagreements in constraint rankings between the younger New Hampshire speakers and all other groups might be the result of the fact that the change is almost gone to completion in this group and that constraints must necessarily fade as the conservative variant becomes vanishingly rare (2010:259-260).

6. The analysis of Piercy (2012) is used rather than the less statistically sophisticated analysis of the same data in Piercy (2006:55).

7. Sharbawi & Deterding examine only START, NORTH, and NURSE. Comparison of their data for these vowels shows no significant difference in rates of rhoticity for either variety studied: for Brunei English, 10/18 START, 24/54 NURSE, and 25/54 NORTH tokens were rhotic ($\chi^2 = 0.68$, $p = 0.7118$); for Singapore English, 1/12 START, 4/36 NURSE, and 2/36 NORTH tokens were rhotic ($\chi^2 =$

0.727, $p = 0.6952$). However, as the sample size is tiny, no strong conclusions should be drawn from this.

8. Sudbury & Hay's (2002) finding applies only to linking r and not coda r.

9. No statistical evidence of the relative effect of the different contexts is offered and the sample is relatively small; the authors suggest that the mismatch with other studies is the result of the fact that this "must represent the last surviving traces of earlier, fuller rhoticity" (2006:240).

10. Note that whilst the specific model actually used in the paper is logistic elastic net regression, here, for reasons of space, we describe linear elastic net regression.

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