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The regularity of regular sound change

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Abstract

Although the Neogrammarian position that sound changes proceed without exception continues to be the working principle of comparative linguistics, many advocates of lexical diffusion maintain that the word is the unit of change. This paper is a study of large scale longitudinal data on current changes in progress which have a regular output, searching for evidence of lexical selection over time.

[1]The raising of pre-consonantal/eyC/ in *made, eight* etc. in Philadelphia is examined in a database of 56,748 /ey/ tokens by forced alignment and automatic vowel measurement, for speakers with dates of birth from 1888 to 1992. Multiple regression analyses show fixed effects of date of birth, gender and ethnicity which exhibit minimal change when random effects of lexicon are added. Random coefficients for the 47 most common /ey/ words do not show the differences for the two halves of the century that would be expected if some words were selected only in the second half. The trajectories for the two halves of the century are examined for the 10 most common /eyC/ words and the 6 most common final /eyF/words. The /eyC/ words are all selected in both halves with a continuous raising process. Words with zero and velar onsets lead at the beginning and join with other pre-

[1] This work is based on the FAVE program for forced alignment and automatic measurement developed by Mark Liberman, Jiahong Yuan, Keelan Evanini, Ingrid Rosenfelder and Josef Fruehwald, with support from NSF Grant 021643 “Automatic Alignment and Analysis of Linguistic Change.” For corrections and new insights bearing on this study, I am indebted to Maciej Baranowski, Aaron Dinkin, Gregory Guy, Daniel Ezra Johnson, Don Ringe and Gillian Sankoff.

consonantal words at the end of the process. It is concluded that the raising of /eyC/ in Philadelphia is a phonologically defined process in which all words that fit the phonological definition are affected by raising throughout the century.

This is a study of the fundamental mechanism of sound change, defined as the *transition* problem: how does the change proceed from one stage to another in the course of time? (Weinreich, Labov & Herzog 1968). Or to put it simply, what is it that changes? Is it the phonetic realization of a phoneme, or is it the pronunciation of particular words?

All such discussions begin with the Neogrammarian position familiar from the 1878 statement of the Neogrammarians:

> Every sound change, inasmuch as it occurs mechanically, takes place according to laws that admit no exception. --Osthoff and Brugmann 1878

and in Bloomfield's re-formulation:

> Sound-change is merely a change in the speakers' manner of producing phonemes and accordingly, affects a phoneme at every occurrence, regardless of the nature of any particular linguistic form in which the phoneme happens to occur. . . The whole assumption can be briefly put into the words: *phonemes change*. --Bloomfield 1933:353-4

This position was challenged early by dialectologists on the evidence of widespread lexical variation in the development of the same process across geographic areas.

> The phonetic *law* does not affect all items at the same time: some are designed to develop quickly, others remain behind, some offer strong resistance and succeed in turning back any effort at transformation.
>
> --Gauchat (cited in Dauzat 1922)

More recently Wang and his colleagues have revived and reinvigorated this position, arguing that the fundamental mechanism of sound change is *lexical diffusion*:

> A phonological rule gradually extends its scope of operation to a larger and larger portion of the lexicon, until all relevant items have been transformed by the process. –Chen and Wang 1975:256.

This position does more than allow for lexical diffusion: it states that the Neogrammarians were fundamentally wrong: that the unit of change is never the phoneme but always the word:

> The lexically gradual view of sound change is incompatible, in principle, with the structuralist way of looking at sound change. --Chen and Wang 1977:257.

Some 30 years ago, I attempted a resolution of this controversy by arguing that both modes of change were to be found (Labov 1981), and the problem was to discover when lexical diffusion occurred and when regular sound change occurred. In the most recent formulation:

> Regular sound change is the result of a gradual transformation of a single phonetic feature of a phoneme in a continuous phonetic space.
> Lexical diffusion is the result of the abrupt substitution of one phoneme for another in words that contain that phoneme. –Labov 2010:260.

Thus a characteristic case of lexical diffusion in the historical record is the categorical shortening of English vowels before /d/, yielding *dead, head,* and *tread* but leaving behind *bead, knead* and *plead*. A characteristic regular sound change is the gradual fronting of the nucleus of/ow/ (*hope, roam*, etc.) except before /l/ in the Southeastern U.S., as documented in the *Atlas of North American English*, henceforth ANAE (Labov, Ash & Boberg 2006, Ch. 12).

This resolution fell short of success. In the years that followed, exponents of Chen and Wang's position continued to find cases of lexical diffusion, but I do not know of any reports of regular sound change that appeared in subsequent years. Following the collection of articles in Wang 1977, -I find 31 further papers reporting lexical diffusion, (e.g., Phillips 1980, 1983, 1984, 2006; Li 1982, Wallace, 1984; Lien 1987; Ogura 1987; Harris 1989; Shen 1990; Krishnamurti 1998, Phillips 2006). None of these authors include findings on the regularity of the sound changes they studied.[2]

Yet the practitioners of historical and comparative linguistics have not changed their view of the matter. The regularity of sound change continues to be the fundamental working principle of this field. But faced with so much evidence of lexical exceptions, it is common to reduce regularity to a working principle rather than a substantive statement. As stated judiciously in the Wikipedia article on sound change (accessed 5/1/13):

> While real-world sound changes often admit exceptions (for a variety of known reasons, and sometimes without one), the expectation of their regularity or "exceptionlessness" is of great heuristic value, since it allows historical linguists to define the notion of regular correspondence.

This is the view of the historical linguists who contributed to the volume on *The Comparative Method Reviewed: Regularity and Irregularity in Sound Change* (Durie and Ross 1996). In general, they recognize the existence of lexical irregularities but propose a separate accounting for them. Campbell (1996:86) lists a narrowly circumscribed set of conditions in which exceptions to the regularity of sound change are to be found, and concludes that "the general assumption of regularity for sound change is necessary in order to recognize the potentially exceptional forms." Blust (1996:153) argues that "irregularity appears to be an integral part of the natural process of language change." Recognizing the probabilistic character of lexically gradual sound changes, Durie (1996:131) concludes that some "will not necessarily be exceptionless."

[2] Among the proponents of lexical diffusion as a basic mechanism of sound change, Bybee stands out in recognizing the existence of regular change (Bybee 2012: Table 1).

Given the proliferation of reports of irregularity, we still have to determine what mode of change is more general in the historical record. Ringe and Eska (2012) address this issue vigorously by an examination of the first 200 words of the glossary in an Old English textbook, Moore and Knott (1955). They find that 88% of the contemporary reflexes can be derived by regular sound changes and known morphological changes. Considering the paths of all segments in these words, they report that no more than 3% per millennium are irregular.

The Ringe and Eska finding is still consistent with the view that lexical diffusion across the vocabulary is the basic mechanism of change, but that this sweep through the lexicon eventually leads to a regular outcome when the choice of lexical items is exhausted. When some factor interrupts the sound change in progress, the end result is not regular but irregular, since items not yet selected are stranded in an earlier form (Wang 1969). Thus the outcome of the debate is muted when proponents of lexical diffusion concede that the outcome of this word-by-word process may be regular, but not the process. A review of the regularity of completed changes cannot be decisive here: only the study of change in progress will yield an answer. Here I follow the lead of Chen and Wang in their original statement:[3]

> Oddly enough, one of the most neglected aspects of historical linguistics, which professes to be a study of language evolving across time, is the time element itself. Of course much discussion has been devoted to the relative chronology of phonological processes, but this concerns the EXTERNAL relation between rules in terms of time sequence; the INTERNAL time dimension has not received equal attention until fairly recent times. By internal dimension we mean the CHRONOLOGICAL PROFILE . . . of the gradual evolution, and expansion or regression, of a single phonological process.

[3] See also Bybee 2012 for the importance of the study of change in progress for inferring the mechanism of change. Her general discussion does not however distinguish stable linguistic variation like (t,d) deletion from change in progress.

--Chen and Wang 1975: 256.

The search for regularity.

Many clear cases of lexical diffusion have been documented, along with many cases of a regular outcome. But it remains to be shown whether any one of the innumerable changes that exhibit regularity in the long run was regular in process—that it did not in fact proceed word by word to achieve that result. The goal of this paper is to search for such evidence of regularity.

What would it mean to publish a report that a sound change is progressing in a regular manner, affecting all members of the phonologically defined class? It might mean the identical development of common homonyms, as in my 1994 regression analysis of the extended recordings of Philadelphian Carol Myers. This showed no significant difference between her productions of 40 tokens of *two* vs 14 of *too,* and no difference for 50 tokens of *know* vs 32 of *no* (Labov 1994: Table 16.7). Or it might mean that every word in the vocabulary had been examined and been found to change at the rate predicted by its phonetic composition with no effect of its lexical identity.

The sound changes we have been studying in North America typically generate the chronological profile demanded by Chen and Wang in the apparent time dimension. This interprets gradual shifts in the use of speakers of different ages as a reflection of change in progress. To the extent that older speakers adopt the change, apparent time understates its magnitude but this is normally a small effect (Sankoff 2005).

Given the continuous and probabilistic character of these changes, Zipf's law tells us that the question cannot be tested on the whole vocabulary. The process, whatever it is, will not be detected in individual *hapax legomena*: the large numbers of words with frequency of 1.

To determine that a change is regular requires a larger number of tokens in the data set than to detect lexical exceptions. The exceptions to be examined will be found only among the most frequent words. Since the essence of lexical diffusion is that the selection of a given word is a historical accident, and not determined by phonetic or grammatical rule, a large number of conditioning factors must be examined in a multivariate analysis. The only general conditioning factor that lexical diffusionists call upon is *frequency*, and here the nature of the relation is again probabilistic—in lexical diffusion, words are not selected in the exact order of their frequencies (Labov 1989). And if the data set should include only the *most* common words, any frequency effect would be minimized. We therefore look for a database with at least 20 to 100 tokens of many words to detect the presence or absence of lexical selection among them.

This article will first summarize earlier studies that traced the degree of regularity of sound changes through data from a small number of speakers in many different communities, and then turn to a new study of many hundred speakers in a single city, Philadelphia, making use of new techniques of forced alignment and automatic measurement.

Lexical effects in the fronting of back upgliding vowels in North America.

A first search for lexical selection took advantage of the 134,000 vowel measurements of ANAE. The most general sound change in North America is the fronting of /uw/ after coronal consonants. A multiple regression analysis of the fronting of /uw/ was carried out for 6,578 tokens. Models were developed with the significant phonological and social predictors. To test the hypothesis of lexical diffusion: that some words were affected by the rule but others were not, all words with frequency greater than 25 were added as fixed effects. The results showed significant phonological effects ($p < .01$) for nine phonological predictors, three social constraints, and two lexical items (*zoo* and *Vancouver*).[4] Frequency was not significant. The onset effects included three positive values for coronal features, and six negative values for non-coronals. The strongest effect by far was the negative effect of a following lateral (-570). This is the same order of magnitude as the

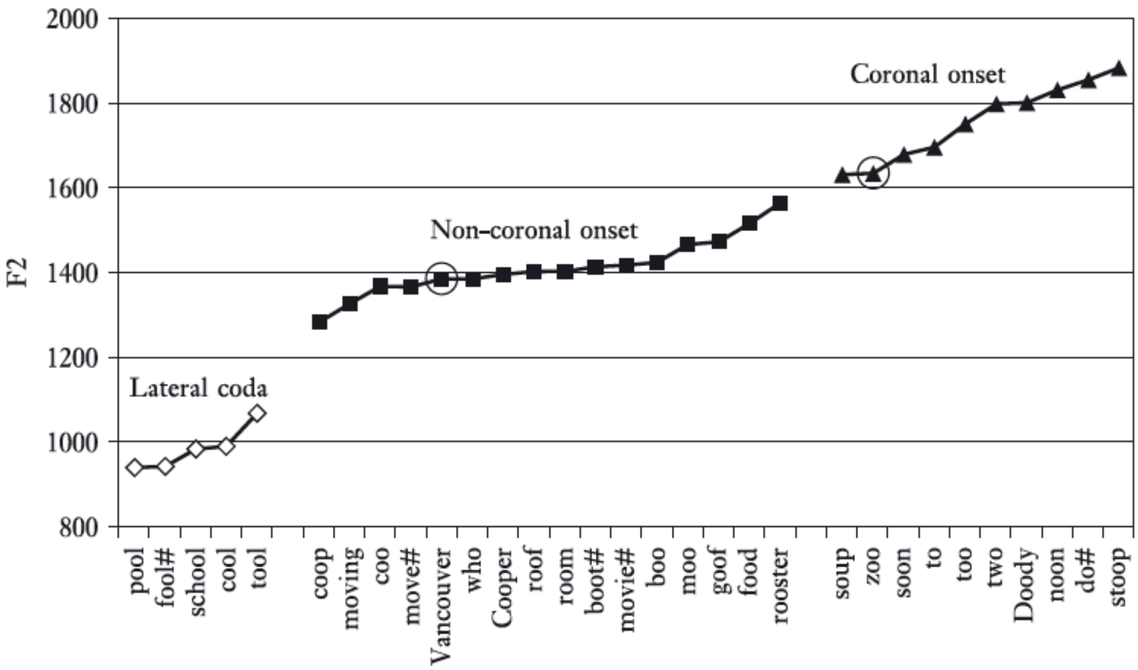
[4] These lexical effects would seem to be distinct from phonological effects, given the onset similarity of *Vancouver* with *Cooper* and *coo* and *zoo* with *soup* and *soon*. For details see Table 13.1 of Labov 2010.

difference between a vowel well front of center (F2 > 1600) and a fully backed vowel (F2 < 1000). The word *zoo* was assigned a coefficient of -172 and *Vancouver* -148, comparable to the effect of a preceding lateral (-170) or labial (-127). To see how robust these effects were, the data were split into two random halves. Phonological and social effects showed very little change and remained in both halves, but the two lexical effects did not.

Figure 1 shows the mean values of F2 for the 31 words that occur more than 25 times in the Atlas data, with *zoo* and *Vancouver* circled. All words with coronal onsets are found in an upper set, and words with non-coronal onsets in a lower set, with none overlapping. Words with vowels before /l/, which are not selected by the sound change, are shown at left.[5] It is evident that, despite their negative values in the regression analysis, *zoo* and *Vancouver* are included in the fronting process along with all other common words with coronal onsets.

[5] ANAE shows that in the South, there is a small tendency to front words of the type *school, tool,* but this is receding faster than most Southern features.

Figure 1. Mean F2 values for the thirty-one /uw/ words which occur more than twenty-five times in the ANAE data. Circled items show significant lexical effects. # indicates stems with more than one inflectional form.



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The fronting of /ow/ follows a somewhat different pattern. First, there is no major effect of coronal onset, which is only one of a number of phonological constraints at the same level. Strong fronting is confined to a Southeastern Superregion where F2 of /ow/ is greater than 1200 Hz. In the North, New England, Canada and the West, F2 of /ow/ is lower. As with /uw/, vowels before /l/ are not selected by this fronting process.

A regression analysis of /ow/ was carried out for this Southeastern region only, with 3,658 tokens. It found six phonological factors of the onset at the $p < .01$ level, and six for the coda. Again, frequency was not significant. The age factor indicates change in progress in apparent time, as with /uw/. But attention paid to speech (word lists, minimal pairs) had the opposite effect, slightly increasing the fronting of /uw/ but decreasing the fronting of /ow/.

Of the thirty-two most common words with /ow/ vowels, only one was selected as a significant factor in the regression analysis: *going,* but not *go*.

A chonological profile: 100 years of sound change in Philadelphia.

The data on the fronting of /uw/ and /ow/ was typical of ANAE studies based on a small number of speakers from many different communities, with no evidence of change in progress in any one. ANAE uses only post hoc controls on age, education and ethnicity, capitalizing on the sample variation in a region. A much more detailed view of change in progress can be drawn from the Philadelphia Neighborhood Corpus [Labov and Rosenfelder 2012, henceforth PNC], allowing us to trace sound change for over a century by date of birth (Labov, Rosenfelder and Fruehwald 2013, henceforth LRF). The PNC is based primarily on interviews carried out in the University of Pennsylvania course LING560, "The Study of the Speech Community."[6] Each year, groups of three to six students select a neighborhood, observe the use of language in the local setting, make initial contacts, carry out recorded interviews, explore local social networks and analyze linguistic variables. The course was taught yearly from 1972 to 1994, and every two years from 1994 to 2012.[7] The accumulated archive to date includes 1,107 recorded interviews from 61 different neighborhoods. A subset of 379 of these interviews has been selected for inclusion in the Philadelphia Neighborhood Corpus, and transcribed with the ELAN program. The distribution of speakers analyzed by age and year of interview is shown in Figure 2. This body of data has been analyzed by the FAVE program for forced alignment and automatic vowel extraction, currently yielding 900,000 measurements of vowel nuclei longer than 50 msec.[8]

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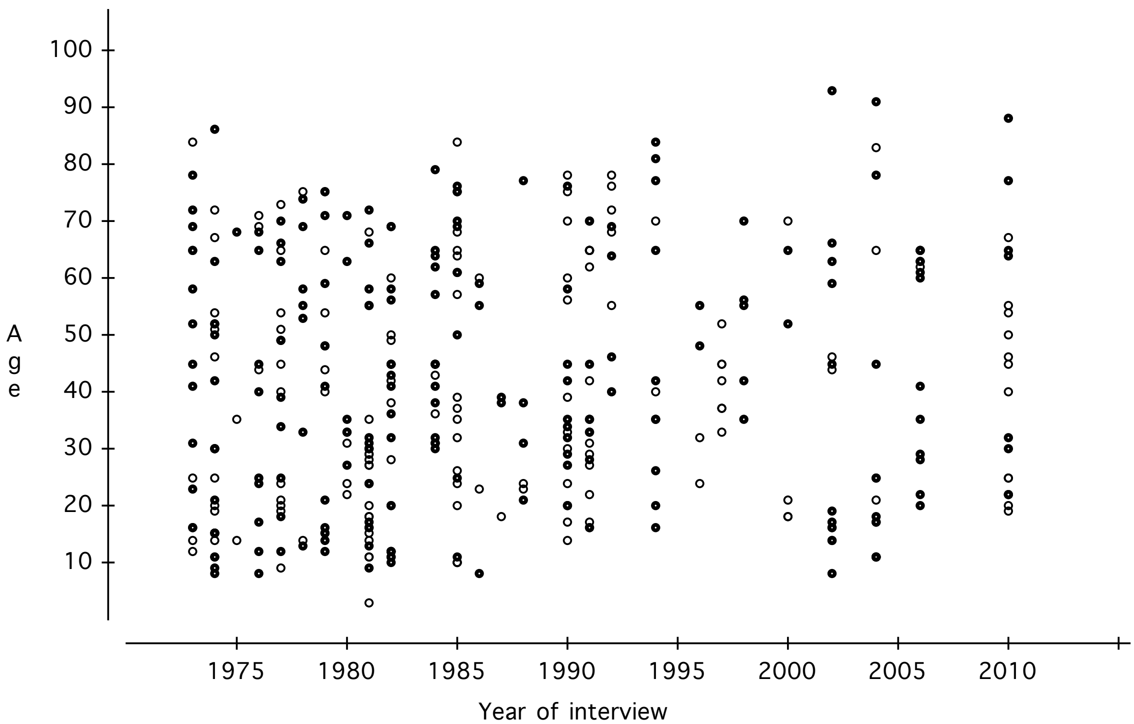
[6] Fifty of the PNC interviews in the early 1970s are drawn from the study of Philadelphia carried out by the Project on Linguistic Change and Variation (Labov 1980, 2001), supported by NSF grants 7500245 and 780910.
7 It continues through the present (academic year 2012-13 at time of writing).

[8]The FAVE web site is http://fave.ling.upenn.edu. For comparison of accuracy with ANAE hand measurements, see Evanini, Isard and Liberman (2009). Labov, Rosenfelder and Fruehwald (2013, Fig. 4) shows considerably lower values of standard error of the mean for FAVE as compared with hand measurement. Data for the PNC are normalized with the Lobanov procedure, while ANAE data are normalized by the log mean method.

Figure 2. Distribution of speakers analyzed in the Philadelphia Neighborhood Corpus by age and year of interview. Solid = male; open = female.



The LPC measurements located manually for ANAE yielded a mean number of measurements per speaker of 305. The automatic coding of the PNC corpus produced a mean number of measurements per speaker of 2,374.[9]

[9] From 20 to 60 minutes of the PNC interviews were transcribed.

A FIRST SEARCH FOR LEXICAL DIFFUSION IN THE PNC

Dinkin (2013) was the first to use the PNC in a search for evidence of lexical diffusion. He examined the raising of short-a before /l/ along the front diagonal in *pal, alley, personality,* etc. It had been reported (Labov 1989) that this expansion of the tense set showed lexical diffusion as in other subsets of short-a. Dinkin entered the 21 /æl/ words that had more than 10 tokens as fixed factors in a multiple regression analysis. Only one word, *gallon*, showed an effect at the $p < .001$ level, which he suggested may have been the favoring effect of the following /n/, given the vocalization of /l/. He attributed the absence of lexical diffusion to the fact that this raising was actually the result of the merger of Philadelphia /æl/ with /aw/.

THE SOCIAL TRAJECTORY OF /EYC/.

We now turn to the examination of a simpler and more prototypical sound change in Philadelphia, the raising of /eyC/ along the front diagonal.

The PNC permits us to trace the histories of sound changes across the relatively uniform community of white mainstream adult speakers of the Philadelphia vernacular, with dates of birth from 1888 to 1992. Since the amount of data for each speaker varies considerably, mean values for each variable for each individual gives us the most accurate view of the process. Several of these sound changes display a linear incrementation by date of birth across the century, which gives us an optimal field for the study of regularity and the search for lexical effects, if any.[10]

The particular change in progress selected for the current study of regularity is the raising along the front diagonal of the mid front upgliding vowel /ey/ in *eight, made, pain*, etc. It was first observed in the quantitative study of the Philadelphia vowel system in the 1970s (Labov 2001, Ch. 5). This raising process is well below the level of conscious awareness. It is never the subject of public observation or comment, nor was it noted in the prior qualitative descriptions of the Philadelphia

[10] Other changes, including the fronting of /ow/, show a reversal in mid-century, which complicates the search for lexical selection (Labov et al. 2013).

dialect by Tucker [1944). It shows several characteristics specific to the Philadelphia system:

• The raising process selects only words with consonants following stressed /ey/ (*made, eight, main, days*) as opposed /ey/ in syllable-final position and before /l/ (*may, mayor, day, hale*). The allophone so defined will be designated here as /eyC/, and all others of the /ey/ class as/eyF/. /eyC/ includes vowels in open syllables (*baby, neighborhood)* as well as closed syllables (*babe, raid*) (Fruehwald 2013).[11]

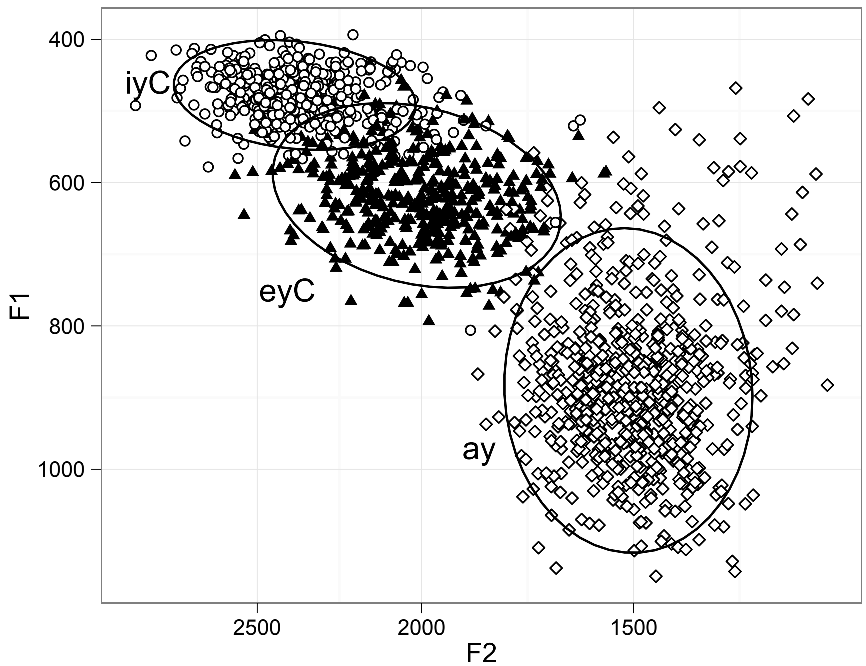
• The allophonic division is not sensitive to word or morpheme boundaries, so that *days* and *rays* are not differentiated from *daze* and *raise* (Fruehwald 2013).

• It can be noted that the change runs counter to the direction predicted by the principle of maximum dispersion within the Vy subset of vowels (Martinet 1955, Liljencrantz and Lindblom 1972, Lindblom 1988). Even in the earliest stages of the Philadelphia dialect, /eyC/ is closer to /iyC/ than to /ay/. This can be seen in Figure 3, the VyC distribution for one of the older speakers in the original LVC study in 1973. The data are drawn from a FAVE re-analysis of 9,101 measurements; the 95% ellipse for /eyC/ shows considerable overlap with /iyC/ but none with /ay/.

The /eyC/ allophone can then be defined at the outset as a member of the /ey/ phoneme followed by a consonant within the word. Post-vocalic /l/ in *hale, mail,* etc. is normally vocalized (Ash 1982) and, like postvocalic /r/, is defined as [-consonantal, -vocalic].

[11] A parallel differentiation is made with /iyC/ vs. /iyF/. However the low member of the Vy subset – /ay/– shows a different partition, distinguishing all nuclei before voiceless obstruents from all others, with the notation /ay0/ vs. /ayV/. Both /ay/ allophones are included in Figure 3.

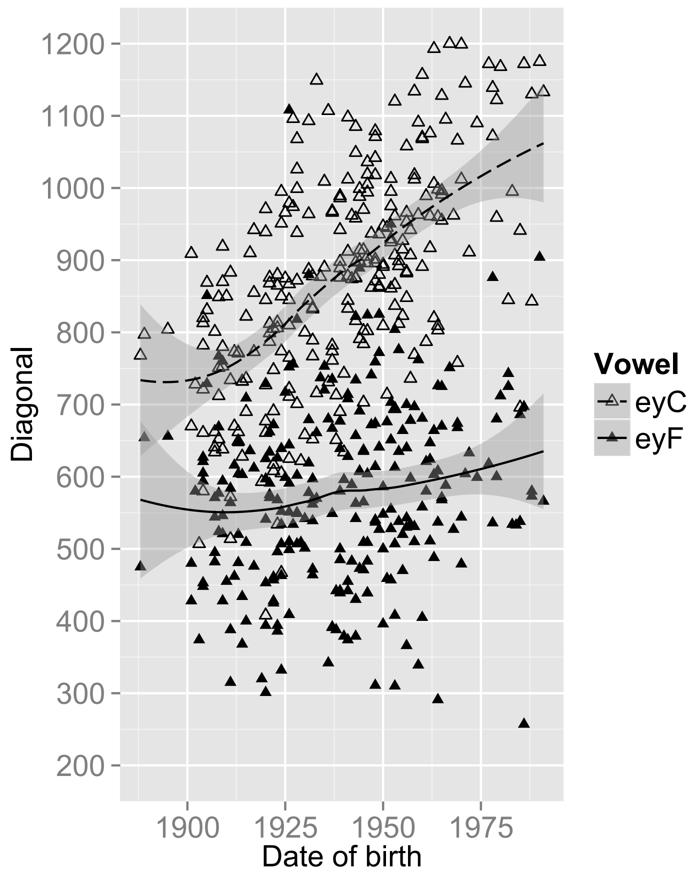
Figure 3. Distribution of /iyC/, /eyC/ and /ay/ with 95% data ellipses for Mary C., 62 [1973], South Philadelphia.



The linear incrementation of /eyC/ is presented for the adult population, since speakers below 18 years of age still show the conservative influence of their parental input (Labov 2001: ch. 12, Tagliamonte and D'Arcy 2009). Since minority members of the Philadelphia speech community follow considerably behind the mainstream in this and other changes in progress, our examination of the regularity of this monotonic change is focused on 264 adult white speakers in the Philadelphia Neighborhood Corpus. Figure 4 is a locally weighted regression (LOESS) analysis of the raising of the mean position of /eyC/ along the front diagonal (F2 – 2 * F1) by date of birth for this population. The vertical axis is distance along the front diagonal, calculated as F2 – 2 * F1. Each symbol represents the mean for one speaker. Grey areas indicate the limits of the 95% confidence interval, so that any white space separating lines represents a significant difference. The upper dashed line for /eyC/ shows a monotonic incrementation from DOB 1888 to 1991. The lower line shows a very different pattern—almost level—for the free allophone /eyF/. There is a small but significant raising of /eyF/ with a DOB coefficient of 11.5

per decade as against 33.9 per decade for /eyC/, and the difference between the two allophones increases steadily over the century.

Figure 4. Locally weighted (LOESS) regression analysis of /eyC/ and /eyF/ along the front diagonal (F2 – 2 * F1) by date of birth for 264 white adults in the Philadelphia Neighborhood Corpus.

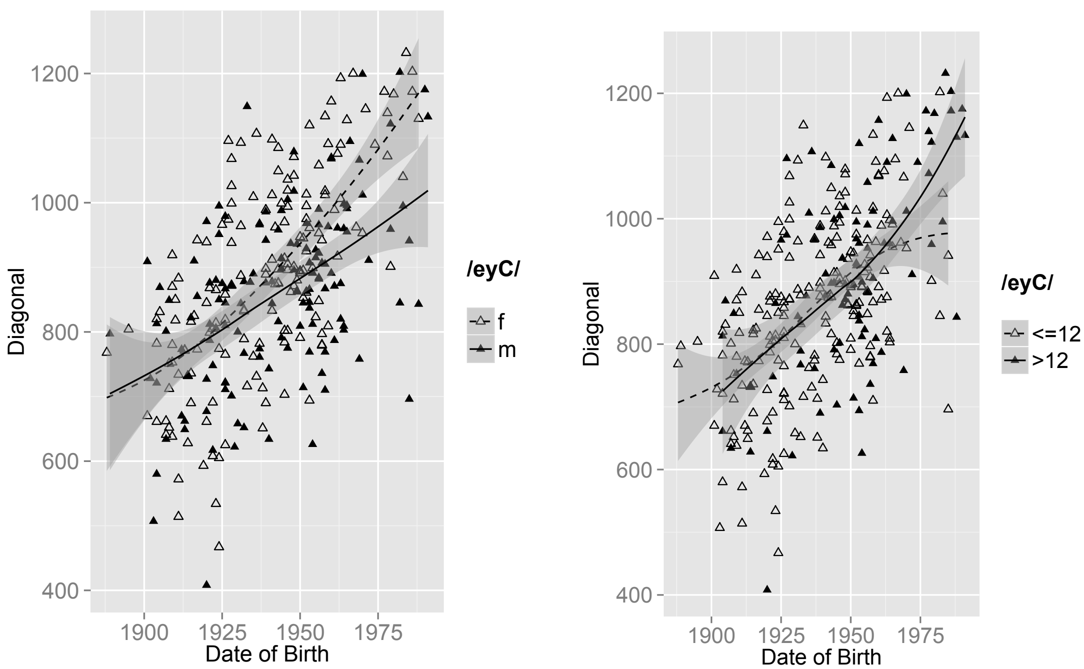


In Figure 4, The mean values for Mary C. of Figure 3, born in 1911, can be located at 804 for /eyC/ and 656 for /eyF/ on the front diagonal, significantly different but nowhere near the differences displayed for those born at the end of the century. The raising process carries Philadelphians from a small phonetic difference between non-final and final allophones to a radical differentiation with non-overlapping distribution in recent decades.

Figure 5 examines the effect on /eyC/ of two major social parameters: sex and education. In Figure 5a, the dashed line and open symbols represent female speakers. As in most sound changes in progress, females are in the lead, and increasingly so in recent decades. In Figure 5b, the dashed line and open symbols represent speakers with college education, the solid symbols speakers with high school or less. For most of the century there is no difference, but in the last two decades those with higher education are in the lead. There is no tendency towards the correction of this sound change by Philadelphians with higher education, an effect which is quite strong on salient variables like /æh/ in *mad, man, pass* and /oh/ in *talk, walk, water* (LRF).

Figure 5. Locally weighted regression analysis of /eyC/ on the front diagonal (F2 – 2 * F1) by date of birth for 264 adult white subjects in the Philadelphia Neighborhood Corpus.

(a) by sex [f: female, m: male]
(b) by education [>12: more than 12 yrs, <= 12: 12 yrs or less]



The behavior of women, and speakers with higher education underlines the nonsalient character of this vigorous change in progress. Almost everyone in the speech community participates in the raising of /eyC/ without being aware of it. Sound changes that operate at a higher level of social awareness do not show such monotonic incrementation, but are reversed for speakers born after 1950, a change led by women and those with higher education.

The overlap of /eyC/ and /iyC/ leads to considerable misunderstanding. A study of cross-dialectal communication included a replication of the Peterson-Barney experiment (1952) in which subjects from Philadelphia, Chicago and Birmingham heard ten vowels pronounced in a standard /k,d/ frame by advanced local speakers of these three dialects (Labov 2010, Table 3.4). Among the Philadelphia vowels, /eyC/ was one of three with misunderstanding rates above 15%. Local subjects were correct only 78% of the time: 22% of the errors were /iyC/ (*cade* heard as *keyed*). The corresponding figures for Chicago subjects were 66% and 32%; for Birmingham subjects 60% and 33%.[12]

The case of /eyC/ is therefore a promising site to examine the regularity of a sound change in its vigorous early stages, before social correction has intervened and before any lexical items have been singled out as stereotypes. As shown in Figure 5b, the advance of the change is also independent of socio-economic factors.[13] It is therefore an ideal site to test the Neogrammarian position that such sound changes select all lexical items in a phonetically defined class. To do so, we shift to a data base of 28,637 tokens of /eyC/ in which lexical identity is defined for each token along with its frequency in the corpus, as well as the features of the phonological environment.

The locally weighted regression graphs of Figures 3 and 4 display patterns over time that are close to linear. These are not the result of any assumption of linearity, since the method will register any non-linear trends (and does so in the case of the three /Vw/ vowels (LRF)). The linear incrementation of Figures 4 and 5 is a clear empirical finding. However, graphic displays of this type register only a

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[12] Labov 2010, Ch. 2 gives examples of natural misunderstandings of /eyC/ as /iyC/. One such long-term instance is reported by Ronald Kim. In the early 1990s, he listened to a local rock station that frequently broadcast ads for a Philadelphia jewelry store which he understood as “Robbins Ethan Walnut,” with the slogan “Our name is our address!” Over the years, he remembered “Ethan Walnut Street” as a strange address. In 1998 he was walking west on Walnut Street in Philadelphia’s Old City, passed 8th Street, and saw the store with its sign reading “Robbins 8th and Walnut.”

[13] As in the case of /oh/ in Philadelphia, where an exaggerated raising of *water* to [wʊɾɚ] is a widespread stereotype of upper mid /oh/.

few of the many independent variables that affect the change. A multiple regression analysis of the 28,637 tokens of the /eyC/ allophone (Table 1) shows us that there are actually eight groups of predictors with a p value of less than .00001. In this model, the effect of each factor is examined as if it were linear—that is, follows the same trajectory in time as the overall path of mean values of Figure 4. We are now able to test the overall effect of the lexicon on these values. The fourth column labeled "-Lex" shows the values in a model with the fixed factor groups listed, and no random group; the fifth column labeled "+Lex" shows whatever differences are found when the identity of the lexical stem is added as a random factor in a mixed levels analysis.

The first row entry in Table 1 is for stem frequency in the corpus. [14] It is not significant even at the .05 level, with or without the addition of the lexicon. This does not mean that there are no lexical effects, but rather that the factor most often associated with lexical diffusion is absent.

Two significant social factors follow in Table 1. Figures for the –Lex and +Lex columns for female gender and ethnicity are all but identical. This does not mean that the effect of the lexicon is insignificant, but rather that as we would expect, that it is independent of social factors.

The chief indicator of change in progress, Date of Birth, is the predominant effect. It predicts a mean increment of 4.04 Hz per year, or 404 Hz over the century, matching the path of the dashed line in Figure 4. Adding the lexicon as a random factor alters this figure by a minute amount—4.05 Hz per year. This is not consistent with expectation in a lexical diffusion model, which assumes that /eyC/ is an arbitrary assemblage of elements of the lexicon, changing unpredictably over the century. On this view, of the 28,637 stems in the data set, a large proportion would not show change by date of birth until the point in time when they happened to be

[14] The advantage of using frequency in the PNC is that the interviews come closer to the topics of everyday life than other corpora, but there is the disadvantage of some skewing towards topics frequently raised in the interviews (as shown by a relatively high frequency of *neighborhood*).

selected. It follows that if words vary so unpredictably, adding lexicon as a random factor would account for some variation in Date of Birth.

Table 1. Regression coefficients for significant predictor groups ($p < .0001$) for the raising of /eyC/ along the front diagonal. **– Lex** = with no random variable. **+Lex** = with *Stem* as random variable.

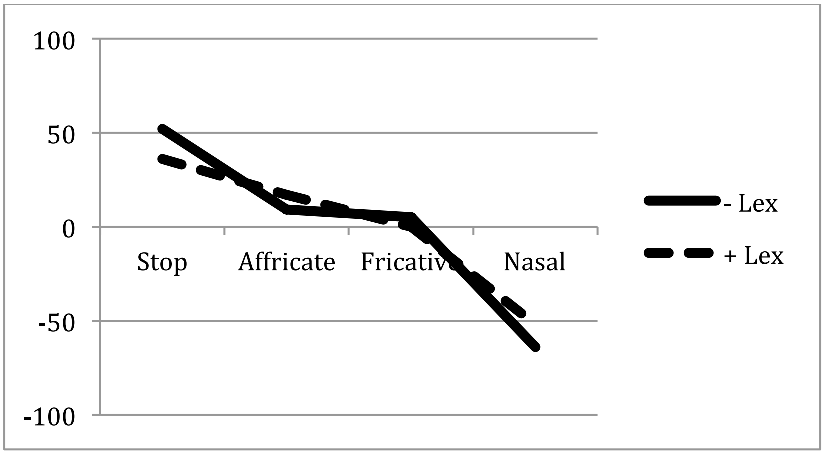
			Coefficient	
		N	-Lex	+Lex
LEXICAL	Frequency	28637	n.s.	n.s.
SOCIAL				
Sex	Female	12195	16.5	15.5
	Male	9782	-16.5	-15.5
Ethnicity	Italian	10652	28.8	26.5
	German	600	30.5	30.6
	Ukrainian	357	25.7	28.6
	Irish	4897	16.0	15.1
	Polish	848	-15.5	-16.6
	White(Other White?)	2994	-36.9	-38.5
	Jewish	1026	-79.3	-76.2
TEMPORAL	Date of birth	21977	4.04	4.05
PHONOLOGICAL				
Coda manner	Stop	11560	50.9	35.9
	Fricative	5183	9.5	-0.32
	Affricate	489	4.0	17.0
	Nasal	4745	-64.0	-52.5
Coda place	Interdental	160	44.9	95.1
	Apical	10307	21.0	11.6
	Labiodental	946	5.1	3.8
	Labial	5791	-9.3	-2.4
	Palatal	1676	2.23	-4
	Velar	3097	-64.0	-107.4
Onset	Velar	2371	277.5	228.1
	Palatal	661	111.5	108.6
	None	1922	134,9	123.9
	/n/	2125	20.4	13.7
	/m/	2816	-20.9	-22.8
	/t,d/	4745	-19.7	5.7
	/p,b/	1918	-39.3	-44.7
	/w,y/	636	-1.05.2	-64.9
	/l,r/	1864	-173.1	-173.0
	Kl/r	2919	-186.0	-174.7

Among phonological factors, manner of the coda consonant has considerable influence on the change in progress, in the order stop > affricate > fricative > nasal. Coda place shows a small number of words with interdental fricatives leading (mostly *eighth* with apical plus interdental), and a strong negative effect of velars. Onset effects are strong, with the opposite effect for initial velars which strongly promote the raising of /eyC/. When the lexicon is added as a random variable, values vary slightly but their ordering does not. Figures 6a.b.c display the differences between the -Lex (dotted line) and +Lex (solid line) analyses for these three phonological groups. There are more small differences than for the social predictors, but no substantial change. For coda manner, adding lexicon moderates the strongest effects; for coda place we see the opposite effect. Onset features are almost identical for the two analyses.[15]

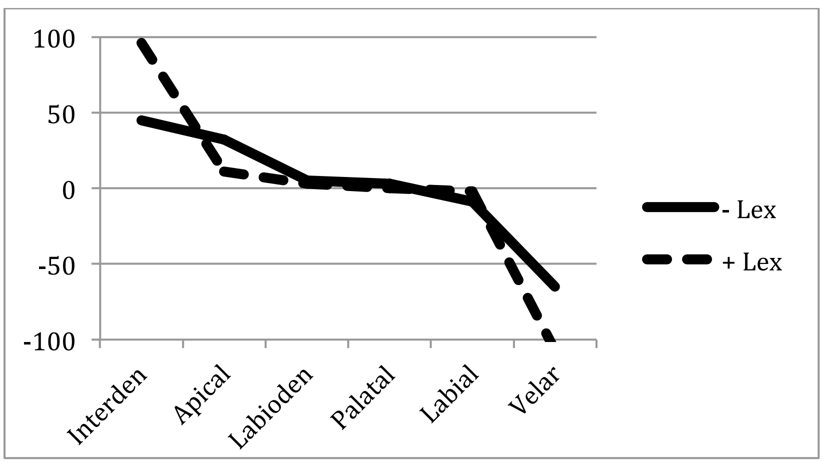
[15] No significant effect of coda voicing appears in either analysis.

Figure 6. Regression coefficients with and without Lexical Stems as a random factor for raising of /eyC/ along the front diagonal.

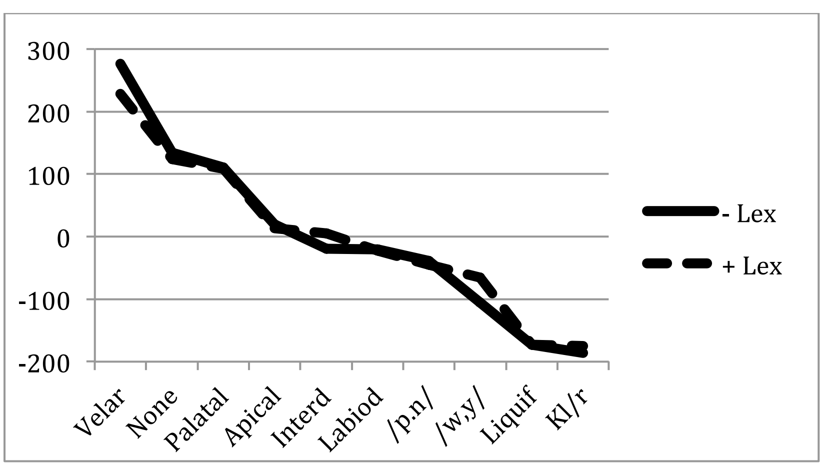
a) For coda manner



b) for Coda place



c) for Onset



If lexical selection were independent of phonetic effects, one would expect that leading lexical items would exhibit phonological features contrary to those of Table 1. This is not the case. The second highest coefficient in the random lexical group, 208, is assigned to 165 tokens of *hate.* Three of the six lowest words in the random coefficients have obstruent/liquid onsets (*plain, plane, playground*), in parallel to the phonological effects.

Figure 6c compares the regression coefficients for the effect of different onset consonants. Initial velars lead as usual in the raising and fronting process, and obstruent/liquid combinations as in *place* and *grade* are furthest behind. The detailed series of fixed onset effects (dotted line) is replicated with very little change in the +Lex series (solid line).

We therefore see in the raising of /eyC/ small interactions between the lexicon and phonological factors, in contrast to the complete absence of such interaction for social factors. The analysis reveals a slight tendency to assign the relative advancement of one word or another to lexical identity rather than to phonological structure, although the major phonological effects remain stable. This is not inconsistent with the view of proponents of lexical diffusion, who concede that phonetic conditioning may be very regular in sound change but that an independent process of lexical selection is involved (Chen & Wang 1975).

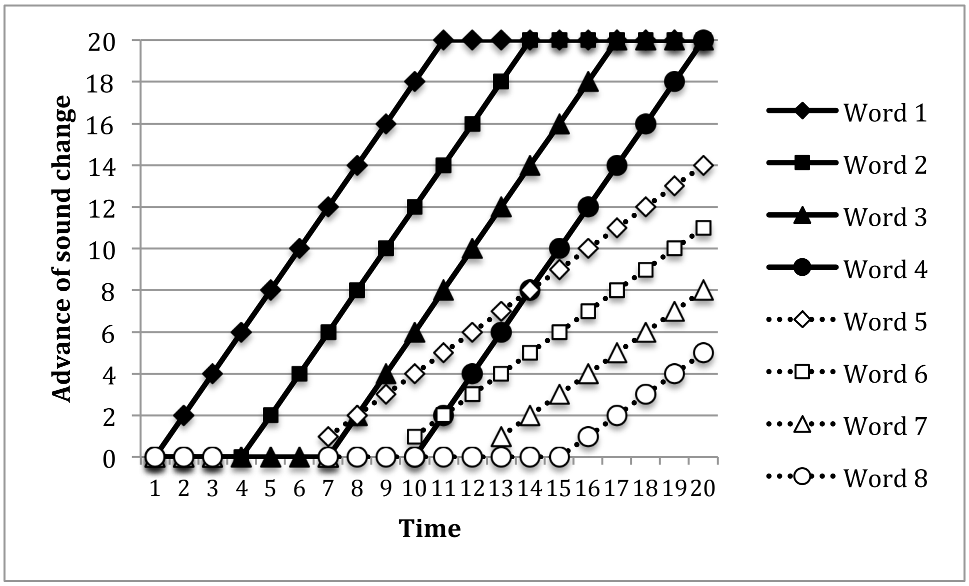
Testing a model of lexical diffusion.

The proponents of lexical diffusion as the basic mechanism of sound change argue that all changes proceed gradually through the lexicon; at the beginning only a few words are involved, and towards the end only a few words are not (Bybee 2002, Chen & Wang 1975). The selection may be affected by phonetic considerations, but for true lexical diffusion to be recognized, there must be a purely arbitrary (and thus inexplicable) random selection of individual words. The only explanatory feature recognized in such selection is frequency.

The model of lexical diffusion projected by these authors can be displayed as in Figure 7. Phonetic constraints are acknowledged and are here symbolized by the difference between Words 1-4 (solid symbols) and words 5-8 (open symbols).

Words 1-4 contain a favoring phonetic context for the change in progress, and one by one they are selected to follow the parallel path of change consistent with that context. In words 5-8 the variable is found in a less favoring context, and the words are individually selected to follow a slower trajectory. It follows that many individual words will have radically different rates of change in the two halves of the time period according to when they were selected. Thus a trend line for Word 1 in the first half, time 1-10, would be y= 2 * t, with a rate of 2, but in the second half the rate of change is 0. The rate of change of Word 6 in the first half is 0, and in the second half 1 in these units of time. [16]

Figure 7. Model of a continuous change proceeding by lexical diffusion.



If we now divide our PNC data into tokens produced by speakers born before and after 1940, we can compare the actual behavior of the lexicon for those two halves in Figure 8, which displays the mean values for the 47 most common words in the first half, ordered by their frequency (from 32 for ABLE to 484 for CAME). The

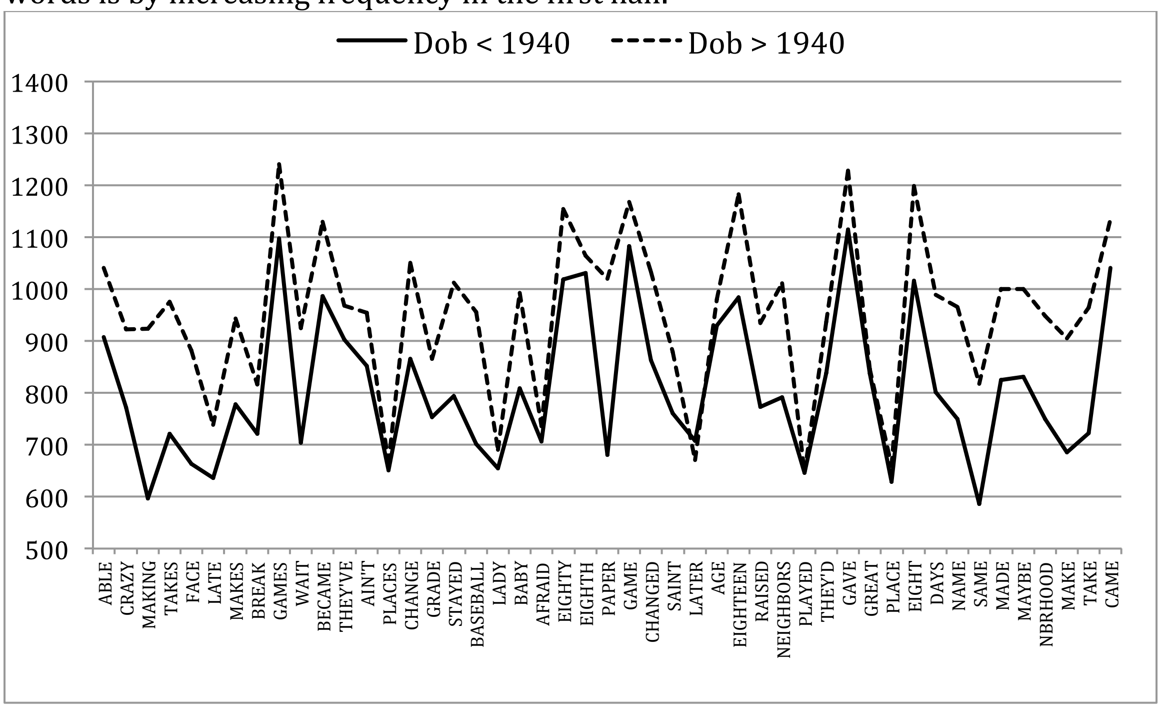
[16] These parallel slopes are of course the simplest possible model; nothing prevents us from projecting radically different slopes, but the same argument will apply to a more complex model.

solid line represents the rates of change for the first half; the dashed line for the second half.

It can readily be seen that the mean values for the second half are higher than for the first (means for DOB < 1940, 807; DOB > 1940, 952). Furthermore, the two curves rise and fall together. The r-correlation is .83.

There are no words with mean values that are equally high at a level above 800. To find evidence of individual words that were not selected by the raising process, we look for words with equally low values for the two halves: PLACES, LADY, LATER, PLAYED, PLACE. The phonetic selection is evident. We will have to redefine the phonological process of raising more closely to eliminate words with lateral onsets as well as lateral codas.

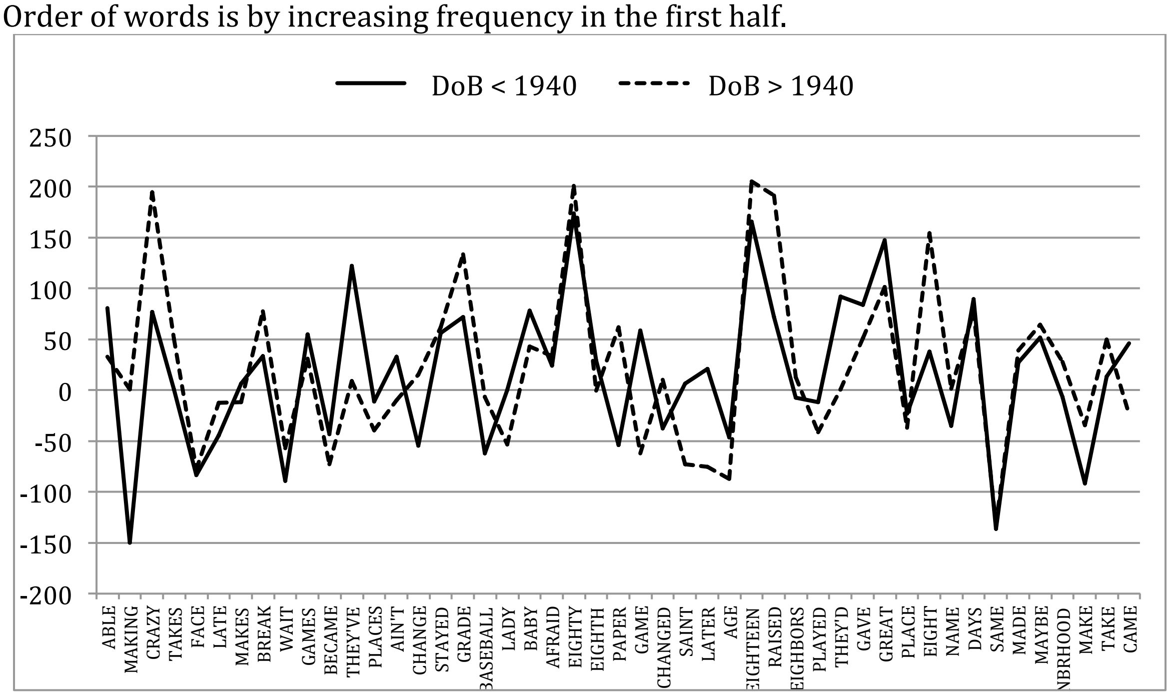
Figure 8. Mean values for raising of 47 most common /eyC/words in PNC for speakers by Date of Birth: those born before 1940 and after 1940. $r^2 = .83$. Order of words is by increasing frequency in the first half.



In Figure 9, the same 47 words are examined for changes in the random coefficients assigned to them by the mixed levels model. These coefficients are the program's effort to represent the contribution of the individual word to the raising process. If lexical diffusion was the basic mechanism of change here, we would expect that words would show very different coefficients in the two halves.

Only one word in Figure 9 follows the pattern of lexical diffusion of Figure 7, with a major jump between the two halves. In the first half, the second item from the left (MAKING) shows a very low coefficient, -150, but in the second half it returns to 0.6, close to 0. This is consistent with an interpretation that it was not selected by the raising process in the first period, 1888-1940, but was raised just like all other words in the second period. However, it is the only case of this kind. Furthermore, there is good reason to think that it is not at all characteristic of the general process, but the kind of statistical outlier predicted for normal distributions. The word MAKING is the third least frequent in this series (33 tokens in the first half, 55 in the second). But the third most frequent word is MAKE (399 in the first half, 356 in the second), and this item shows the parallel behavior in the two halves characteristic of the vocabulary as a whole, advancing from -92 to -34.

Figure 9. Random coefficients for raising in the 47 most common /eyC/words in PNC for speakers by Date of Birth: those born before 1940 and after 1940. $r^2 = .67$. Order of words is by increasing frequency in the first half.



One word appears not to be involved in the raising process. The seventh item from the right shows the same low value in both halves (-136, -132). This is the word *same*. Its anomalous position may be due to its frequent use with secondary stress in noun phrases such as "same day" but it remains exceptional. Otherwise, the raising of /eyC/ is imposed upon the relevant vocabulary as a whole. There is no evidence that words are selected individually as the change proceeds, although in the process there are some words which move somewhat further than others in ways that cannot be accounted for entirely by their phonetic competition. Frequency is not a factor.

Lexical trajectories across time.

Let us now extract from the dataset of 28,637/eyC/ words, the separate trajectories for the two halves of the century by date of birth for the ten most common /eyC/ content words: *gave, eight, hate, came, days*[17]*, change, made, take, make, name*). Figure 10 (a,b) shows a common pattern of raising on the front diagonal across the two fifty year periods. The two sets exhibit parallel slopes along a continuous trend. There is no instance of a word being exempted from raising in either half. One word, *came,* shows a flat trend line in the first half. It is, however, a member of a subset already raised at the beginning of the century: words with zero,. /h/ and velar onsets. These reflect the strong favoring of velar and no onset in the raising of /eyC/ in Table 1.[18]

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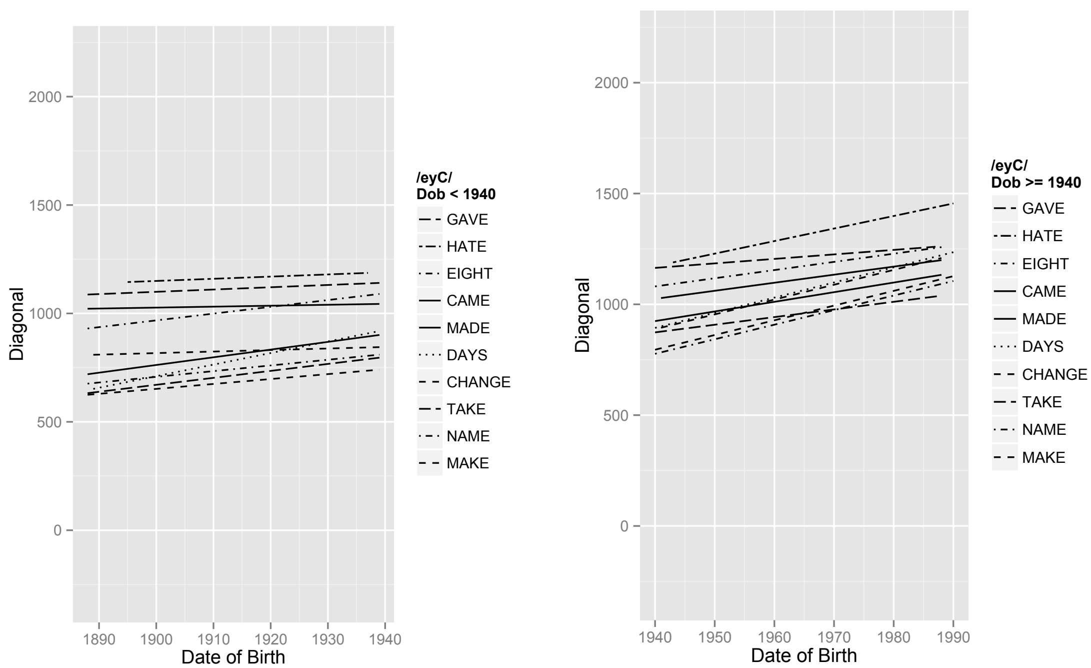
[17] As shown in Fruehwald 2013, *days* does not follow the pattern of /eyF/ final *day,* as the raising rule does not take into account morphological boundaries.
[18] This set may be seen as sharing the absence of a transition from relatively low loci.

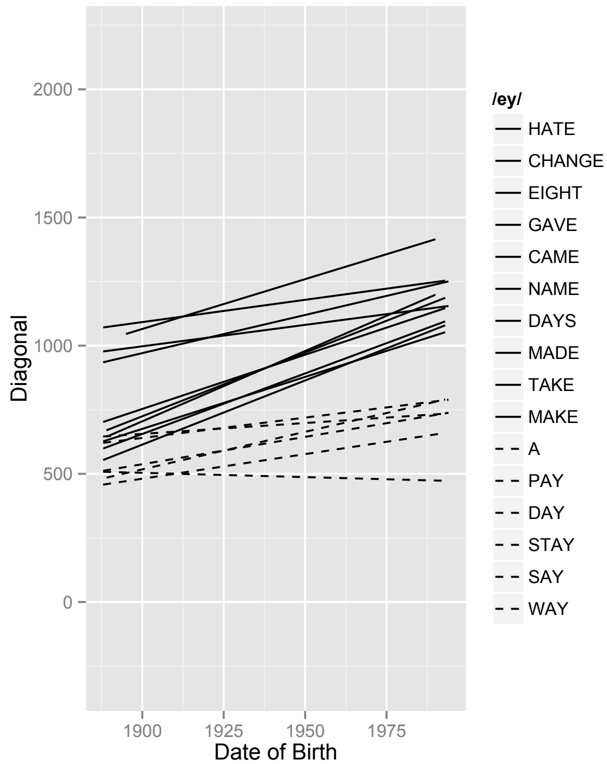
Figure 10. Linear regression trend lines of ten common /eyC/ words by date of birth for speakers born (a) before 1940 and (b) after 1940. Words in legend ordered by height on right hand margin.

(a) (b)



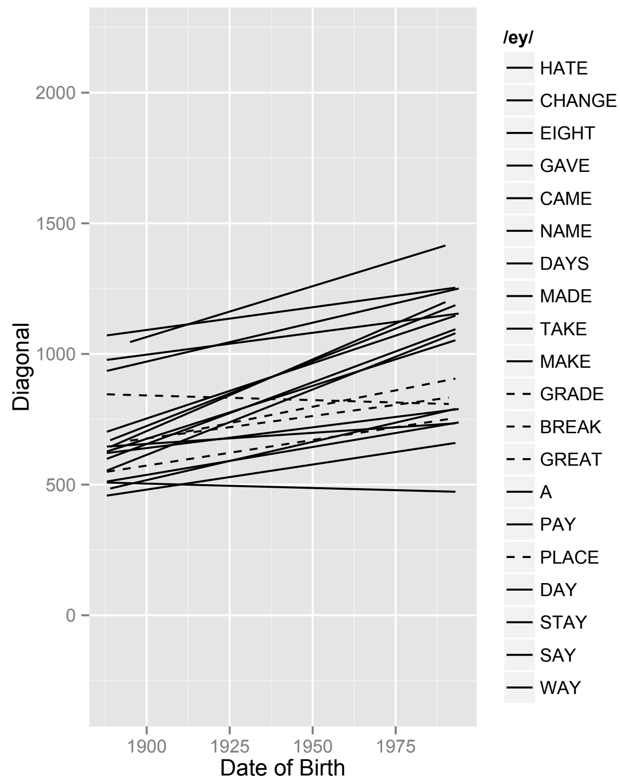
This reorganization appears more clearly in Figure 11 for trend lines across the whole century, adding the six most common content words from the /eyF/ category: *a, day, pay, say, stay, way.* Among speakers born at the beginning of the century these were not differentiated from the lower /eyC/ allophone of checked vowels with labial and apical onsets. The individual words in this lower/eyC/ set follow a parallel track upward. By the end of the century, they are clearly identified with the entire set of vowels with consonantal codas. The other /eyC/ set, words with velar and zero onsets, were also subjected to the raising process, but register a ceiling effect so that at the end they are no longer differentiated from any other /eyC/ words. In this process, all of these sixteen most common words behave in a manner dictated by their phonetic composition, and there is no sign of their being selected individually by the phonological process.

Figure 11. Linear regression trend lines of sixteen common /ey/ words by date of birth. Words in legend ordered by height on right hand margin.



There remains a set of four common words that behave differently and would seem at first glance to constitute lexical exceptions, exemplified here by *grade, great, break* and *place.* These are added to the trend line display in Figure 11. Though these words fall into the phonological class of words with consonantal codas, they show little or no upward movement, winding up only slightly ahead of the free words. Plainly this is the phonetic effect of stop/liquid onsets, which generally leads to lower and backer nuclei (-195 in Table 1), and indicate another aspect of phonological re-organization in the course of this sound change.

Figure 12. Linear regression trend lines of twenty common /ey/ words by date of birth including /eyC/words *grade, break, great* and *place.* (dashed lines).



A similar phonological displacement is echoed in a dramatic chapter of the history of English: the general sound law that merged open long /ɛ:/ with closed long /e:/ in the 16th-17th centuries, *meat* merging with *meet* (Labov 1975). This occurred in the course of the Great Vowel Shift which moved /i:/ to [ai], /e:/ to [i:] and /æ:/ to [e:]. Three words with Middle English /ɛ:/ did not follow the merger, but stayed behind to merge with the rising long /æ/: in *mate.* These three words were *great, break* and *drain,* long considered by historians of English to be exceptions to regular sound laws and a challenge to Neogrammarian doctrine.[19] But we can note that these words are the same phonetically defined class that separated from the main /eyC/ class to align with /eyF/. They are not lexical exceptions but part of a recurring process in which allophones most strongly differentiated by coarticulatory effects are re-assigned to the neighboring phonemes.

[19] The two other exceptions, *yea* and *steak*, have a different dialectal history (Labov 1975).

A second such case can be observed in the English back vowels, where long open /ɔ:/ spelled *oa* as in *boat, moat, goat* etc. rose in the back section of the vowel shift to /o:/ One word remained behind, *broad*, now the only English word spelled with *oa* and pronounced as long open /ɔ:/. It is of course no accident that it too has a stop/liquid onset.

What has been learned

I have examined the raising of /eyC/ as a prototypical sound change in a continuous phonetic space, below the level of conscious awareness, which has continued in the same direction for over a century. As an ideal candidate for a Neogrammarian sound change, it has been selected to test the diffusionist hypothesis that change propagates gradually through the vocabulary. The extended time period, the volume of data and the linear incrementation of /eyC/ has facilitated the comparison of the rates of change of individual words at different stages. Only a few candidates for lexical effects were detected in the course of this study, but none were decisive. A reasonable inference is that all words in which the phoneme occurs in the phonologically defined environment were selected simultaneously to participate in the change.

Given this finding, there remains the question of how typical this prototypical case may be. We know that lexical diffusion does occur, sometimes rooted in complex histories of dialect contact. The Philadelphia tensing of short-a has been repeatedly cited as a prototypical case of such lexical diffusion (Ferguson 1975, Labov 1989, 2001, Kiparsky 1988, Bermudez-Otero 2007). More recently, Fruehwald 2013 has advanced our understanding of the origins of lexical diffusion in the Philadelphia raising of /ay0/ before voiceless obstruents.[20] But these are minority cases. So far, the study of a century of sound change in Philadelphia has found no evidence of lexical irregularity in the fronting of /aw/, /ow/ and /uw/, the

[20] Fruehwald 2013 shows that the lexical selection of individual words before voiced obstruents (*Snyder, spider, tiger* etc.) was triggered by the opacity of the basic rule that raised *writer* [rəɪɾɚ] but not *rider* [raɪɾɚ], and followed the initial raising before flaps in real time.

raising of /ahr/ and /ohr/, the raising of /oh/or the backing of /e/, as well as the raising of /eyC/ examined here.

In the broader and less extended studies of the *Atlas of North American English* the great majority of the sound changes examined were found to be regular and lexical effects to be minimal (see Figure 1; Labov 2010, Ch. 15). It is to be understood that as the size of the database increases, small lexical effects may appear at significant levels.[21] The problem of replicating such effects is a serious one. Since lexical diffusion is defined by arbitrary and unmotivated selection, one would not expect the same words in studies of other communities, but rather a different arbitrary selection to appear. To the extent that lexical selection is found, it is a valuable heuristic for determining the outer limits of a speech community.[22]

The success of the FAVE suite for automatic alignment and measurement of sound change poses the question: What has been learned from 56,748 measurements of the /ey/ nucleus that could not have been learned from the 60 measurements of the three Atlas subjects? So far we have learned that this sound change has continued in the same direction for a hundred years; that it is led by women; that it is found in all neighborhoods of the city and all educational levels (LRF); that it is defined phonologically from the outset (Fruehwald 2013). This study has given us a clear view of phonological re-organization superimposed on a continuous phonetic process. The characterization of sound change advanced in Bloomfield 1933 years ago – *phonemes change* – can be understood in two senses. A phoneme changes its phonetic realization: here members of the /ey/ phoneme are realized as increasingly higher and fronter in phonetic space. Phonemes also change in their internal structure: here the initial opposition of zero and velar onsets to all

[21] To test the significance of such significant levels is to see whether the effects persist in randomly selected halves and quarters of the data. In general, phonological effects do; lexical effects do not (Labov 2010: Ch. 13).
[22] Thus in many r-pronouncing communities of the East there is lexical selection for which words show loss of /r/ in dissimilating words. North Jersey and Philadelphia show such vocalization of the first /r/ in *quarter* and *ordinary,* but only Philadelphia in *corner.*

others was seen to give way to a different opposition: consonantal coda as against all others.

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