Phonetic Change and Phonology

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In this paper, I will attempt to support the following two arguments

(1) Phonetic change is a distinct type of language change, displaying qualitatively different dynamics from syntactic, morphological, and phonological change.

(2) However, there is good evidence that categorical phonology plays a crucial role in the mediation of phonetic change.

I will propose that a model of phonetic change which adequately captures these effects, describes it as a change in language specific phonetic implementation of phonological objects. Phonetic change, then, can be localized to the implementation of particular phonological features, or bundle of features. I will conclude with some remarks about the consequences of this model for the nature of phonological representation.

Phonetic Change is Qualitatively Distinct from Other Language Change

When introducing the topic of language change, the fact that it typically follows an S-shaped curve is mentioned early on (Kroch, 1989; Labov, 1994, inter alia). However, there is a crucial difference between the S-shaped curve in most language changes, and the S-shaped curve in phonetic changes. In syntactic changes, the curve represents the *frequency of use* of the novel variant. The observations from syntactic change are categorically either the old, or innovative form, as illustrated in Figure 1.

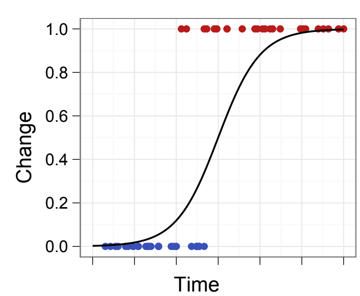

Figure 1: Distribution of observations in syntactic, morphological, and phonological change.

This categorical variation, combined with the logistic curve of change, led Kroch (1989, 1994) to treat syntactic change as competing syntactic grammars. The canonical example is the rise of *do*–support, which Kroch (1994) treats as competing variants of Tense. One variant triggers V-to-T movement (T^+) and the other does not (T^-). By hypothesis, speakers who acquired language at some point part way through the change would use both variants according to the frequency of use in the speech community at the time. An example from Samuel Pepys is given in (3).

(3) The Diary of Samuel Pepys, 1666–1667 (emphasis added)
  a. "He *understands not* the nature of the war."
  b. "Fellows that *did not understand* them . . . "

This approach to variation shares much in common with variable rules (Cedergren and Sankoff, 1974), which incorporates the probability of application into the rule description itself. While the grammar contains probabilities in variable rule analyses, the outcomes of those rules are still categorical.

In phonetic changes, on the other hand, the S-shaped curve represents the *quality of use* of a linguistic form, as illustrated in Figure 2. The first large scale acoustic study of phonetic change, Labov et al. (1972), concluded that phonetic changes progress continuously through the phonetic space. That is, midway through a phonetic change, speakers don't produce a mixture of maximally innovative forms and the old forms. Rather, they produce forms intermediate between the starting point and ending point of a change.

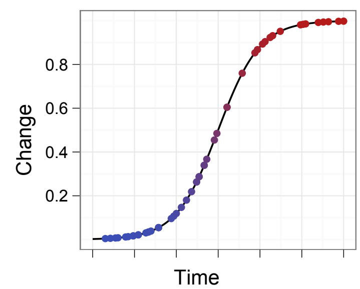

Figure 2: Distribution of observations in phonetic change.

Neither grammar competition nor variable rules are immediately extendable to describe continuous phonetic change.

Is phonetic change truly continuous?

Of course, it is necessary to *demonstrate* that phonetic change progresses continuously. If speakers were actually producing tokens drawn from highly overlapping bimodal distributions, and we were to simply calculate the mean of that mixture, it would produce the appearance of continuous change.

I will take the raising of /ay/ before voiceless consonants (henceforth (ay0)) in Philadelphia as a test case. This was originally identified as a new and vigorous change led by men, (Labov, 1994), and has been linked to masculinity and toughness (Conn, 2005; Wagner, 2007). The raised variant has also started to appear in contexts where it was not previously conditioned (Fruehwald, 2007), but I will be focusing exclusively on contexts which unambiguously trigger raising. My data is drawn from the developing Philadelphia Neighborhood Corpus (Labov and Rosenfelder, 2011).

See the section on the Philadelphia Neighborhood Corpus below for details about this data.

Figure 3 displays the mean F1 value (in normalized z-scores) for (ay0) for 47 Philadelphian speakers born between 1889 and 1991. We can observe a rapid and cohesive shift from a not-quite fully low position to a mid position in this data.

However, these means don't necessarily indicate that (ay0) is raising in a continuous change. In order to determine that, we have to decide whether for speakers midway through the change, their distribution of their tokens looks more like it has a single mode, or two.

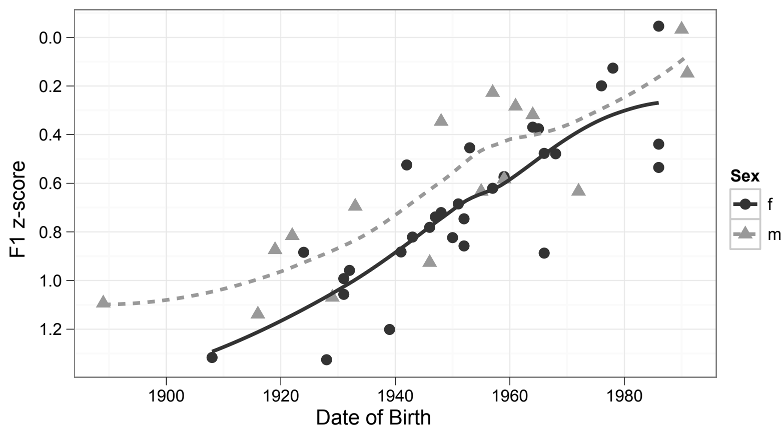

Figure 3: Change in (ayo) height in Philadelphia by date of birth.

That is, we have to determine if speakers have a single phonological object that is changing in its phonetic realization over time, or whether they have two phonological objects with fixed phonetics (say, /ɐɪ/ and /əɪ/) which are shifting in frequency of use.

If the situation is the latter, we can develop a hypothesis of what the the distribution of pure /ɐɪ/ and pure /əɪ/ should look like. Presumably, speakers with the lowest realizations of (ayo) should be closest to pure /ɐɪ/, and speakers with the highest realizations should be closest to pure /əɪ/. So, I took the 4 speakers with the lowest (ayo), and calculated their average F1, and average standard deviation for F1 to represent the distribution parameters of /ɐɪ/. I did likewise for the 4 speakers with the highest (ayo) to represent the distribution parameters of /əɪ/. These parameters are displayed in Table 1.

	Mean F1	Sd
ɐɪ	1.29	0.41
əɪ	0.05	0.48

Table 1: Mean and standard deviations of z-scored F1 for the 4 most advanced, and 4 most conservative speakers with respect to (ayo)

Using these parameters, I simulated the change from /ɐɪ/ to /əɪ/ as changing mixture of the two (Figure 4). If the observed data from the change is sufficiently similar to the simulation, then a categorical model of phonetic change could be reasonable. If it is not, then I would conclude that this change has progressed continuously.

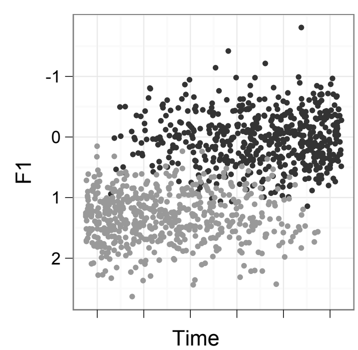

Figure 4: Simulated change in (ayo) height based on mixing two distributions

One clear consequence of the mixture model is that there should be a strict relationship between the estimated mean value of a speaker, and the standard deviation of their distribution. The standard deviation of a mixture of two distributions will be larger than the the standard deviation of either one in isolation, and it should be larger the more even the mix. Therefore, if the mixture model is correct, we should predict that the standard deviation of speakers' distributions of (ayo) should reach a peak mid-way through the change. In fact, we can estimate what the s.d. of a speaker's distribution ought to be based on the simulation. Figure 5 compares the relationship between the mean and s.d. from the simulation to the observed data.

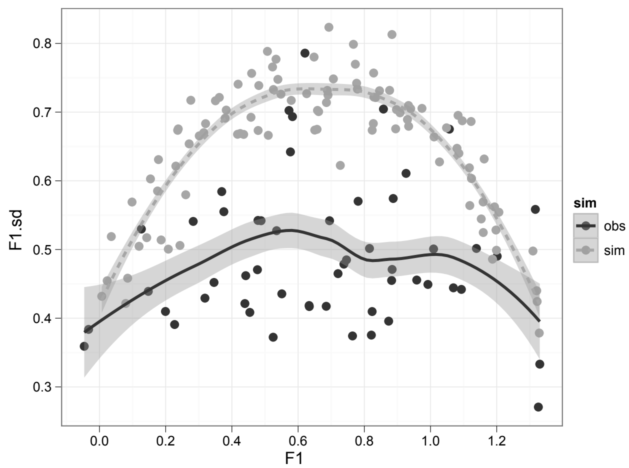

Figure 5: Comparing the relationship of the sample mean to sample standard deviation for observed speakers and simulations. Observed data in black.

There may be a slight tendency for speakers midway through the (ayo) raising change to have larger standard deviations, but most speakers have the same standard deviation throughout all stages of the change. I conclude from this that phonetic change progresses as a single target moving through the phonetic space, estimates of which are represented in Figure 3 above.

IS THERE ANY WAY THAT CATEGORICAL VARIATION could produce the appearance of continuous change? I will briefly consider two options. First, perhaps it is possible that in cases of competition between two categorical phonological objects can result in their blend in production. This blending would be possible for phonetic change, since something halfway between [ɐɪ] and [əɪ] is well defined, while for syntactic change, head movement half way to Tense is not.

Some evidence from speech production research suggests that such blending may be possible. Utilizing a variant of the tongue-twister paradigm, McMillan et al. (2009) induced the probable transposition of the onsets of nonsense words in their participants, leading to these onsets being in competition for production. Their main result, reproduced in Figure 7, was that while in most cases, speakers produced either fully canonical versions of the target segment (upper left quadrant) or fully canonical versions of the competitor (lower right quadrant), they also produced quite a few intermediate forms.

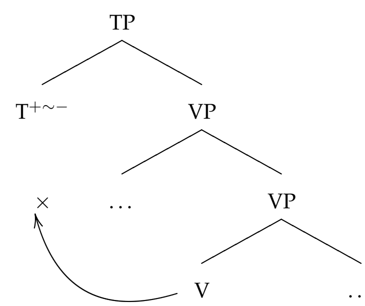

Figure 6: Not a well defined syntactic movement given competition on T.

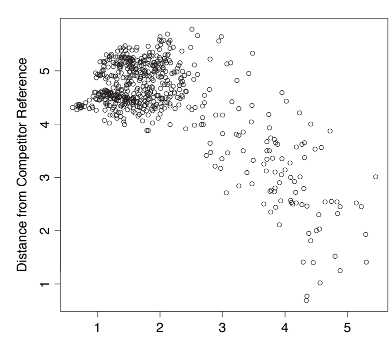

Figure 7: Gradient productions resulting from categorical competition, from McMillan et al. (2009)

However, I don't believe this result is extendable to explain continuous phonetic change. To begin with, it would reduce the observed patterns in phonetic change to speech errors. Secondly, unblended categorical competition does take place. To choose a relatively uninteresting example, Figure 8 plots all tokens of *either* from the Philadelphia Neighborhood Corpus. Most speakers say [iːðɚ], some say [aɪðɚ], and [eɪðɚ] is unattested. Finally, in the case of (ayo), the allophone undergoing a phonetic change is the product of a phonological process. For this blending account to apply to (ayo), the phonological process which produces (ayo) would have to produce two outputs simultaneously, which then blend in production.

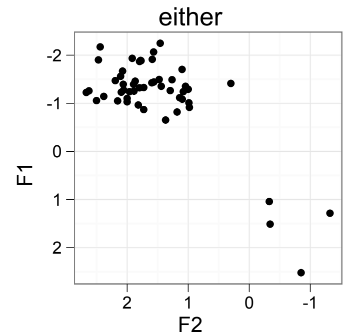

Figure 8: All tokens if *either* from the Philadelphia Neighborhood Corpus. No intermediate tokens are observed.

ANOTHER APPROACH to treating phonetic change as categorical variation would be to either expand the feature set, or increase the number of possible values a feature can take (Weinreich et al., 1968; Flemming, 2004). The major problem with an *n*-ary approach is that in order to capture the necessary degrees of freedom involved in a phonetic change, the role features play in defining natural classes would be eroded. Taking Philadelphia, for example, given the number of phonetic changes in progress in the vowel system, it would be surprising if the natural class defined by any given feature and value were larger than 1.

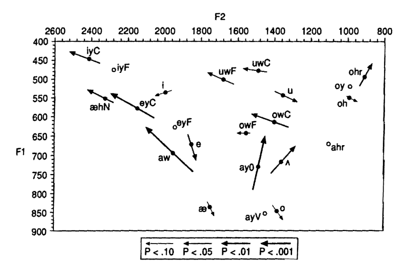

Figure 9: Active sound changes in progress in Philadelphia, from Labov (2001)

Conclusion

Phonetic change is qualitatively different from other kinds of language change, and cannot be described in terms of competition, or variation between categorical alternatives. Rather, it is best described as the continuous movement of a phonetic target through the phonetic space.

Furthermore, speakers are clearly sensitive to fine grained phonetic differences, as they index important social and indexical information (Labov, 2001; Conn, 2005; Wagner, 2007; Eckert, 2010) without altering phonological identity. [fʌɪt] and [fʌ̝ɪt] are not phonological minimal pairs, but you should be more cautious about someone who says [fʌ̝ɪt miː].

I leave aside, here, the literature suggesting that knowledge of the phonetic target in phonetic space affects not only speaker's production, but also phonological perception (Hay et al., 2006; De Decker, 2008; Kendall and Fridland, 2010).

Categorical phonology plays a role in phonetic change.

Despite the fact that phonetic change cannot be described as occurring at the level of categorical phonology, there is some evidence to suggest that it plays a crucial role as a mediator.

Most importantly, given the regularity of sound change, the unit of phonetic change is typically defined as the phonological segment.

Labov (2010, Ch 13) walks through a number of case studies of phonetic change in North America, and concludes that most apparent lexical effects are explicable by phonetic context. Phonetic change affects all members of a higher organizational unit. True cases of lexical diffusion seem to occur not at the lower levels of phonetic implementation of these units, but rather, at the higher organizational level, thus are outside the purview of discussion here.

Additionally, it is the case that at all stages of a phonetic change, the sound system as a whole remains analyzable as a system of equivalencies and contrasts. That is, if a language undergoes a change from stage A to stage B, all intermediate stages are also a language. This is a non-trivial fact, and can be contrasted with the exemplar based modeling of de Boer (2001), where languages pass through "brief period[s] of chaos" from one stage to another.

Parallel chain shifts are also important evidence that the unit of phonetic change may be even smaller than a segment, encompassing a phonological natural class. For example, there is the trend across North America to front the long, back upgliding vowels, /uw/, /ow/ and /aw/. Looking at the mean values from the Atlas of North American English (Labov et al., 2006), the backness of these three vowels are more highly correlated with each other than with any other vowels. Table 2 displays a correlation matrix containing Pearson correlation coefficients, and Figure 10 plots these relationships.

	uw	ow
ow	0.73	
aw	0.48	0.57

Table 2: Pearson correlation coefficients for /uw/, /ow/ and /aw/ backness across North America (Labov et al., 2006)

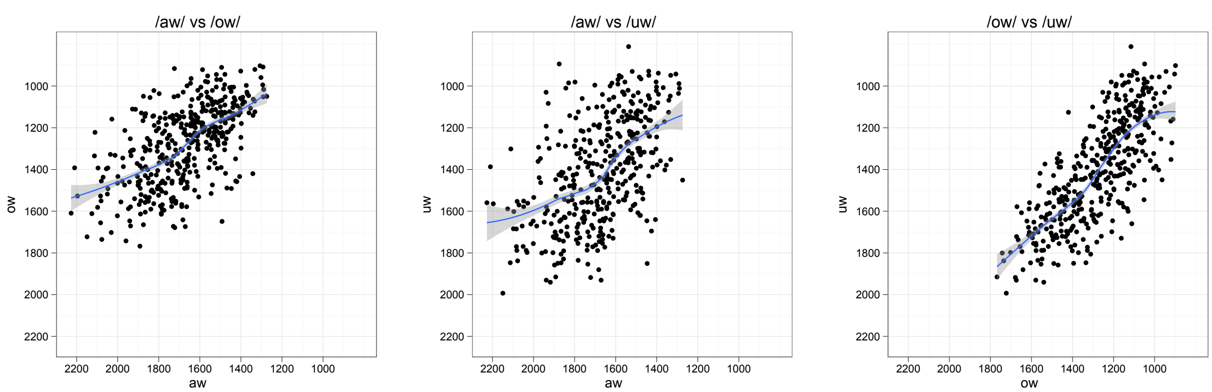

Figure 10: The correlation of /uw/, /ow/ and /aw backness across North America (Labov et al., 2006)

Given the high correlation of phonetic backness between these vowels, it is tempting to say these are all realizations of a single phonetic change which has generalized to a phonological natural class.

An even more important case is the Canadian Shift, where the precipitating cause affects only one element of the natural class undergoing the shift. First described by Clarke et al. (1995), the Canadian shift is presumed to be triggered by the merger of /a/ to /ɔː/.

Clarke et al. (1995) described the following steps of the shift as the retraction of /æ/, followed by the lowering of /ɛ/ and /ɪ/. However, recent investigations in Montreal (Boberg, 2005) and Columbus, OH (Durian, 2009) have described the stages following the low-back merger instead as parallel retraction of /æ/, /ɛ/ and /ɪ/.

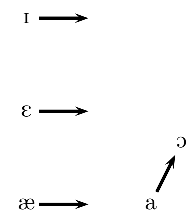

Figure 11: Canadian Parallel Shift.

Regardless of the particular ordering, or the definition of necessary or sufficient events (Bigham, 2009), clearly the only vowel on which there is a relevant phonetic pressure for retraction is /æ/. The generalization of retraction to /ɛ/ and /ɪ/ occurs exactly along lines we would expect to be defined by a phonological natural class (specifically [-tense, -back]). Describing this generalization merely as "analogy" calls for a principled way to delimit the elements for which the analogy extends to ({æ, ɛ, ɪ}) from those which it does not ({ʌ, ʊ}). My suspicion is that any such principled attempt would look very similar to [-tense, -back].

Phonetic change in language specific phonetics

Based on the arguments in the previous two sections, I propose that the best way to account for both the continuousness of phonetic change, and the mediating role of phonology, is to treat phonetic change as changing phonetic implementation of (relatively stable) phonological representations. This approach captures both the continuous and categorical properties of phonetic change. First, phonetic implementation involves the computation of targets in continuous phonetic space. Changes in this computation will produce different targets in this phonetic space. Second, the output of the computation is strictly dependent on its input, which is (by hypothesis) categorical phonological objects.

The model of the phonology-phonetics interface I'm adopting here is similar to "generative phonetics." Figure 12 is a slightly modified version of system proposed in Keating (1990).

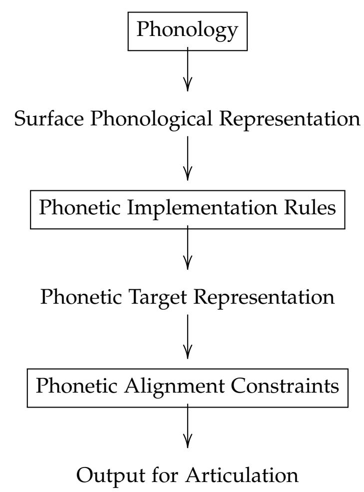

Figure 12: The Phonology-Phonetics Interface

(4) Phonology
categorical→categorical

(5) Phonetic Implementation Rules
categorical→continuous

(6) Phonetic Alignment Constraints (Cohn, 1993; Zsiga, 2000)
continuous→continuous

The substantive content of my proposal is that Phonetic Implementation Rules are part of a speaker's non-arbitrary, learned knowledge of their language (Pierrehumbert, 1990; Kinston and Diehl, 1994). I believe this is a necessary assumption, given the available data on phonetic change.

What are the units that the phonetic implementation rules operate over? Arguing strictly from data on phonetic change, I believe there are two answers.

(7) Phonological Features

(8) Surface Segments

Features

Clearly, there are many other reasons to presume that phonetic implementation rules operate over phonological features. For instance, if segments didn't share phonetic properties with other segments with which they also share phonological features, how could their featural identities be learned?

On the basis of data from phonetic change, parallel shifts are also evidence that phonetic implementation rules operate over features. If phonetic change takes place in phonetic implementation, as I am arguing, and if a phonetic change is affecting an entire natural class, as is the case in the Canadian Shift, then the process of phonetic implementation undergoing the change must be one that makes reference to the natural class.

Surface Segments

When looking at phonetic change, there are some cases where it appears that one segment is changing, but not any of the other elements in its natural class. For example, (ay0) is raising and backing in Philadelphia, but no other segment it might share a natural class with is. Perhaps this change could be connected to the fronting and raising of /aw/, or /ey/ in non-final position, but that may be a stretch.

Words?

As I discussed above, Labov (2010) found that for the most part, apparently lexical effects on phonetic change are the product of contextual effects. I would conclude, then, that phonetic change does not provide strong evidence for word specific phonetics (Pierrehumbert, 2002). Language changes where clear lexical effects have been identified can be described at a higher level of abstraction than the phonetics.

Phonological Reasoning about Phonetic Change

This approach to reasoning about phonetic changes can also enrich phonological investigation. Take, for example, the phonetic change in /ow/ in the American South (Labov et al., 2006). Figure 13 plots the fronting of /ow/ before stops, and the retraction of /ow/ before /l/.

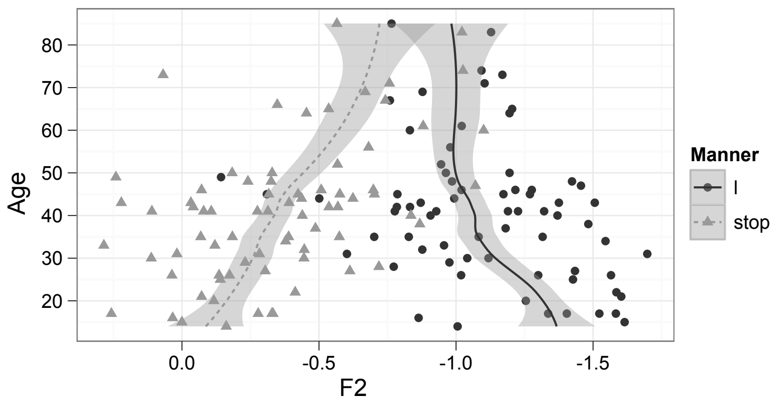

Figure 13: Phonetic change of /ow/ before stops and /l/ in the American South

Under my account of phonetic change, there are two possible reasons for why /ow/ is shifting in two different directions.

(9) a. There has been a phonetic change in /l/, causing it to have a different contextual effect on /ow/.

b. /owT/ and /owL/ have different surface phonological representations, and the phonetic implementations of these representations are changing independantly.

If (9b) is the cause, then there are two possible ways for /owT/ and /owL/ to appear different in their surface phonology.

(10) a. There has been a phonemic split between /owT/ and /owL/, so that they now have different underlying forms.

b. There is an active synchronic phonological process which changes /ow/ in the context of a following /l/.

Further empirical investigation would be necessary to determine whether or not there has been a relevant phonetic change in /l/. Alternatively, if there is a phonological difference between /owT/ and /owL/, further investigation would be necessary to determine *what* the difference is, and whether or not it's the product of an active phonological process.

To be sure, my proposal for phonetic change does not answer these questions, but it does a lot to define the relevant questions for future research.

Another similar case is the split between /ey/ in word final position and /ey/ in all other positions in Philadelphia. Figure 14 plots the data from the Philadelphia Neighborhood Corpus.

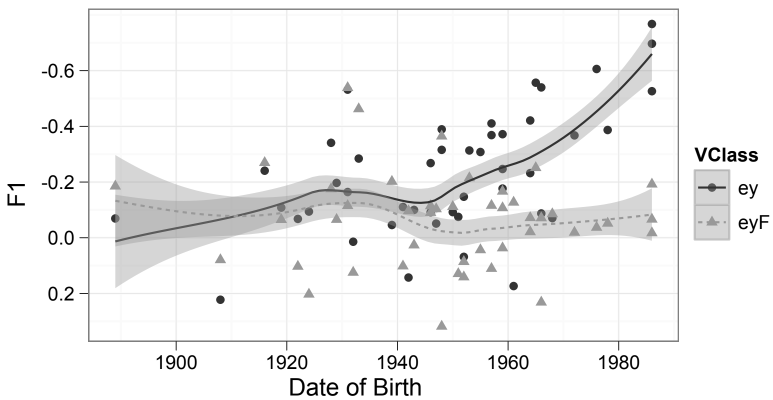

Figure 14: Phonetic change in Philadelphia affecting /ey/ in non-final position.

In this case, I believe the only possible explanation for this split is different surface phonological representations between /ey/ and /ey#/, allowing /ey/ to undergo a phonetic change independently from /ey#/. Again, there are two possibilities for what may cause this difference.

(11) a. There has been a phonemic split between /ey/ and /ey#/, so that they now have different underlying forms.

b. There is an active synchronic phonological process which changes /ey/ in word final contexts.

In this case, I believe there is sufficient data to suggest that (11b) is the most probable explanation. Figure 15 illustrates that for most speakers born after 1945, there is a consistent difference between *day* and *days* in the expected direction. Given the direction of the phonetic difference between /ey/ and /ey#/, an initial formulation of the phonological process which differentiates them is given in 12.

(12) ey → [−peripheral] / ___#

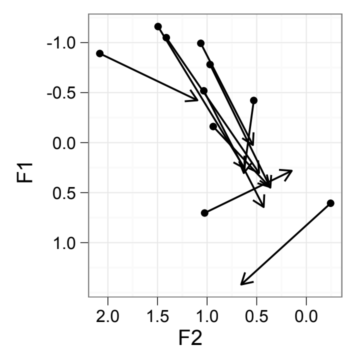

Figure 15: Comparing *days* (points) to *day* (arrowheads) in Philadelphians born after 1945.

Of course, this description of the situation implies that there were actually two changes which occurred, necessarily in the following order.

(13) a. A phonological change, introducing the process of /ey/ laxing in word final position.

b. A phonetic change raising tense /ey/.

Conclusion

The proposal I've put forth here is intended to be an initial sketch of a framework within which to reason about sound change. Phonetic change has unique dynamics from language change in other domains, thus requires a specialized change model. Further work in this vein should attempt to provide descriptions of the phonetic implementation rules, descriptions of the phonetic target representations, and an account of any feedback relationship between the phonetic implementation of features, and those features' contrastive roles (i.e. dispersion (Liljencrants and Lindblom, 1972) or margins of security (Martinet, 1952)).

My proposal also implies that phonological representations are "substance free" (Odden, 2006; Blaho, 2008), since the phonetic implementation of particular phonological features are language specific, and learned. If the role of phonological features are not to define the phonetics of a segment (it's the implementation rules which do that), then their purpose is strictly formal.

Philadelphia Neighborhood Corpus Data

This data is drawn from transcribed interviews with native Philadelphians, which were conducted between 1973 and 2010. The transcriptions were time aligned to the audio at the word and phone level using a modified version of the Penn Phonetics Lab Forced Aligner (Yuan and Liberman, 2008). Formant measurements were then automatically measured (Evanini, 2009; Labov and Rosenfelder, 2010).

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