

# Vowel Shifts and Phonology Phonetics Interface

Josef Fruehwald  
University of Pennsylvania  
joseff@ling.upenn.edu

April 30, 2010

## Introduction

1. I will be arguing from data on vowel shifts in progress, and from principles of language change, that language specific phonetic implementation rules must be part of speaker knowledge, and thus part of language acquisition. Then, I will sketch an abstract model of what phonetic implementation could be like. Having argued these points, I will address how this approach interacts with phonological theory. Specifically, I have four assertions to make:

- (2) The relationship between phonological representation and phonetic realization is non-arbitrary.
- (3) Yet, a theoretically reasonable phonological representation cannot uniquely determine a phonetic realization in every language, dialect, or generation.
- (4) Therefore, processes of phonetic implementation are also targets of acquisition.
- (5) This effectively leaves the features of phonology devoid of any reference to phonetic substance.

## Vowel Shifts

6. Typically, historical sound changes are described by a series of discrete steps. For example, the diphthongization and lowering of Middle English /i:/ to Modern English /ay/ may be described with the following progression (Labov, 1994, p. 146):

(7) i: → iy → iy → əy → ay

8. However, such a description is merely a notational convenience, or due to the imprecision of the measurement tools (e.g. historical texts). Studies of modern vowels shifts utilizing instrumental phonetic

analysis have found that vowels shift through the phonetic space more or less continuously (Labov et al., 1972). There does not appear to be quantal leaps in vowel quality from one generation to the next. Figure 1 illustrates such a continuous shift in opposite directions in two North American dialects (Labov et al., 2006).

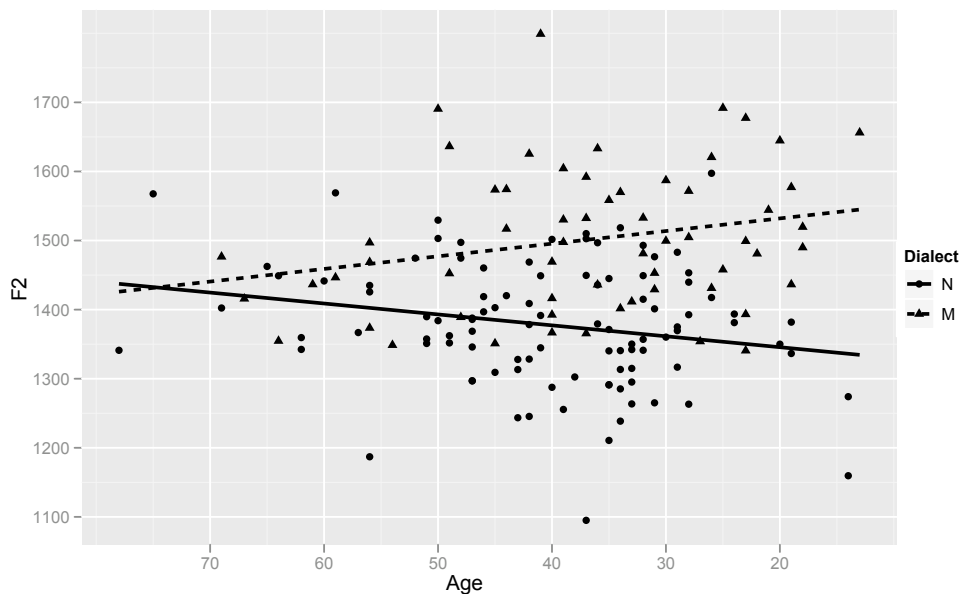


Figure 1: Shifts of /ʌ/ in two North American Dialects  
 North: Backing  
 Midland: Fronting  
 Data from Atlas of North American English

**9.** It is my assumption that in order for differences across generations to constitute change, these generations must be meaningfully different from each other in their linguistic knowledge. Otherwise, observed variation simply represents noise. In this sense, phonetic changes like vowel shifts are the same as changes in other domains of language, like syntax, morphology or phonology.

**10.** However, phonetic changes are very different in their propagation across generations. In the domain of syntactic change, generations differ in their *frequency of use* of distinct variants. For example, over the course of the loss of V-to-T movement in Middle English, speakers produced both V-to-T sentences and No-V-to-T sentences, with an increasing frequency of No-V-to-T (Kroch, 1989). Since this is the mechanism of syntactic change, it is open to analysis in terms of competition, and allows for the fruitful importation of mathematics from biological evolution (Yang, 2002).

**11.** In contrast, during phonetic change generations appear to differ in their *quality of use* of a single object. Figure 2 illustrates this point by picking out three representative Midland speakers and plotting their distributions of /ʌ/. What appears to be changing is not the frequency of use of some distinct fronted form of /ʌ/, but rather the overall distribution of /ʌ/ production. This closes off phonetic change from analyses based on competition and biological dynamics, much to the consternation of researchers of sound change.

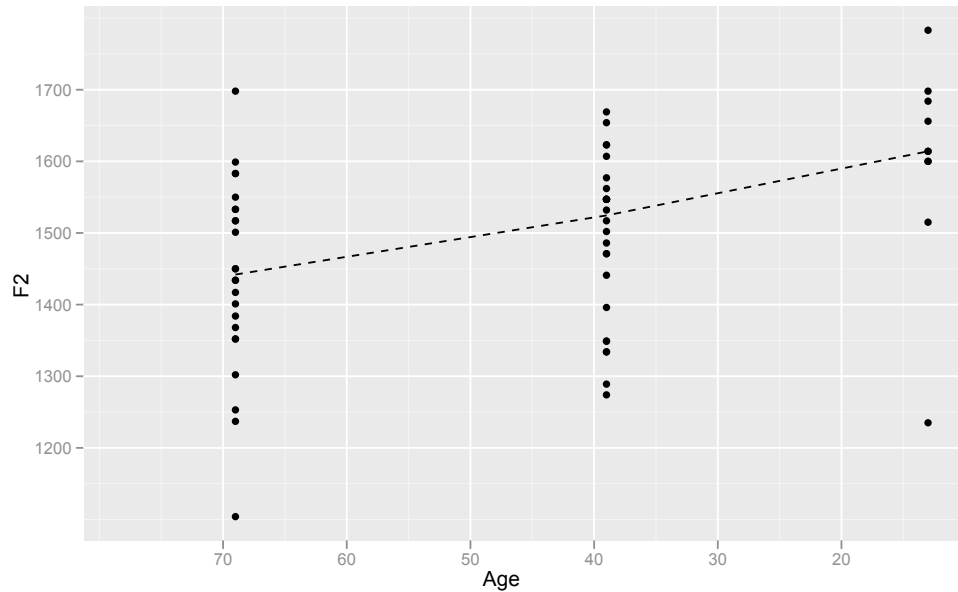


Figure 2: Three Representative Midland Speakers  
Data from Atlas of North American English

**12.** However, it also seems clear that the phonological system exerts a coherence (or “binding force” (Labov, forthcoming)) over the phonetic distribution of the vowels in motion. That is, at all points during the course of a phonetic change, vowels are expressible within and recoverable as a system of equivalencies and contrasts. It has never been attested that phonetic change progresses by a temporary suspension of contrasts within one generation, followed by new emergent contrasts. However, this should be possible under a strictly phonetic account of sound change, as in the agent based modeling of de Boer (2001).

**13.** Moreover, even though vowel shifts have always progressed continuously (per the Uniformitarian Principle (Labov, 1994)), they can almost always be described after the fact as a phonological rule added to the grammar (King, 1973; Kiparsky, 1995). This regularity of sound change seems to indicate that phonology must be involved, somehow, since the consequences of phonetic change are ultimately phonological.

**14.** Capturing both the phonological constraints and the phonetic gradience of phonetic change is not straightforward. In other domains, the fact of change is not challenging to theories of grammar and representation. Any theoretical apparatus that can handle a V-to-T grammar and a No-V-to-T grammar in isolation can also handle their competition. However, given some standard models of phonology and its interface with phonetics (Hale and Reiss (2008, ch. 5) to pick an example), there doesn't seem to be a way to capture the difference between a language with a slightly fronted /ʌ/ from another with backer /ʌ/, all other things being equal.

**15.** These are the basic facts of phonetic change. It is my assertion that the continuousness of phonetic change described in **11.** is challenging to purely featural representations of speech sounds. It is also my as-

sertion that the phonological “binding force” imposed upon phonetic change, described in **12.**, is challenging to a purely phonetic account of speech sound representation. If my arguments below should be inadequate to resolve these challenges, they will continue to stand.

## Accounting for Vowel Shifts

### No Phonetic Learning

**16.** If we assume that phonetic implementation is not a learned part of speaker knowledge, then we must account for these facts of phonetic change entirely the phonology. To do so, it is necessary to introduce gradience into phonological representation, since the gradience of vowel shifts would have approximately reflect the “size” of a feature in phonetic space. However, this approach eliminates the most important role of phonological features in defining natural classes.

**17.** In (18), I sketch a few approaches to capturing this gradience phonologically. Specifically, these are  $n$ -ary feature values (18a) (Weinreich et al., 1968; Labov et al., 1972), percentage feature values (18b), and blending of features in competition (18c).

(18) (a) / $\Lambda$ /  

$$\left[ \begin{array}{c} - \text{hi} \\ - \text{lo} \\ 3 \text{ back} \end{array} \right]$$
 $[\alpha \text{ back}]$  where  $1 \leq \alpha \leq 5$  and  $\alpha$  is an integer

(b) / $\Lambda$ /  

$$\left[ \begin{array}{c} - \text{hi} \\ - \text{lo} \\ 70\% \text{ back} \end{array} \right]$$

(c) / $\Lambda$ /  

$$\left[ \begin{array}{c} - \text{hi} \\ - \text{lo} \\ \{+ \text{back}; -\text{back}\} \end{array} \right]$$
 SELECT: [- back] 70%

**19.** These could all be sophisticated models of phonological representation, and effectively capture the facts of vowel shifts. However, they do not effectively capture the phonological patterning of speech sounds into natural classes. Under hypotheses of binary or privative features, two phonemes are considered to belong to the same natural class for some feature iff they have the same specification for that feature. If  $n$ -ary feature values are admitted, then suddenly a slightly fronted /u/ is no longer in the same natural class for backness as a fully back /o/.

20. This fragmentation of natural classes is, of course, undesirable for many reasons, including a loss of explanatory power for some kinds of vowel shifts. There are some vowel shifts which appear to apply to entire natural classes, which I will call *Parallel Shifts*. Two examples from North American English are back-glide vowel fronting and the Canadian Shift. In the South and Mid-Atlantic, /uw, ow, æw/ are all fronting. In Canada, the West, the Midland and parts of the South, /ɪ, ε, æ/ are all backing. However, in both of these shifts, some vowels in the class are more in advance than others. If advancement of the shift must be represented phonologically with *n*-ary values, then there is actually no natural class description of which vowels are undergoing the change.

## Phonetic Learning

21. It seems only reasonable, given how problematic introducing gradience directly into phonology is, that the phonetic implementation of phonological objects must be also acquired.

## Atomic Relation to Targets

22. One approach to implementation might be to say that a phoneme as an atom, i.e. a unique combination of feature values, is related to some particular phonetic target. Phonetic learning would then involve figuring out the mapping between a phonemic atom and target value. This is, in fact, in line with the usual rhetoric of sociophonetic literature, which talks about /a/-fronting, /æ/-retraction and /ʌ/-lowering. This approach would also “plug-in” easily to the kind of autonomous phonetic representations suggested to exist both by exemplar theory (Pierrehumbert, 2006), or by a prototype theory (Kuhl et al., 2008).

23. However, Atomic Relation does not require that there be any isomorphism between the featural representation of a phoneme, describing its natural class memberships, and its phonetic realization. It is usually the case that phonological natural classes, i.e. targets or triggers of some phonological process, are also phonetically similar on some dimension (Mielke, 2008). This need not be the case under Atomic Relation, and there’s no principled reason for it to be impossible to define natural classes strictly on grounds of targets and trigger.

24. It’s not necessarily clear that an isomorphism between phonological features and phonetic form must be enforced by the architecture of the interface; however, I will be assuming that is. So, while we’ve established that features can’t fully determine what the phonetic realization, they must be used for *something* in the determination of phonetic form.

## Functions over Features

25. Instead, I propose that a phonetic target is computed by means of subfunctions over phonological features, with an overarching function to combine them. This approach is in line with work in generative phonetics (Pierrehumbert, 1980; Keating, 1988; Cohn, 1993, 2007, *inter alia*), but more focused on deter-

mination of targets than allowances for interpolation. An initial sketch of the system is given in (26), and an illustration of what it may look like in a phonetic space is given in (27).

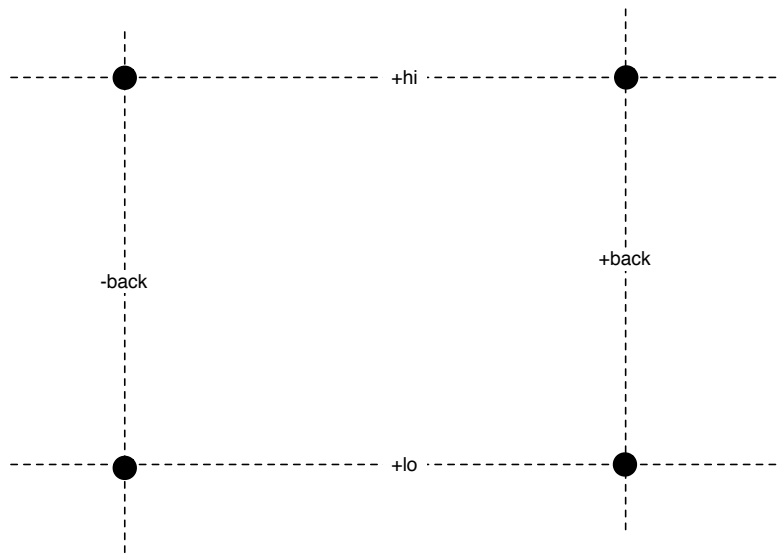
(26) COMPUTING PHONETIC TARGET (to be revised)

(a) Phoneme: /A/

(b) 
$$\begin{bmatrix} +X \\ +Y \\ +Z \end{bmatrix}$$

(c)  $[A] = F(f([+X]), f([+Y]), f([+Z]))$

(27)



**28.** In this system, all phonemes which share some feature  $X$  will share some implementation function  $f(X)$ , thus share some value along some phonetic dimension. The location of phonetic targets are completely dependent on the phonological features of the segment, thus ensuring isomorphism across the two domains.

**29.** The observed patterns of many Parallel Shifts, and even many Chain Shifts can be easily captured under this model. For example, the retraction of /ɪ, ε, æ/ in the Canadian Shift could be understood as a change in the implementation subfunction  $f([-back])$ .

**30.** However, the model in (26) is insufficient to capture vowel shifts involving only one vowel. It is not the case that all vowel shifts affect an entire natural class. There must be some way to “protect” a natural class from the shift of one of its members. Additionally, it is not clear that any given vowel system, even a relatively static one, could be described by implementation functions over single features.

31. The revised system in (32) is meant to allow for both individual vowel shifts and for “idiosyncrasies” of a single vowel with respect to the rest of the system. It includes implementation functions for larger feature matrices. The figure in (33) illustrates how a complex implementation function would look in a system with a slightly backer and higher low front vowel than would be expected from the rest of the system. Within this system, an individual vowel’s shift could be described by changing values of a complex subfunction.

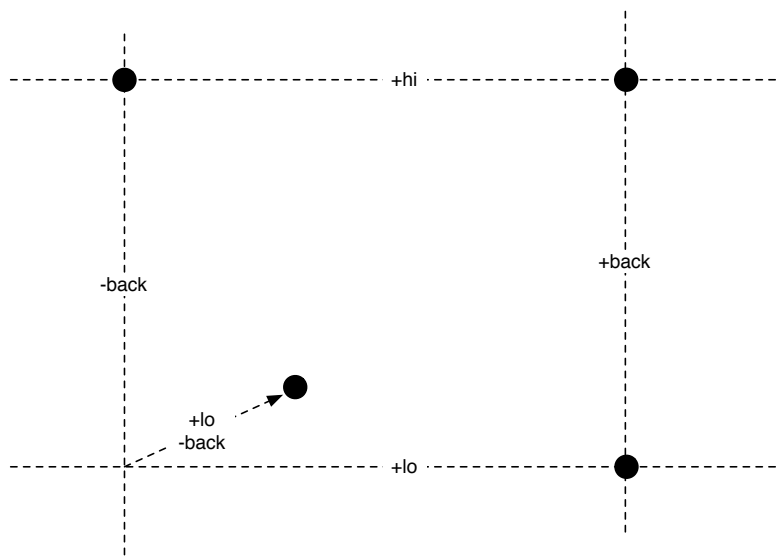
(32) COMPUTING PHONETIC TARGET (revised)

(a) Phoneme: /A/

(b) 
$$\begin{bmatrix} +X \\ +Y \\ +Z \end{bmatrix}$$

(c) 
$$[A] = F(f([+X]), f([+Y]), f([+Z]), f\left(\begin{bmatrix} +X \\ +Y \end{bmatrix}\right), f\left(\begin{bmatrix} +X \\ +Z \end{bmatrix}\right), f\left(\begin{bmatrix} +Y \\ +Z \end{bmatrix}\right), f\left(\begin{bmatrix} +X \\ +Y \\ +Z \end{bmatrix}\right))$$

(33)



34. One thing to note is that the largest subfunction referring to all features is identical to what Atomic Relation would look like. If this function did most of the work in determining the phonetic target of a phoneme, then the isomorphism between phonetic realization and natural class membership would, again, break down. For this reason, there must be a bias towards maximizing the utilization of simplex subfunctions, and minimizing utilization of complex subfunctions.

35. Assuming this bias towards more simplex functions, a clear opportunity to reintroduce notions of competition arises. For some phonetic realization of a phoneme, [A], there may be more than one possible featural representation. The best representation would be the one requiring the fewest complex subfunc-

tions, but in the midst of the change there would be some indeterminacy, and structural pressures at all points. In this way, the ultimate phonological reanalysis and reorganization following sound change could be described.

### Possible Evidence for Simplex Bias

**36.** There is some potential evidence that simplex functions should be preferred over complex function in the work of Preston (2008). Preston reports on the “restructuring” of the Northern Cities Shift by ethnic minorities in Michigan. In Figure 3, a representative speaker of the Northern Cities Shift drawn from the Atlas of North American English (Labov et al., 2006) is compared to the observed restructuring by Preston.

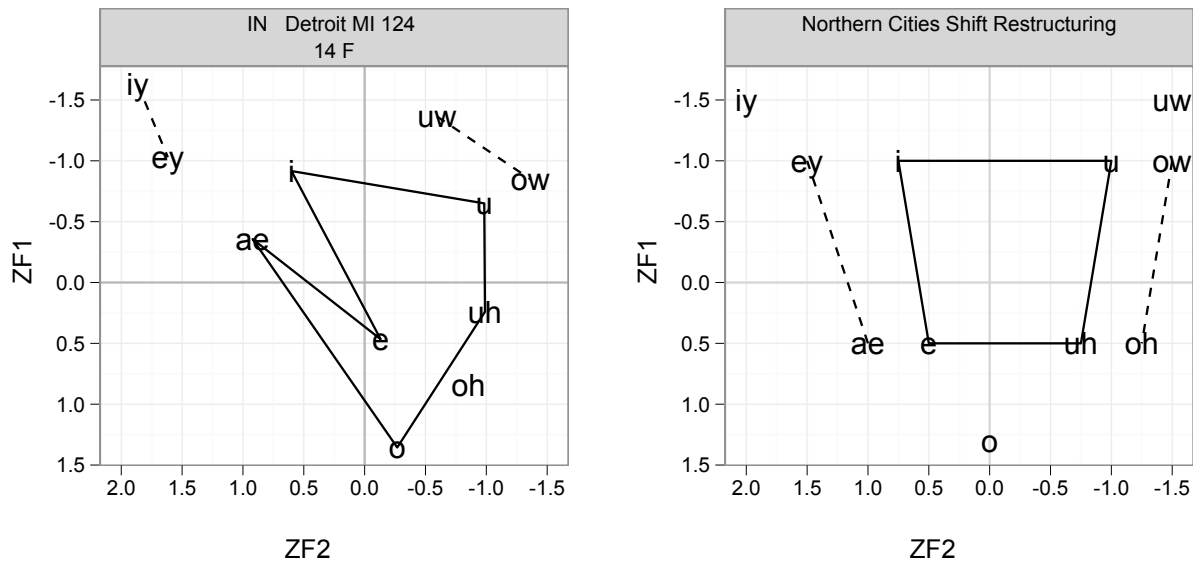


Figure 3: Left: A representative NCS Speaker  
Right: Preston’s proposed restructuring

**37.** If there is a bias towards utilizing simplex functions, it would follow that a sufficient amount of evidence would have to be present to justify increasing the load of complex functions. The social context of being an ethnic minority with limited communication with the dominant local dialect, or with a large competing input from other sources, could be noisy enough a channel to obscure this sufficient evidence. The data presented by Preston (2008) very impressively suggests that this is the kind of process involved. The very same restructuring is observed in many different communities with different linguistic and dialectal substrates.



## Satisfaction of the Vowel Shift Problems

**38.** The specific problems posed by vowel shifts are that they propagate continuously, but their elements must simultaneously be represented in a categorical phonology. With the approach laid out here, continuous change is realized by shifting output values of implementation functions, and representation within a categorical phonology is maintained via the input to these implementation functions.

**39.** Up to this point, I have also supported the assertions (2) through (4): (2) The relationship between phonological representation and phonetic realization is non-arbitrary, (3) yet a theoretically reasonable phonological representation cannot uniquely determine a phonetic realization in every language, dialect, or generation. (4) Therefore, processes of phonetic implementation are also targets of acquisition.

## Phonological Theory

### Derivational Placement

**40.** Where should this process of computing a phonetic target be placed within the derivational structure of producing an utterance? Hale and Reiss (2008) lay out the following derivational structure from Phonological objects to bodily output.

(41) UR – Phonology → SR – Transduction → Gestural Score

**42.** The output of the phonetic implementation functions I have been discussing cannot be the Surface Representation in (41). These functions are not part of Phonology, and their output is not of the same representational form. The Transduction from phonological Surface Representations to a Gestural score seems to be the best location for the phonetic implementation rules discussed here. However, Hale and Reiss (2008) specifically hypothesize that there should be no learning involved in the Transduction of a mental representation to/from a physical signal.

**43.** Cohn (1993), to pick an example, provides another derivational structure in which there seems to be a place for the phonetic implementation functions discussed here, specifically within the Language Specific Phonetics.

(44) UR – Phonology → SR – Language Specific Phonetics → Universal Phonetics → Physical Output

**45.** Since Universal Phonetics in (44) and Transduction in (41) seem to be doing the same kind of work, a hybrid model incorporating insights from both, as well as from this work, is given in (46).

(46) UR – Phonology → SR – Phonetics → Phonetic Representation – Transduction → Gestural Score

## Nature of Features

47. The role of phonological features in phonetic implementation within this model is purely algebraic. There is no sense in which a feature like [+hi] makes any reference to any phonetic dimension. Phonological features are, then, substance free, in the sense of Hale and Reiss (2008).

48. I believe this fact calls into question the innateness of particularly named features. If there were an innate feature called [+hi] with a concomitant implementation function,  $f([+hi])$ , there is nothing in the architecture proposed here to prevent  $f([+hi])$  from mapping onto a phonetically low position. Introducing a constraint that  $f([+hi])$  map to conventionally high region would reintroduce substance to the phonology, and would reintroduce most of the problems to phonology that exist if there is no phonetic learning.

49. All that matters to the approach laid out here is that there be *some* feature which is shared by a set of vowels, that this feature can mark this set of vowels as triggers or targets of phonological processes, and that the implementation function for feature maps those vowels to a common phonetic (say, high) position. That this feature be called [+hi] is more of a notational convenience. In this sense, the approach laid out here is highly compatible with work done in Emergent Feature theory (Lin and Mielke, 2008; Mielke, 2008). In fact, Mielke (2008) comes to the same conclusion with regards to the abstractness of features: while derived from phonetic substance, their role is algebraic and computational.

50. The fact that there should appear to be a consistently reoccurring feature [+hi] may have more to do with a shared articulatory apparatus among humans, the shared acoustic properties of that apparatus (c.f. Quantal Theory (Stevens, 1989)), the shared perceptual system amongst human beings, and the common kinds of sound changes to occur given these shared systems (c.f. Evolutionary Phonology (Blevins, 2004)). For the most part, assuming that some set of conventionally named features can describe the sound system of some language is a useful approximation until one attempts to address exactly the kind of phenomenon I've approached here. However, it should not be the case that a theory of grammar, or Universal Grammar, relies crucially on the ontological status of innate, named features.

## Conclusion

51. To reiterate, I have made four primary assertions with this work.

(52) The relationship between phonological representation and phonetic realization is non-arbitrary.

(53) Yet, a theoretically reasonable phonological representation cannot uniquely determine a phonetic realization in every language, dialect, or generation.

(54) Therefore, processes of phonetic implementation are also targets of acquisition.

(55) This effectively leaves the features of phonology devoid of any reference to phonetic substance.

**56.** These conclusions interact most directly with Conditions 2 and 3 on a theory of phonology from Halle (1959). It is my assertion that phonological features (binary or otherwise) do not characterize the phonetic properties of a language's speech sounds. If they did so, then the problems raised in **16. – 20.** would be unresolvable. It is also my assertion that given the derivational system in (46), the output of Phonology is not the ultimate linguistic characterization of an utterance. However, in all other respects the phonological derivation is deterministic, and does not make reference to external domains.

## References

- Blevins, Juliette. 2004. *Evolutionary phonology: the emergence of sound patterns*. Cambridge University Press.
- Cohn, Abigail. 1993. Nasalisation in English: Phonology or Phonetics. *Phonology* 10:43–81.
- Cohn, Abigail. 2007. Phonetics in Phonology and Phonology in Phonetics. *Working Papers of the Cornell Phonetics Laboratory* 16:1–31.
- de Boer, Bart. 2001. *The Origins of Vowel Systems*. New York: Oxford University Press.
- Hale, Mark, and Charles Reiss. 2008. *The Phonological Enterprise*. New York: Oxford University Press.
- Halle, Morris. 1959. *The Sound Pattern of Russian: A Linguistic and Acoustical Investigation*. The Hague: Mouton & Co.
- Keating, Patricia A. 1988. Underspecification in phonetics. *Phonology* 5:275–292.
- King, Robert D. 1973. Rule insertion. *Language* 49:551–578.
- Kiparsky, Paul. 1995. The Phonological Basis of Sound Change. In *Handbook of Phonological Theory*, ed. John Goldsmith. Blackwell.
- Kroch, Anthony. 1989. Reflexes of grammar in patterns of language change. *Language Variation and Change* 1:199–244.
- Kuhl, Patricia K., Barbara T. Conboy, Sharon Coffey-Corina, Denise Padden, Maritza Rivera-Gaxiola, and Tobey Nelson. 2008. Phonetic learning as a pathway to language: new data and native language magnet theory expanded (NLM-e). *Philosophical Transactions of the Royal Society* 363:979–1000.
- Labov, William. 1994. *Principles of linguistic change. Volume 1: Internal Factors*. Blackwell.
- Labov, William. forthcoming. *Principles of Linguistic Change. Volume 3: Cognitive and Cultural Factors*.
- Labov, William, Sherry Ash, and Charles Boberg. 2006. *The Atlas of North American English. Phonetics, Phonology and Sound Change*. Berlin: Mouton de Gruyter.
- Labov, William, Malcah Yaeger, and Richard Steiner. 1972. *A Quantitative Study of Sound Change in Progress*. The U.S. National Survey.
- Lin, Ying, and Jeff Mielke. 2008. Discovering place and manner features: What can be learned from acoustic and articulatory data. In *Penn Working Papers in Linguistics*, ed. Joshua Tauberer, Aviad Eilam, and Laurel MacKenzie, volume 14.1, 241–254.

- Mielke, Jeff. 2008. *The Emergence of Distinctive Features*. New York: Oxford University Press.
- Pierrehumbert, Janet B. 1980. The phonology and phonetics of English intonation. Doctoral Dissertation, MIT.
- Pierrehumbert, Janet B. 2006. The next toolkit. *Journal of Phonetics* 34:516–530.
- Preston, Dennis R. 2008. What is a Speech Community Anyway. Talk presented at NWAV37.
- Stevens, Kenneth. 1989. On the *quantal* nature of speech. *Journal of Phonetics* 17:3–45.
- Weinreich, Uriel, William Labov, and Marvin Herzog. 1968. Empirical foundations for a theory of language change. In *Directions for Historical Linguistics*, ed. W. Lehmann and Y. Malkiel. U. of Texas Press.
- Yang, Charles. 2002. *Knowledge and learning in natural language*. New York: Oxford University Press.