Phonetics in Phonology

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At least since Trubetzkoy (1933, 1939) many have thought of phonology and phonetics as separate, largely autonomous, disciplines with distinct goals and distinct methodologies. Some linguists even seem to doubt whether phonetics is properly part of linguistics at all (Sommerstein 1977:1). The commonly encountered expression 'the interface between phonology and phonetics' implies that the two domains are largely separate and interact only at specific, proscribed points (Ohala 1990a).

In this paper I will attempt to make the case that phonetics is one of the essential areas of study for phonology. Without phonetics, I would maintain, (and allied empirical disciplines such as psycholinguistics and sociolinguistics) phonology runs the risk of being a sterile, purely descriptive and taxonomic, discipline; with phonetics it can achieve a high level of explanation and prediction as well as finding applications in areas such as language teaching, communication disorders, and speech technology (Ohala 1991).

1. Introduction

The central task within phonology (as well as in speech technology, etc.) is to explain the variability and the patterning -- the "behavior" -- of speech sounds. What are regarded as functionally the 'same' units, whether word, syllable, or phoneme, show considerable physical variation depending on context and style of speaking, not to mention speaker-specific factors. Documenting and explaining this variation constitutes a major challenge. Variability is evident in several domains: in everyday speech where the same word shows different phonetic shapes in different contexts, e.g., the release of the /t/ in *tea* has more noise than that in *toe* when spoken in isolation. Variability also manifests itself dialectally, morphologically, and in sound change. All of these forms of variation are related. Todays's allophonic variation can lead to tomorrow's sound change. Sound change that takes place in one language community and not another leads to dialectal variation; sound change that occurs in one morphological environment and not another leads to morphophonemic variation. But the variable behavior of speech sounds is not random; there are statistically favored patterns in it. Part of our task in explaining sound patternings, then, is to attempt to understand the universal factors that give rise to allophonic variation and how they can lead to sound change.

Below I will first give a brief sketch of two areas -- among many possible -- where phonetics can provide a principled and empirically-supported account of certain sound patterns (see also Ohala 1992, 1993). Then I will give an account of sound change that connects the phonetic variation to the phonological variation.

2. Phonetic Accounts of Sound Patterns

2..1 The Aerodynamic Voicing Constraint

The aerodynamic voicing constraint (AVC) (which I treat in more detail in another paper presented at this SICOL, "Aerodynamics of phonology") provides an example of a phonetic constraint on speech production. It is manifest phonetically in everyday speech as well as having an impact on the phonology of languages through sound change. Briefly, the AVC arises as follows: voicing requires that the vocal cords be lightly approximated and that there be air flowing through them. During a stop, even if the vocal cords are in the right configuration, air will accumulate in the oral cavity and eventually reach the same level of air pressure as that in the trachea. When the pressure differential across the glottis is zero or even near zero, the air flow is reduced to a point where vocal cord vibration ceases.

There are ways to moderate the effects of the AVC -- it is not an absolute constraint against voicing in obstruents. Obviously many languages have voiced stops, even voiced geminate stops, e.g., Hindi. For example, one can allow the oral cavity to expand passively thus creating more room for the accumulating air and in that way delaying the moment when oral pressure equals subglottal pressure. One can also actively expand the oral cavity, e.g., by enlarging the pharynx, lowering the larynx and the jaw, and thus prolonging voicing even more. But these maneuvers have their own limits and costs and therefore phonological consequences. To exploit passive expansion of the vocal tract, one must keep the duration of the stop somewhat short (at least in comparison to the duration of cognate voiceless stops). A consequence of this, I believe, is that intervocalic voiced stops, because they need to have their closure interval kept short, are more likely to cross the stop vs. "spirant" boundary and become voiced spirants or approximants than is true of intervocalic voiceless stops. This is evident, e.g., in Spanish stops where breath-group-initial voiced stops have voiced spirant allophones intervocalically: /ˈbaɲo/ 'bath' but /ˈnaβo/ 'turnip' (the voiceless stops show no such manner change in the same environments: /ˈpiko/ 'beak', /ˈkapa/ 'cape'). Given the "cost" of maintaining voicing in spite of the AVC, one finds an asymmetrical incidence of voicing in geminate stops. As noted by Jaeger (1978), although both voiced and voiceless geminate stops are attested, in many languages there are only voiceless geminates. Moreover, in some cases we can trace the history of geminates and their voicing. There are many instances of voiced geminate stops becoming voiceless but I am unaware of any cases of voiceless geminate stops becoming voiced (Klingenheben 1927). Moreover, whether passive or active expansion of the oral cavity solves the problem of how to maintain voicing during a stop, the possibilities for such expansion are less with back-articulated stops such as velars and uvulars than with front-articulated ones such as labials and apicals. Thus there are many instances of languages having a voicing distinction in stops but lacking a voiced velar stop, e.g., Dutch, Thai, Czech (in native vocabulary) (Gamkrelidze 1975, Sherman 1975). In Nobiin Nubian morphologically-derived geminates from voiced stops retain voicing with labials but not with stops articulated further back: /fabːɔn/ (< /fab/ 'father' + suffix) but /mʊkːɔn/ (< /mʊg/ 'dog' + suffix) (Bell 1971, Ohala 1983).

2.2. Acoustic-Perceptual Factors in Changes in Place of Articulation

A quite familiar process in speech sound variation is the assimilation of the place of articulation of a consonant to that of an adjacent consonant, e.g., in English the final stop of *wide* is alveolar but that in the related derived word *width* is dental under the influence of the adjacent dental fricative [θ]. Here it is one articulator, the tongue apex, which shifts its place because it is also involved in making an adjacent sound at a place different from its original place. But there are some cases of consonantal changes in place of articulation where the articulators involved before and after the change are distinct. Although these have often been characterized as being articulatorily-motivated changes, a more careful examination shows that this cannot be the case.[1]T Representative examples of the cases I am referring to are exemplified in Table 1.

Here, as mentioned, the articulators used in the "before" state and the "after" are different. This is obviously true when p > t / __i,j and k > p / __u, w, where lips and tongue are involved but it is also true in the case of k > t, tʃ, ʃ, s / __i, j (also called 'velar palatalization'), where the articulator is the tongue dorsum before the change and tongue apex afterwards. Although both apex and dorsum are part of the tongue, they are for the most part functionally independent. Thus this change cannot be exactly like the [t] ~ [t̪] variation in *wide* ~*width*. Further evidence that velar palatalization is not articulatorily motivated is the fact that the place of articulation of the after state ([t, tʃ, ʃ, s] are further forward of the place of the conditioning environment ([i, j]).

Table 1. Examples of sound changes involving large changes in place of articulation.

Sound Change	Language	Example	Origin, Root
k > t, tʃ, ʃ, s / __ i, j	English	*chicken* [ˈtʃɪkən]	*cocc* + diminutive
“	French	*racine* [ʁasin] ‘root’ < ratsinə̯	Gallo-Roman rɑdiˈkiːnɑ
k > p / ___ u, w	Cl. Greek	hippos ‘horse’	PIE *ekwōs
“	West Teke	pfuma ‘chief’	PB *-kumu
p > t / ___ i, j	E. Bohemian Czech	tɛt ‘five’	pʲɛt
“	Genoese Italian	tʃena ‘full’	pjeno
“	Zulu	-tʃʰɑ ‘new’	PB *pia

If there were a purely articulatory motivation for the shift we should rather expect the outcome of this change to be the palatal consonants [c, ç]. Instead, as argued in Ohala 1986, 1992, velar palatalization as well as the other two place changes are best explained by the acoustic-perceptual similarity and thus confusability of the sounds involved. In fact, laboratory-based confusion studies duplicate these sound changes, showing a high incidence of confusions of the type [ki] > [ti] (where ‘>’ means ‘is confused with’), [pi] > [ti] and [ku] > [pu] (Winitz et al. 1972; see also Guion 1996).[2] These results show that sound change can be studied in the laboratory (Ohala 1993).

3. From phonetic variations to phonological variations

3.1. Theoretical foundations

The type of phonetic constraints discussed above are constant and timeless. They are responsible for numerous phonetic variations in pronunciation and perception every day in every language each time a speaker speaks and a listener listens. What is the relationship between these constant production and perceptual variations in speech and the events designated as sound change which occur in a particular language at a particular period in history?

My view of this can be stated very simply (see also Ohala 1992, 1993):

1. Physical phonetic constraints in speech production lead to distortions or perturbations of the speech signal which may make it ambiguous to the listener. These phonetic constraints may be of various types: neurological, neuro-muscular, articulatory (inertial and elastic properties of the speech organs), aerodynamic, as well as the constraints governing the mapping of articulation-to-sound.
2. The listener occasionally misinterprets or misparses the speech signal due to these ambiguities and arrives at a different pronunciation norm from that intended by the speaker. A change in pronunciation norm constitutes a “mini” sound change.
3. Whether the new pronunciation norm is “nipped in the bud”, i.e., eliminated by being corrected or whether it spreads through the lexicon and from one speaker to the next is determined by psychological and sociological factors. Unlike the physical phonetic constraints, these latter factors have a definite historical aspect. They occur in a definite place and time.

Phonetics has a role in studying the first two of these stages. This can be characterized as studying and duplicating “mini” sound changes in the laboratory. Together these constitute what might be called the initiation of sound change or more colorfully, the germination of the seeds of sound change. Step three covers the transmission or spread of sound change.

3.2. Implications

If the above proposal is accepted about the relation of universal phonetics on the one hand and language- and time-specific sound change on the other, there are some important implications which follow:

- Any attempt to construct truly general, explanatory, theories of natural sound patterns, i.e., ones capable of reflecting natural classes of speech sounds and making the maximal generalizations about speech sound behavior, will have to exploit physical phonetic models of speech processes. In short, phonological naturalness is based on universal physical phonetic constraints. Most of the phonological notations in current use in mainstream phonology, e.g., autosegmental notation and feature geometry, are inherently incapable of representing such naturalness in a principled and general way (Ohala 1990a,b, 1995).
- Because the representations that do reflect the naturalness of sound patterns employ complex mathematical models using continuous parameters, it is extremely unlikely that any of this is psychological, i.e., it is unlikely that native speakers are aware or need to be aware of the naturalness of the sound patterns in their language. Native speakers do not need to be aware of Boyle's Law in order to be subject to it any more than they have to know chemistry in order to digest their food. Thus the attempts in mainstream phonology to attribute phonological naturalness to "Universal Grammar", part of the psychological/genetic endowment of all humans, is just redundant.
- Sound change is not teleological; it does not serve to optimize articulation, perception, or the way language is processed in the speaker's brain. It is just an inadvertent error on the part of listeners.
- As a corollary to the above: sound change is not implemented by a novel or altered rule of grammar. Just as the transcription errors of a student taking notes on a teacher's lectures were not intended by the teacher nor the student, so too a listener's errors in interpreting the speech signal were not implemented as a rule changing the pronunciation norm either by the speaker or the listener.
- Many linguists, e.g., Weinreich, Labov, and Herzog (1968), Martinet (1949), Jakobson (1978), Lass (1980), Vennemann (1993), believe that it should be possible, ideally or actually, to answer the questions "[w]hy do changes in a structural feature take place in a particular language at a given time, but not in other languages with the same feature, or in the same language at other times?" (Weinreich, et al., 1968:102). Insofar as this question may have an answer, it is not to be found in the *initiation* of the sound change. If, as I propose, a new pronunciation norm is initiated when a listener misapprehends the speech signal, the question of why this occurred reduces to why some listener made such a mistake. But the studies of sound change in the laboratory show that some percentage of listeners invariably make such perceptual mistakes. There is always some probability for misperception -- sometimes higher, sometimes lower -- associated with any given ambiguous signal. Just as in the lab-based perception studies no one bothers asking why a specific subject A misperceived stimulus B, so, too, I believe it is fruitless to ask why a given sound change arose in a specific language A at a specific time B, and not in some other language or not in language A at some other time. Rather, in both lab studies and in sound change we should be more concerned with the probability levels for confusion given the total population of speaker-listener interactions -- where the 'total population' is all languages at all points in time. It may be possible (though difficult) to find the social and/or psychological factors which led a given sound change, once it had been initiated, to spread to other speakers and to other words in the lexicon, in other words, to become "popular" enough to be characteristic of a whole speech community. However, most attempts to identify such factors suffer from the "too many degrees of freedom" problem: a whole host of causative factors can be drawn upon including the language's phonology, morphology, spelling, syntax, lexicon, semantics, pragmatics, even the "personality" of the speakers, etc., where each of these contain multiple factors. There seems

to be no scientific rigor in invoking these alleged causal factors and, unlike the enterprise of studying sound change in the laboratory, there have been no controlled tests of the hypotheses offered.

4. Conclusion

Phonetics is one of the disciplines that helps to provide answers to phonology's questions about why speech sounds behave as they do. Moreover, in its growth over the past couple of centuries it has developed a respectable level of scientific rigor in creating and testing models of various aspects of the speech mechanism. Phonology can benefit from phonetics' methods, data, and theories (Ohala 1991).

Notes

[1] For additional challenges to articulatory-based accounts of assimilation, see Ohala 1990b.

[2] Regarding the asymmetry in the direction of confusion, see Ohala 1985, 1997, Plauché et al. 1997.

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