Journal of Phonetics (1990) **18**, 153–171

There is no interface between phonology and phonetics: a personal view

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The recently popular collocation "the interface between phonology and phonetics" implies that the two disciplines are, except for the place where they interface, largely independent and autonomous. I argue against this conception. Whether conceived of as separate stages in the generation of speech or as separate disciplines, phonology and phonetics must instead be closely integrated, not simply interfaced. Some of the pitfalls of practicing phonology as an autonomous discipline are detailed and exemplified under the headings: circularity, reification, projection, and myopia. Integrating the two disciplines allow us to explain sound patterns in language in terms that have greater simplicity, generality, empirical verifiability, fruitfulness and convergence.

> . . . It is my purpose to show that a sharp distinction between phonetics and phonemics cannot usefully be maintained; that phonetics actually makes use of considerations which are strictly phonemic; that physical criteria are an integral part of phonemics; and that a description of language of any level, from phonetics to stylistics, cannot be properly evaluated without considering its consequences on all other levels.
>
> (Halle, 1954)

1. Introduction

The phrase "interface between phonology and phonetics" has been cropping up more and more these days (Fromkin, 1975; Nolan, 1990; Keating, 1988). What does this phrase mean? I can identify two senses:

(A) There are two domains in the universe of speech, one covered by phonology (the speakers' knowledge?), another covered by phonetics (the physical side of speech); there is a point at which these two meet, for example where phonological representations become implemented physically.

(B) Phonology and phonetics are two largely autonomous disciplines whose subject matters may be similar (like those of chemistry and physics) but which study them in different ways; there is an area in between where the two can cooperate.

In this paper I argue against both of these conceptions.

0095–4470/90/020153 + 19 $03.00/0

2. Terms

Let us first try to be clear on the meaning of the terms *phonology* and *phonetics* as well as the term *interface*.

2.1. "*Phonology*" *and* "*phonetics*"

As a discipline, phonology is traditionally conceived of as the study of the logical and functional structure and behavior of speech sounds. The phonologist is supposed to answer questions such as: how does language X differentiate words?, why are there cross-language regularities evident in the sequencing of sounds within syllables and in patterns of place assimilation on medial stops, e.g., the much greater frequency with which C1 assimilates to C2 as in Late Latin /okto/ > Italian /otto/? As a part of the speech universe phonology is probably taken to be the "software" that drives speech behavior, the mental representation of words and the knowledge speakers have of the relationships between words.

Phonetics, on the other hand, as a discipline is the study of how speech sounds are produced and perceived. The phonetician is supposed to explain, for example, why certain fricatives require greater glottal opening than cognate stops, why it is difficult to maintain both voicing and frication simultaneously, why obstruency itself threatens simultaneous voicing, why the cues for place of consonant articulation reside primarily in the second formant, etc. As a part of the speech universe, phonetics is thought to be the "hardware" that implements the control signals from the phonological component.

2.2. "*Interface*"

The term "interface" is used metaphorically. To understand that word we can see how it is used in other, non-linguistic, contexts. It is used to describe a semi-permeable membrane, e.g., the placenta is characterized as the interface between the fetus and the mother. Nutrients and wastes pass through but not blood. The cell wall, another semi-permeable membrane, is the interface between the metabolic factories of the body on the inside and the source of raw materials and the destination of the manufactured proteins, etc. on the outside. "Interface" is the standard term for the connection between computers and their peripherals such as printers. Interfaces are separate mechanisms which translate materials or signals from one device or system into a form utilizable by the other. What is common to all of these usages is the implication that there exists two largely autonomous entities which have little or only occasional interaction. A dictionary definition of "interface" is as follows:

> the place at which (or means by which) independent systems meet and act on or communicate with each other (*Webster's*, 1985).

I argue that phonology and phonetics are not mutually autonomous or independent whether as parts of the speech universe or as disciplines. They are no more autonomous than chemistry and biology are within molecular biology and no more so than physics and chemistry within physical chemistry. The term "interface" is inappropriate for phonology and phonetics because it deliberately under-represents the overlap in the domains covered by these disciplines as well as their interests,

methods, and data. To argue this point I will first address view (A), above, phonology and phonetics as two independent domains and will then consider view (B) which regards them as independent disciplines.

3. Phonology and phonetics as part of the speech universe

I am not aware that anyone has made precise claims as to where in the speech universe phonology is to be located but it seems clear that the domain of phonetics would include the vocal tract plus the neuromuscular machinery which drives it as well as the ear and its underlying neurological structures. A possible proposal might be that phonology is what is stored, e.g., the lexicon and knowledge about the relationships between items in it, whereas phonetics consists of any operation done on this word store including retrieving, concatenating, and actual implementation of the latent instructions for pronunciation. Perhaps we should wait until someone makes and attempts to defend a specific proposal on this point but I venture to say that no matter what division is made on anatomical or functional grounds, it will be impossible to characterize either discipline as autonomous or independent. If it boils down to a kind of "phonology = knowing" *vs.* "phonetics = doing" dichtomy, the knowledge—of units, distinctive features, etc.—is acquired and updated by complex phonetic analysis. One gets the impression from much of the phonological literature that features, segments, syllables are somehow just "given"—perhaps innate. To date all we can be sure of is that the anatomy and neuroanatomy which serves speech (and many other non-speech activities) are genetically specified. There is a growing literature showing that phonological units and processes are what they are largely due to the physical and physiological structure of the speech mechanism (e.g., Lindblom, 1984, 1986; Ohala, 1983, 1989, 1990*a*, *c*; Wright, 1986; Goldstein, 1983). Even the knowledge speakers may have about systematic phonological relationships between words such as *music* and *musician* must be influenced by a phonetic comparison of them (Derwing, 1976; Ohala & Ohala, 1987).

It is equally impossible to imagine a "phonetic" component working largely independently of the phonological knowledge or competence of a speaker. It is true that some events in the speech signal are apparently contributed by the speech organs themselves and may not be part of the lexical or phonological specification of pronunciation, e.g., the intrinsic F_0 of vowels or perhaps the F_0 perturbation induced by consonants (Ohala, 1978; Ohala & Eukel, 1987). Nevertheless, aside from such few exceptions there has never been any question that the movements in speech are implementations of phonologically-specified word shapes. Moreover, there is evidence that the speech output is being continuously monitored or even "edited" (i.e., checked before output) in order to guarantee that it accurately implements the intended signal (Ohala 1981*a*; Baars, Motley & MacKay, 1975). Certain patterns of assimilation, e.g., how far in advance of a nasal the velum lowers in American English, are influenced by the presence of certain phonological boundaries, word or syllable, before the nasal (Ohala, 1971*a*; McLean, 1973).

Listening to speech is also highly determined by the phonological patterns of the listener's language. When speech stimuli are made to vary along certain continua, not only the identification functions but also the discrimination functions show discontinuities that are unlike those found with other sensory stimuli varying continuously, e.g., temperature or light intensity. The difference apparently is that

speech stimuli are compared with stored patterns in memory whereas other stimuli are not (Pisoni, 1973; Fujisaki, 1979; Nearey & Hogan, 1986). I have presented evidence that the way listeners extract constancy out of the extreme variation in speech is by having very detailed knowledge of how rate and other factors influence the shape of speech—in some sense this knowledge enables them to "undo" the effects of phonological rules such as elision and assimilation (Mann & Repp, 1980; Ohala, 1981*b*, 1986*a*, 1989; Ohala & Feder, 1987).

In short, a serious examination of the activities that speakers engage in under the labels of "phonology" and "phonetics" will show that there is an intimate interaction between the two; viewing them as autonomous is artificial and unnecessarily complicates the study of speech.

4. Phonology and phonetics as autonomous disciplines

In this section I propose to review very briefly (too briefly) the history of the relations between the two disciplines. In the sections to follow I demonstrate some of the pitfalls of practicing phonology autonomously and finally offer examples of the benefits from the integration (not the "interface") of phonetics and phonology.

4.1. *Preliminaries*

For the following discussion it is necessary to make a distinction between two different "phonetics". There is, first, a predominantly descriptive or taxonomic phonetics which was introduced by Panini about two and a half millenia ago. This consists of a set of more or less objective anatomical-physiological descriptors of speech sounds that have been used successfully by everyone dealing with speech, and this includes phonologists.[1] There is also a more truly scientific phonetics which attempts to understand, to explain, to generalize, about the form of speech sounds. Wolfgang von Kempelen's 1791 work *Mechanismus der menschlichen Sprache* represents one of the first scientifically serious entries in this quest. Some of the key works in the subsequent evolution of this form of phonetics—to mention a random few just for the sake of illustration—would include Willis (1830), Helmholtz (1863), Rousselot (1891), and, more recently, Chiba & Kajiyama (1941), Fant (1960), Lindblom (1986), and Stevens (1989). In actuality, what I am calling taxonomic phonetics and scientific phonetics are just different stages of development of the same basic discipline. For its time, Panini's choice of articulatory descriptors of speech sounds[2] represented an important advance in the understanding of the physical structure of speech. Nevertheless, the recent advances in the study of speech have gone so far beyond the lore accumulated in the Paninian tradition that is it justified to characterize it as a different, a "scientific", phonetics. Taxonomic phonetics is more or less well integrated in phonology; it is the integration of scientific phonetics (henceforth, simply "phonetics") within phonology that is less evident and which is the focus here.

[1] Also stenographers, spelling reformers, voice teachers.

[2] As opposed to the kind of impressionistic labels proposed by other grammatical traditions, e.g., the Greeks and Romans, who employed labels such as "thin" (*tenuis*).

4.2. *History*

I think the relationship between phonetics and phonology is similar to that between the physical sciences (e.g., physics and chemistry) on the one hand and the life sciences (e.g., physiology and medicine) on the other. With few exceptions (e.g., William Harvey, Stephen Hales, Antoine Lavoisier) the physical sciences and physiology were practiced in isolation up to the mid-19th century. Those opposed to the integration of these disciplines cited the essential differences, including the degree of complexity, between living and non-living things and moreover attributed to living things a "vital principle" lacking in inanimate objects. In addition, they had the weight of tradition behind them: physiology and medicine had been done without the physical sciences for more than 2000 years, they said, why should this practice change?[3] It was through the efforts of experimental physiologists such as Johannes Müller, Hermann von Helmholtz, and Claude Bernard that a scientific revolution took place which resulted in the integration of the life sciences and the physical sciences. This does not mean that all problems of physiology can be handled by methods and concepts first introduced by the physical sciences[4]—there will always be some that cannot—but the number of physiological problems successfully handled in this way keeps increasing. Thus there should be no *a priori* boundaries put on the problems treated in physical terms; the test of what concepts and methods to use in physiology should be "whatever works".

Throughout the 19th century one can find a few works that represent a remarkably fruitful integration of phonology and phonetics (though perhaps not as grand as William Harvey's work on the circulation of blood). Some examples are Bindseil (1838), Weymouth (1856), Key (1855), and Rousselot (1891). Verner conducted his own phonetic studies of accent so that he could understand why accent influenced sound change (Verner, 1913).

It is difficult to say whether such early integration of phonetics with phonology represented a genuinely robust line of investigation. It is probably true that the vast majority of phonologists did not embrace phonetics either due to disinclination and/or lack of training. Nevertheless, serious and influential opposition to the merger of phonetics and phonology did not appear until the development of structuralism in the early decades of the 20th century which emphasized the important difference between the sound system (the relations and contrasts between sounds) as opposed to their physical substance. Trubetzkoy (1939), for example, argued forcefully that phonology and phonetics were separate disciplines dealing with different entities and even employing different methods:

> . . . the study of sound pertaining to the act of speech [i.e., phonetics], which is concerned with concrete physical phenomena, would have to use the methods of the natural sciences, while the study of sound pertaining to the system of language [i.e., phonology] would use only the methods of linguistics, or the humanities, or the social sciences (p. 4).
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> It is the task of phonology to study which differences in sound are

[3] A brief but instructive historical account of the approach of pre-19th century physiology and medicine is given by Helmholtz (1971).

[4] I choose the phrase "methods and concepts first introduced by the physical sciences" because I explicitly want to avoid the implication that these methods belong exclusively to these disciplines; rather, they are the intellectual heritage of all scientific disciplines.

> related to differences in meaning in a given language, in which way the discriminative elements . . . are related to each other, and the rules according to which they may be combined into words and sentences. It is clear that these objectives cannot be attained by the methods of the natural sciences (p. 10).

Further evidence of the division that developed between phonetics and phonology at this time is the fact that Zwirner & Zwirner (1936) felt the necessity to argue against such a trend, proposing instead phonological studies that while taking into account the linguistic function of speech sounds were still informed and guided by experimental phonetic principles and methods. Their approach, called "Phonometry" failed to have much influence due to unfortunate historical circumstances (Fischer-Jørgensen, 1985).

With few exceptions the education of a linguist after structuralism took hold did not include phonetics. Taxonomic phonetics, as noted, might be included, but this was typically regarded as mostly a closed system. The idea that principles of speech sound production, i.e., neuromuscular, anatomical, aerodynamic, acoustic, auditory, could or should be pursued for answers they could give to phonological questions was (and still is) completely foreign to most phonologists' thinking (see also Tobin, 1988).

I do not pass judgement on the decision of the structuralists to divorce phonology from phonetics. Insofar as this helped to emphasize the necessity for a functional and systemic analysis of speech sounds, this may have been the right political thing to do at the time. If the exponential growth of phonological studies of various languages that followed since the early decades of this century can be attributed to this move, then it must be deemed a success. Also, it must be admitted that certain somewhat positivist trends in phonetics (associated, for example, with the writings of E. W. Scripture and G. Panconcelli-Calzia—see Kohler, 1984) aggravated the division between the two disciplines. In addition, it must be acknowledged that the explanatory power of phonetic research for phonology was extremely limited except for the past three or four decades. Thus any time spent by phonologists in phonetics before then would not have given satisfying returns on their investment.

My claim is that the situation has changed now. The practices and the attitudes of structuralist linguistics (and in this I include generative and post-generative linguistics) regarding the relationship between phonetics and phonology are not useful guides for current phonological practice. For *true* explanation for speech sound behavior, phonetics now outstrips autonomous phonology. The phoneticians have done their homework. They have accumulated a treasure of both "lore and laws" about virtually all stages of the speech chain, from the "motor program" which controls the gestures of speech to the auditory system where the speech signals are decoded. Moreover, much of this work in phonetics is based on an integration of the concepts of phonology, i.e., notions which define what is functionally the "same" among the highly variable events in the speech signal (Halle, 1954).

I am not claiming that the solutions which phonetics gives to phonological problems are "true" and others are "false". Obviously no one could make such a judgement. The history of science tells us (if our philosophy does not) that solutions which seem to merit our allegiance at one time are likely to be overthrown eventually and replaced by other solutions. All we can hope for are viable *candidate*

solutions which avoid certain well known flaws and which possess certain advantages. It is precisely in these respects that phonetics surpasses autonomous phonology. I elaborate on this in the next sections.

5. Some pitfalls of pursuing phonology as an autonomous discipline

5.1. *Circularity*

Circularity consists of assuming what one has to prove, of constructing explanations of the sort X because X. Explaining the better performance of squirrels over rabbits in running three dimensional mazes by saying that the former have better spatial sense is an example of circularity. One exposes this flaw by tracing the meaning of the terms used in the explanation to see if they ultimately reduce to the terms in the thing explained.

5.1.1. *Markedness*

Markedness, often dignified with the term "theory", is a prime example of circularity (as has long been recognized; see Dingwall, 1971; Ohala, 1971*b*). Markedness is invoked to explain[5] why certain sounds are more common than others, why certain features do not co-occur with other features, etc. For example, we might wonder why low vowels often do not have distinctive rounding. The answer to this latter question, we are told (Halle, 1970; Chomsky & Halle, 1968, p. 405) is the marking convention in (1)

$$(1) \qquad [u \text{ round}] \rightarrow [-\text{round}] / \overline{[+\text{low}]}$$

which is formal shorthand for the statement that the unmarked or expected value for the feature round on low vowels is minus (or unround). But where did this marking convention come from? Clearly, it comes from our accumulated experience with vowel systems of various languages that low vowels have distinctive rounding less often than nonlow vowels. So our explanation reduces to the tautology: low vowels are less often distinctively round because low vowels are less often distinctively round. In this case the shorthand notation and other formal complexities (linking rules) just serve to lengthen and obscure the chain of equivalences between the terms of the explained and the alleged explanation. Further "patches" (or "epicycles") on markedness, including "naturalness", "atomic rules", "dependency

[5] It is sometimes denied that marking conventions were ever intended to "explain" anything, rather just to formalize the expectations phonologists have from inductive knowledge about sound patterns in languages of the world. I dispute this. In Halle (1970, delivered in 1967 and thus an early exposition on markedness) one finds the following passages:

> Why is the [vowel] set [a i u] preferable to the set [æ ɨ ü]? The answer is obvious if we examine the table (6a) [which specifies the number of marked feature values for various vowels]. The former set has 2 marked features in toto; the latter has 6 marked features.
>
> . . . [marking conventions] account for the predominant types of phonological rules incorporated into the grammar of each individual language.

The structure of the first passage is that of any explanation. In the second passage the phrase "account for", a synonym for "explain", is used.

There is in addition the fact that marking conventions were added to generative theory in order to correct perceived deficiencies of the evaluation metric; the evaluation metric is one of the primary mechanisms by which a theory of human language achieves explanatory adequacy. Marking conventions, therefore, are offered as explanations for the behavior of speech sounds.

relations", and "charm"—as long as they are established by decree—do not escape from this circularity.

5.1.2. *The "Sonority" hierarchy*

That speech sounds are generally ordered in specific ways in syllables, e.g., in initial position, (optional) obstruent + (optional) sonorant consonant + vowel, is a very old observation (the earliest reference I have come across is de Brosches, 1765, vol. 1, pp. 130–133). Such a ranking, elaborated, for example, to: stops, fricatives, nasals, liquids, glides, vowels, has been called the "sonority hierarchy" where stops are said to have the least sonority and vowels, the most. (An equivalent but reverse hierarchy is the so-called "strength hierarchy".) All of this is innocent enough. The circularity enters in when the sonority hierarchy is said to "explain" the sequencing of sounds in syllables (see Hooper, 1976, chapter 11). The circularity would be avoided if the "sonority" of segments were definable in some way that was independent of their position in this hierarchy. But this is not the case; sonority has never been satisfactorily defined, claims to the contrary notwithstanding (Hankamer & Aissen, 1974). Furthermore there are no prospects that anyone is even getting close to solving this problem—except, perhaps, by abandoning it and invoking an entirely new notion to explain segment sequences (see Ohala & Kawasaki, 1984; Ohala, 1990*c*).

5.1.3. *Constraints*

One often encounters statements in the phonological literature of the sort "X does not happen (or happens) because the language has a constraint against (or permitting) X". This can be circular if the observation that the language has a constraint against X was based in part on the absence of X anywhere in the language, including in the domain where the X had the opportunity to occur but did not.

For example, Piggott & Singh (1985), in deriving the Old English form *þymel* from the underlying form /θyml/ assert that the epenthetic *e* was required to break up the final cluster since the language had constraints which disallowed both consonant clusters of the sort /ml/ in the syllable coda and sonorant consonants (e.g., the /l/) occupying the nucleus position. It would seem that it is the form of Old English words including *þymel* which prompts the claim that such constraints on syllable structure existed.

If the statement of the constraint was based on observations in a domain different from that where the X failed to appear, it would not, strictly speaking, be circular but like all extrapolations from inductive generalizations, it would still not be explanatory. The observation over a lifetime up to day N that the sun rises in the East does not explain why the sun rises in the East on day $N + 1$.

5.1.4. *Binarity*

Whether the classificatory features which speakers use to code the form of words in their mental lexicon are binary or not is an empirical matter. We are a long way from getting good psycholinguistic evidence on this issue (but see Jaeger & Ohala, 1984); nevertheless one would expect an open-minded consideration of the issue in which attention would be paid to the natural divisions in the parameters needed to describe the behavior of sounds in languages of the world. Instead, the matter is

handled by decree and justified by a tautology:

> In view of the fact that phonological features are classificatory devices, they are binary . . . for the natural way of indicating *whether or not* an item belongs to a particular category is by means of binary features (Chomsky & Halle, 1968, p. 297, italics added).

The complications caused by an across-the-board use of binarity in features is well known, especially for feature pairs such as [high] and [low], [spread glottis] and [constricted glottis], [tense vocal cords] and [slack vocal cords], where "+" values of both cannot co-exist.[6]

5.2. *Reification*

Reification is the "process of . . . regard[ing] (something abstract) as a material or concrete thing" (*Webster's* 1985). This has left its impression on our language and our religions. Expressions such as "lady luck", "famine stalked the countryside", "death came knocking at his door" are common examples of reification. In many cultures such concepts as wealth, fertility, art, disease, and evil have been reified into deities or demons which are made concrete enough to have names, images, and life histories. In most cases the reification is recognized as a figure of speech or a bit of poetry but problems arise when the reifications are taken seriously. To the unwary this is an invitation to behave as if the reification is a real thing, to expect to have direct evidence of it, to regard it as a direct cause of observed effects, to be able to influence the course of events by obtaining control over it, etc. Exorcisms and other bizarre and often cruel practices can be seen as a direct result of the reification of aberrant behavior into imagined demons. Less cruel but no less futile are offerings and appeals made toward deities who are thought to be the embodiments and controllers of wealth, fertility, and the like. The trouble with reification, then, is that it puts the problem solvers one step further away from the real causes of the problem; their limited resources—both psychic and material—may be wasted on the nonexistent reified entity rather than the true root causes of the problems they face.

Is there reification in phonology? Yes:

> As we know from the study of tone, vowel harmony, nasality and the like, rules may affect segments on one tier without affecting segments on other tiers. By grouping together entire sets of features on single tiers, we in effect make it possible for them to behave as a functional unit with regard to rules of deletion, assimilation, and so forth. . . . *If we regard features not as matrix entries but as independent units or segments in their own right,* defined by specific sets of gestures and

[6] Other reasons were given for making features binary:

> In the d.f. system a consistent attempt is made to minimize the number of features used in the description. . . . the simplicity of a description [can] be measured by the average number of features [used] per phoneme. . . . [But] there is no obvious way for setting an "exchange rate" between binary and ternary features without simultaneously complicating the framework . . . [Therefore, we make all features the same: binary.] (Halle, 1957).

This is not a persuasive argument for across-the-board binarity since quantitative comparison of binary and non-binary systems is possible, as anyone knows who is familiar with how Claude Shannon proposed to measure information.

> acoustic effects, then it is quite natural to suppose that they may display the behaviour of *real entities*, and engage in such processes as extension, contraction, deletion, and insertion (Clements, 1985; italics added).

Phonological features are useful descriptors for speech, just as "red", "health", or "ovoviviparous" are useful descriptors in other domains. But to claim that they are independent entities requires considerable justification. I have argued elsewhere (Ohala, 1990*a*) that articulatory features should not be regarded as independent entities but rather as being parts of integrated phonetic events, the gestures needed to produce sequences of distinct acoustic modulations. The independence of articulatory features is, of course, an empirical matter, but the arguments in favor of that idea have for the most part been advanced from contemplation of a purely formal or notational representation of speech. The alternative view, that they are integral parts of complex speech gestures, could only emerge from a close examination and understanding of the phonetics of speech; autonomous phonology unfortunately seems to have little interest in this.

Reification of an unproducitve sort is more likely to occur in a discipline that cuts itself off from the root causes of the phenomena it studies. If phonology is treated as an autonomous discipline distinct from phonetics and other relevant disciplines which study these causes, then there is little in the way of an empirical rein on the tendency to reify.

Treating elements of the notation for phonological events as somehow having more interest than the events themselves is an old problem within phonology as evidenced by the fact that the practice has been so often disparaged:

> Some [scholars of language] . . . have allowed themselves . . . to be led astray by paying more attention to the symbols of sound than to sounds themselves (Key, 1855).

> . . . on paper almost everything is possible (Osthoff & Brugmann, 1967).

> Real languages are not minimal redundancy codes invented by scholars fascinated by the powers of algebra, but social institutions serving fundamental needs of living people in a real world (Halle, 1954).

5.3. *Projection*

"Projection" in psychology is "the attribution of one's own ideas, feelings, or attitudes to other people or objects. . ." (*Webster's* 1985). The habitual thief is reluctant to entrust his property to others because he thinks they, like him, would take any opportunity to steal. Probably few of us can suppress a sense of awe when seeing the cross-section of a chambered nautilus in part, perhaps, because we cannot imagine how such a perfect shape could be created without the application of complex and precise geometric measurements—and yet, as any zoologist could tell us, this and many other marvelous shapes in nature come about in very simple ways. We project onto a situation the only way we know of treating it. As such, a projection is a good hypothesis and there is no way of knowing in advance whether it is a good one or not. It must be tested. Nevertheless, on a purely practical level we see that hypothesis-making can be more efficient if we entertain a wide range of hypotheses at the start and then devote our energies to testing just the simplest.

Autonomous phonology, by virtue of isolating itself from phonetics and other potentially relevant domains, increases the risk of making unproductive hypotheses via projection. In this case the knowledge the linguist has about spoken forms, including historical derivational relationships between words, the morphemic structure of complex words, and the inductively-based knowledge of common cross-language sound patterns, is projected onto the mental grammar of linguistically-naive native speakers. Common cross-language patterns, including those formalized in the marking conventions, are said to be part of "universal grammar", i.e., innate knowledge of all speakers. As has been noted many times, it is hardly plausible that every pattern found in language is part of the native speaker's internalized grammar (Householder, 1966; Derwing, 1977; Derwing & Skousen, 1989; Ohala, 1974, 1976*b*, 1990*b*; McCawley, 1986). Psycholinguistic evidence is accumulating that undercuts the assumption that the language user knows everything the linguist knows (Zimmer, 1969; Jaeger, 1984; Wang & Derwing, 1986; Ohala & Ohala, 1987). Phonetically natural patterns may be present in language not because they are motivated by universal grammar but because speakers live in a physical world where they, along with every other physical object, are subject to physical constraints (aerodynamic, kinetic, elastic). To account for the cross-language tendency of obstruents to devoice it is extravagant to attribute it a universal marking convention imbedded in their DNA. Devoicing will occur under given aerodynamic conditions whether speakers "know" the physical principles governing it or not. The natural patterns which arise in language can become fossilized in the mental grammar or lexicon of speakers without their natural roots being preserved.

5.4. *Myopia*

Habitually approaching a problem in an isolated way tends to produce a kind of myopia which prevents one from seeing and taking advantage of hints derived from other domains—even those very close by. Examples from the history of science of isolated attacks on problems are hard to come by since it is rather those who have broad views and who see and make connections who receive the most attention. It is part of the genius of Darwin, for example, that he was able to propose his theory of evolution by making connections between (among other things) Malthus' point about populations tending to exceed material resources, artificial selection of plants and animals by breeders, and the natural variation within several species that he himself had observed. Far-sightedness in problem solving has two requirements: knowing lots of things and being able to make connections between some of those things. Myopia starts not so much from an inability to make connections but from neglecting data from multiple sources.

Wetzels (1985) correctly accounts for the epenthetic stops in words such as French *chambre* (<Latin *camera*) and *prendre* (<Old French *pren* + *re*) or English *warm*[*p*]*th* as due to the latter half of the preceding nasal showing anticipatory assimilation of the orality of the following *r* or [θ].[7] He thus corrects a less informed analysis of such cases by Singh (1980) (and repeated in essentially the same form by

[7] Although Wetzels only cites Barnitz (1974) and Anderson (1976) as having proposed this analysis earlier, in fact, it was given in essentially the same form as early as 1838 by Bindseil and again in 1856 by Weymouth and repeated many times since then, including by Ohala (1972, 1974, 1983).

Piggott & Singh, 1985). Another way of stating this is as follows: there are two principal valves in the vocal tract by which air may be vented, the mouth and the soft palate. During a nasal the first of these is closed but the second is open; during the following oral segment[8] the reverse is true. If the closed position of the second segment is anticipated due to assimilation during the first segment what results is that all valves are closed. This results, of course, in a stop. However, Wetzels seems not to see the parallelism between such cases and those where an epenthetic stop appears between an apical fricative and a lateral, e.g., those in (2) (Wetzels cited the Italian case but without the *stl*-intermediate form; I have added that and the examples from English).

(2) Late Latin *slavo* > **stlavo* > **sklavo* > Italian *schiaffo* "slave"

English else [ɛls] ~ [ɛlts]

pulse [p^{h}ʌls] ~ [p^{h}ʌlts]

He recognizes that the intrusive stop is created as a melange of features from the adjoining segments but doesn't see where the stop, which is [−continuant], comes from since both [s] and [l] are [+continuant]. He decides to treat the [l] as [−continuant]. The phenomenon of epenthetic stops breaking up sequences such as *sl* had been treated earlier by Phelps (1937, who, by the way, justifies intermediate forms such the *stlavo,* above) and Ohala (1974). As with the case of nasal + oral segment, it is a matter of analyzing the airflow as exiting potentially via two valves, only this time both of them controlled by the tongue: one at the midline of the tongue and the other at the sides of the tongue. During an [s] the first is open and the second closed; during an [l] the reverse is true. During the transition between these two sounds it may happen that both valves get closed simultaneously, thus inadvertently creating a stop. It *is* possible to create a [−continuant] by the combination of two adjacent [+continuants]![9] But to understand how this is possible one has to see beyond the crude feature descriptions and deal instead with the actual articulations of sounds.

McCarthy (1988) offers the following explanation for the lack of an oral *vs.* nasal distinction on the glottal fricative [h]:

> With *h,* even when voiced, the lack of resistance in the oral vocal tract would significantly reduce nasal airflow, rendering the nasality essentially inaudible.

If the relatively lower resistance to airflow in the oral cavity *vis-à-vis* the nasal cavity were important in this case, then an oral/nasal contrast would not be possible on vowels either, where the airflow is even less than that during [h], yet we know this is not the case. Furthermore, if contrasts require that air move through relevant cavities, then neither nasal nor oral speech sounds could be produced with an

[8] The following segment may be "oral" by virtue of its aerodynamic requirements, as in the case of oral obstruents [s, f, θ], etc., or by virtue of its acoustic requirements, as in the case of sonorant consonants which would suffer distortion by nasalization, e.g., [l, w]. If "r" is an obstruent (trill, tap) it would fall under the first category; if a sonorant, under the second category (Ohala, 1975).

[9] For that matter, the same applies in cases such as *warm*[*p*]*th,* too. The recent practice of regarding nasals as [−continuant] is not only counter-intuitive, it leaves us with nasals as virtually the only class of non-continuants that can carry tone, be syllabic, etc. Given a more enlightened analysis of nasals as continuants, the parallelism is even more obvious between m + θ and l + s (or the reverse order) both yielding intrusive stops.

artificial larynx since in that case it is simply the sound (*ac* not *dc* pressure variations—from a pulse source applied to the side of the neck) that diffuses through the vocal tract. There is no net movement of air anywhere in the vocal tract. Actual (dc) movement of air is important only for sound sources (vocal cord vibration, stop bursts, frication), not for the vocal tract's resonances.

As it happens, [h] and [ʔ] are often nasalized in the sense of being produced with lowered soft palate. At least in the case of [h] there can be significant airflow through the nasal cavity. The well-known transparency of glottal consonants to spreading nasalization in various languages, e.g., Sundanese (Robins, 1957) derives from this. In fact, Robins provides kymographic evidence showing nasal airflow during [h]'s when surrounded by nasalized vowels (these kymographic records have been misread by Anderson (1972) and Vago (1988), who claim that [h] is not nasalized but that spreading nasalization leapfrogs over it[10]). However, it is true as McCarthy remarks, that *distinctive* nasalization is not found on glottal consonants. However, I think a more plausible reason for this is that the primary acoustic cues for these consonants, which involve primarily variations in the ampitude envelope (rise time and fall time), characteristic glottal pulse shapes, and, in the case of [h], optional high frequency noise, cannot be distinctively modulated by varying the position of the soft palate (see Ohala, 1975). These cues are largely the same whether produced nasalized or oral.

McCarthy is to be commended for looking to the phonetic realm for a genuine explanation for a phonological fact but speech is simultaneously an articulatory, aerodynamic, and acoustic system (not to mention auditory and neurophysiological); it is risky to focus on just one of these domains and to overlook the others.

6. The benefits of integrating phonology and phonetics

The advantages of integrating phonetics (and other sister disciplines) into phonology go beyond simply avoiding the pitfalls mentioned above; some tangible benefits are obtained, too.

6.1. *Generality and simplicity*

One of the great quests of science is generality. Counteracting the exponential growth of knowledge and the emergence of ever narrower specializations and sub-specializations, generality tries to shrink the universe in order to make it fit inside a small number of general, explanatory principles. Newton was able to show that the principles that govern the motion of objects on earth also determined the movements of the planets. Wohler, by synthesizing urea, helped to unify the chemistry of the inanimate and the chemistry of life. It seems to me that phonetics offers one of the most obvious paths between phonology and other disciplines.[11]

[10] In all likelihood, the [ʔ] in Sundanese is also nasalized in the environment of adjacent nasal vowels, but the nasal airflow traces provided by Robins would not give a reliable indication of it since, obviously, if airflow is blocked at the glottis it will not show up in a nasal airflow trace. See Ohala (1971*a*) for an example of how a more direct transducer of velic elevation can show physiological nasalization in the absence of airflow.

[11] I am interested here in the application of the *same* principles in phonology and other scientific domains, not just the use of other disciplines' ideas as metaphors for linguistic principles. Thus many linguists have used biological metaphors when describing language and its development (Fr. Schlegel, Max Müller, William Dwight Whitney) but only a few have taken this comparison literally (perhaps fortunately). Zipf (1935, 1949) exemplifies much better what I advocate: he made creditable attempts to show that the principle of least effort underlies much of linguistic and non-linguistic behavior.

When aerodynamic factors are invoked to account for devoicing of stops, affrication of stops before high close vowels and glides, the greater likelihood of close vowels being devoiced than open vowels, etc., the principles cited are the same as those which apply in fluid dynamics, including, e.g., Boyle–Mariotte's law (Ohala, 1976, 1983, 1989).

When dissimilation is explained as due to the listener's overcompensation for expected coloring of one sound by another (Ohala, 1981*b*, 1986*a*), the same general perceptual principles underlie camouflage in the visual domain; when the figure resembles the ground, the perceiver may not recognize the figure as distinct from (not predictable from) the ground. In dissimilation of the sort in (3), for example,

(3) Late Latin kwiŋkwē > *kiŋkwē > Italian tʃiŋkwe

the listener attributes the labialization in the initial part of the word ("figure") as the predictable result of anticipatory assimilation of labialization in the second syllable ("ground"). The listener factors out the figure, leaving the ground; his own pronunciation would reflect this misapprehension. This account of dissimilation, which assumes that it derives from the listener "undoing" the expected effects of assimialtion, correctly predicts that the only features which will be subject to "long distance" dissimilation (i.e., with intervening segments which are not affected) will be those known to migrate far from the segment on which they are distinctive, e.g., labialization, palatalization, retroflexion, but not "continuancy" or "affrication".

The primary elements used by Lindblom in his modeling of vowel systems (Liljencrants & Lindblom, 1972; Lindblom, 1986) are the physically possible vowel space (formant frequencies of the human vocal tract or auditory transforms of the formant patterns) plus the task constraint that vowels should ideally be equally far apart from each other within the available vowel space. It is interesting to compare Lindblom's results with some of the Chomsky & Halle's (1986 p. 405) marking conventions for vowels, given in (4)–(7) with added annotations on the right.

(4) [u low] → [−low]

(5) [u high] → [+high]

Presumably reflects greater incidence of high and mid vowels over low vowels.

(6) $[\text{u round}] \rightarrow [\alpha \text{ round}] \Big/ \begin{bmatrix} \alpha \overline{\text{back}} \\ -\text{low} \end{bmatrix}$

Non-low front vowels are generally unround; back vowels round.

(7) $[\text{u round}] \rightarrow [-\text{round}] / [\overline{+\text{low}}]$

Low vowels generally do not have distinctive rounding.

All of these tendencies (as well as others) are predicted without special stipulation by Lindblom's model which, unlike the marking conventions, is not circular. When ones asks "where did these results come from?", Lindblom is able to point to independent principles which are distinct from the facts he set out to explain. Moreover, *these principles are part of the same, familiar universe in which we live*; we will not be asked to accept the existence of "occult" entities invented just for task at hand. Educated people in any other scientific discipline could understand his results without having to steep themselves in phonological esoterica.

Perhaps one of the most interesting aspects of all such models is that they are

most valuable not when they succeed in predicting the behavior of the target world but when they do not. When this happens one is made to realize that the model, which is an embodiment of one's understanding of the world, is deficient in some way. When the failure is highly specific, it directs the search for new data and principles which correct the deficiencies. Lindblom's models, for example, were initially plagued with too many high central vowels in systems with small numbers of vowels (although in other respects the models behaved well). This led him eventually to define the possible vowel space in auditory rather than acoustic terms. Each change in the evolution of his models, however, was constrained by independently motivated psychoacoustic principles.

6.2. *Empirically testable*

Perhaps the most significant aspects of integrating phonetics and phonology is that the accounts given for speech sound behavior are empirically testable. Phonetics lends itself to this in a way that autonomous phonology does not since, after all, the domain of phonetics is (real world) speech production and perception not the make-it-up-as-you-go-along world of autonomous phonology. This should not be misconstrued as advocacy of positivism; indeed some of the most ingenious phonetic studies are attempts to investigate unseen mechanisms; to cite just a few randomly chosen examples: Czermak (1857), Vencov (1968), Sternberg, Monsell, Knoll & Wright (1980), Fowler (1981). The evidence obtained in support of a hypothesis can be quite indirect but is no less revealing because of it.

In addition to a growing mass of individual works exemplifying how experimental phonetic works can test phonological claims, there are now several collections of such works (some of which include psycholinguistic experiments as well): Prideaux, Derwing & Baker (1980) Ohala & Jaeger (1986*a*), Ohala (1986*c*), Kingston & Beckman (1989), Docherty & Ladd (in press) and a bibliography (Ohala, 1988).

6.3. *Fruitfulness*; *convergence*

Although candidate answers to questions may eventually be rejected or modified, they are successful or fruitful if even in their error they stimulate a directed search for new data and for the formulation of new generalizations. Furthermore, a succession of theories and their modifications show convergence if they progress more or less in the same direction and are not repeatedly going off in all directions (what I have called a "Brownian movement through the space of possible theories"—Ohala, 1986*b*). I have argued that a phonology whose theory making is checked by experiments, be they in the phonetic or psychological domain, exhibits fruitfulness and convergence (Ohala & Jaeger, 1986*b*; Ohala, 1986*c*, 1988).

It must be allowed that advocates of an autonomous phonology see much the same advantages in their practice, i.e., generality, simplicity, empirically testable, fruitfulness, and convergence. Ultimately, readers will have to decide for themselves which approach has better claim to these properties. An informed judgement on this should be based on an awareness of what phonetics has to offer phonology; the references at the end of this paper may help in this regard.

7. Conclusion

A wedge was driven between phonetics and phonology at a time when both disciplines may have had little idea of how one could benefit from the other. It happened at a time when phonology—maybe phonetics, too—felt that for political reasons it had to stake its claim to a well-defined "turf", define its intellectual territory, and do so in a way that excluded close competitors—even to the point of allying their discipline either with "humanities" or "natural sciences". We should not persist in such a wasteful "turf war". In any case, these days walls all over the world are crumbling, even those thought to divide humanities and natural sciences. We should recognize that the definition of a discipline is the sum total of the questions it asks. The methods that are used, the paths followed in getting answers to these questions are not necessarily those currently in fashion or those endorsed by the "leading figures in the field". They will also not necessarily be those that we studied as students. Ultimately, the only acceptable paths to follow will be those that lead to genuine answers, not re-formulations or re-labelings of the questions.

My own view is that between phonology and phonetics, phonology is the superordinate discipline, not because it has accomplished more or is better developed—the opposite may be true—but simply because it looks at and seeks answers to a much broader range of phenomena involving speech behavior. The answers to these questions will come, I believe, from phonetics, psychology, and studies of culture and society—including both the ways these domains determine speech behavior currently and in the past. Although in this paper I have emphasized the necessity of drawing on phonetics for phonological questions, I do not mean to neglect the resources in these other domains. (In other papers I have attempted to contribute to the psycholinguistic domain of phonology; Ohala 1974, 1986*b*, 1990*b*; Ohala & Ohala, 1987.[12])

No doubt those who use the term "interface between phonology and phonetics" believe that they are taking positive steps to break down the barrier between the two fields. But I maintain that if the term "interface" preserves the outdated view that we are dealing with largely autonomous fields, it will impede our chances of improving on the past. I propose an alternative phrase and venture: the integration of phonology and phonetics.

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[12] Phonologists have, in general, made little effort to integrate psychology into their work, except perhaps simply to declare that linguistics is a branch of cognitive psychology. See Derwing (1980) and McCawley (1986) for an analysis of the "linguistics-is-psychology-because-I-say-it-is" strategy.

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