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Introduction, Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech(Reprint)

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Abstract and Keywords

This article explores several papers presented to demonstrate the relationship between the phonological component and the phonetic component. The papers discussed address at least three questions. First, how, in the twin processes of producing and perceiving speech, do the discrete symbolic or cognitive units of the phonological representation of an utterance map into the continuous psychoacoustic and motoric functions of its phonetic representation. Second, how should the task of explaining speech patterns be divided between the models of grammatical function that are encoded in phonological representations and the models of physical or sensory function that are encoded in phonetic representations. Third, what sorts of research methods are most likely to provide good models for the two components and for the mapping between them. Several specific topics addressed by the article include suprasegmental phenomena in language, metrical representation of pitch register, and status of register in intonation theory, and alignment and composition of tonal accents. The article also covers topics such as the separation of prosodies, lengthenings and shortenings and the nature of prosodic constituency, the nature of prosodic constituency, and lengthenings and the nature of prosodic constituency.

Keywords: laboratory phonology, linguistic sign, phonological contrast, suprasegmental phenomena, phonetics

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(p. 11) While each of the papers in this volume has its specific individual topic, collectively they address a more general issue, that of the relationship between the phonological component and the phonetic component. This issue encompasses at least three large questions. First, how, in the twin processes of producing and perceiving speech, do the discrete symbolic or cognitive units of the phonological representation of an utterance map into the continuous psychoacoustic and motoric functions of its phonetic representation? Second, how should the task of explaining speech patterns be divided between the models of grammatical function that are encoded in phonological representations and the models of physical or sensory function that are encoded in phonetic representations? And third, what sorts of research methods are most likely to provide good models for the two components and for the mapping between them?

Previous answers to these questions have been largely unsatisfactory, we think, because they have been assumed *a priori*, on the basis of prejudices arising in the social history of modern linguistics. In this history, phonology and phonetics were not at first distinguished. For example, in the entries for the two terms in the *Oxford English Dictionary* each is listed as a synonym for the other; *phonology* is defined as “The science of vocal sounds (= PHONETICS)” and *phonetics* as “The department of linguistic science which treats of the sounds of speech; phonology.” The subsequent division of this nineteenth-century “science of sounds” into the two distinct subdisciplines of phonology and phonetics gave administrative recognition to the importance of the grammatical function of speech as distinct from its physical structure and also to the necessity of studying the physical structure for its own sake. But this recognition was accomplished at the cost of creating two separate and sometimes mutually disaffected scientific subcultures.

We can trace the origin of this cultural fissure to two trends. One is the everincreasing reliance of phonetic research on technology, rather than on just the analyst's kinesthetic and auditory sensibilities. This trend began at least in the first decade of this century, with the use of the X-ray to examine vowel production and the adoption of the kymograph for examining waveforms. With such technical aids, phoneticians could observe the physical aspects of speech unfiltered by its grammatical function. With this capability, phonetics expanded its subject matter far beyond the taxonomic description of “speech sounds” found in phonological contrast, to develop a broader, domain-specific attention to such extra-grammatical matters as the physiology of speech articulation and the physics of speech acoustics, the peripheral and central processes of speech perception, and the machine synthesis and recognition of speech.

The other trend that led to the separation of the two subdisciplines was the development of more complete formal models of the grammatical function of speech than are instantiated in the International Phonetic Alphabet. This trend had its initial main effect in the 1930s, with the emergence of distinctive feature theory, as elaborated explicitly in Prague Circle phonology (Trubetzkoy 1939) and implicitly (p. 12) in the American structuralists' emphasis on symmetry in analyzing phonological systems (Sapir 1925).

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Distinctive feature theory effectively shifted the focus of twentieth-century phonology away from the physical and psychological nature of speech sounds to their role in systems of phonemic contrast and morphological relatedness.

Both of these trends undermined the alphabetic model that underlay the nineteenth-century synonymy between phonetics and phonology, but they did so in radically different ways. The analysis of “vocal sounds” into their component units of phonological contrast eventually led to new non-alphabetic representations in which phonological features were first accorded independent commutability in different rows of a matrix and then given independent segmentation on different autosegmental tiers. The use of new technology, on the other hand, questioned the physical basis originally assumed for alphabetic segmentation and commutability, by revealing the lack of discrete sequential invariant events in articulation or acoustics that might be identified with the discrete symbols of the IPA. These radically different grounds for doing away with a strictly alphabetic notation for either phonological or phonetic representations produced an apparent contradiction.

Modeling the cognitive function of speech as linguistic sign requires two things: first, some way of segmenting the speech signal into the primitive grammatical entities that contrast and organize signs and second, some way of capturing the discrete categorical nature of distinctive differences among these entities. A direct representation of these two aspects of the grammar of speech is so obviously necessary in phonological models that it is hardly surprising that the early, rudimentary phonetic evidence against physical segmentation and discreteness should elicit the reaction that it did, a reaction caricatured in Trubetzkoy's declaration that “Phonetics is to phonology as numismatics is to economics.” A more benign form of this prejudice recurs in the common assumption among phonologists that nonautomatic, language-specific aspects of phonetic representations and processes should share the discrete segmental nature of phonological symbols and rules.

This apparent contradiction induced also a complementary prejudice on the part of phoneticians. Instrumentally aided investigation of speech has resulted in decades of cumulative progress in phonetic modeling, including the monumental achievement of the acoustic theory of speech production (Fant 1960). A great deal of this research has necessarily been concerned with the details of mapping from one extra-grammatical system to another—for example, from acoustic pattern to cochlear nerve response or from motor excitation to articulatory pattern. This research into the relationships among different phonetic subcomponents has derived little direct benefit from advances in phonological theory. As a result, it has often been assumed that arguments about phonological representations and processes are irrelevant to the phonetic component as a whole, a prejudice that could be expressed in its most malignant form as “phonology is to phonetics as astrology is to astronomy.”

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(p. 13) We have caricatured these prejudices at some length because we feel that they are a major impediment to answering our three questions concerning the relationship between phonology and phonetics. They distort our pictures of the two linguistic components and of the shape of the mapping between them. One set of theories describes the mapping as a trivial translation at the point where the linguistically relevant manipulations of discrete symbolic categories are passed to the rote mechanics of production and perception. Another set of theories places the dividing line at the point where the arbitrary taxonomy of linguistic units yields to experimentally verifiable models of speech motor control, aerodynamics, acoustics, and perception.

Such distortions are inevitable as long as the relegation of aspects of sound patterns between the two linguistic components is guided by unquestioned assumptions about what research methods are appropriate to which field. Therefore, we ask: how can we use the physical models and experimental paradigms of phonetics to construct more viable surface phonological representations? Conversely, what can we learn about underlying phonetic representations and processes from the formal cognitive models and computational paradigms of phonology? Determining the relationship between the phonological component and the phonetic component demands a hybrid methodology. It requires experimental paradigms that control for details of phonological structure, and it requires observational techniques that go beyond standard field methods. The techniques and attitudes of this hybrid laboratory phonology are essential to investigating the large group of phonic phenomena which cannot be identified *a priori* as the exclusive province of either component.

An example of such a phenomenon is fundamental frequency downtrend. It is a common observation that f_0 tends to fall over the course of an utterance. Phonologists have generally assumed that this downtrend belongs to the phonological component. They have postulated simple tone changes that add intermediate tone levels (e.g. McCawley's 1968 rule lowering High tones in Japanese to Mid tone after the first unbroken string of Highs in a phrase), or they have proposed hierarchical representations that group unbroken strings of High tones together with following Lows in tree structures that are interpreted as triggering a downshift in tonal register at each branch (e.g. Clements 1981). Phoneticians, on the other hand, have typically considered downtrend to belong exclusively to the phonetic component. They have characterized it as a continuous backdrop decline that unfolds over time, independent of the phonological tone categories. They have motivated the backdrop decline either as a physiological artifact of decaying subglottal pressure during a "breath group" (e.g. Lieberman 1967), or as a phonetic strategy for defining syntactic constituents within the temporal constraints of articulatory planning (e.g. Cooper and Sorensen 1981).

Each of these models is circumscribed by our notions about what research methods are appropriate to which linguistic subcomponent. If the observed downtrend (p. 14) in a language is to be in the province of phonological investigation, it must be audible as a categorical tone change or register difference, and its immediate cause must be something that can be discovered just by examining the paradigm of possible

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phonological environments. If the downtrend is to be in the province of phonetic investigation, on the other hand, it must be quantifiable as a response to some physically specifiable variable, either by correlating fundamental frequency point-by-point to subglottal air pressure or by relating fundamental frequency averages for syllables to their positions within phonologically unanalyzed utterances of varying length. Each sort of model accounts for only those features of downtrend which can be observed by the methods used. Suppose, however, that the downtrend observed in a given language is not a single homogeneous effect, or suppose that it crucially refers both to discrete phonological categories and to continuous phonetic functions. Then there will be essential features of the downtrend that cannot be accounted for in either model. Indeed these features could not even be observed, because the research strategy attributes downtrend *a priori* either to manipulations of phonological representations or to phonologically blind phonetic processes.

In recent examples of the hybrid methods of laboratory phonology, Pierrehumbert (1980) has argued with respect to English and Poser (1984) and others (e.g. Pierrehumbert and Beckman 1988) regarding Japanese that downtrend is just such a heterogeneous complex of different components, many of which are generated in the mapping between phonological and phonetic representations. In both English and Japanese, certain phrase-final tones trigger a gradual lowering and compression of the pitch range as a function of the distance in time from the phrase edge. This component of downtrend is like the phonologically blind declination assumed in earlier phonetic models in that it seems to be a gradual backdrop decline. Yet it is unlike them in that it refers crucially to phonological phrasing and phrase-final tone features. Also, in both languages, certain other, phrase-internal, tonal configurations trigger a compression of the overall pitch range, which drastically lowers all following fundamental frequency values within some intermediate level of phonological phrasing. This largest component of downtrend is like the intermediate tone levels or register shifts in earlier phonological models in that it is a step-like change triggered by a particular phonological event, the bitonal pitch accent. Yet it is unlike them in that it is implemented only in the phonetic representation, without changing the phonological specification of the affected tones. If these characterizations are accurate, then downtrend cannot be modeled just by reference to the phonological or the phonetic structure. Indeed neither of these two components of downtrend can even be observed without instrumental measurements of fundamental frequency values in experiments that control for phonological tone values and phrasal structures. The phenomenon of downtrend seems to require such hybrid methods.

(p. 15) We think, moreover, that the list of phenomena requiring such hybrid methods and models is much larger than hitherto supposed. We believe that the time has come to undo the assumed division of labor between phonologists and other speech scientists; we believe this division of labor creates a harmful illusion that we can compartmentalize phonological facts from phonetic facts. At the very least, we maintain that the endeavor of

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modeling the grammar and the physics of speech can only benefit from explicit argument on this point. In support of this thesis, we present to you the papers in this volume.

Most of these papers were first presented at a conference we held in early June of 1987 at the Ohio State University. To this conference we invited about thirty phonologists and phoneticians. The papers at the conference were of two sorts. We asked some of the participants to report on their own research or ideas about some phenomenon in this area between phonology and phonetics. We asked the other participants to present papers reacting to these reports, by showing how the research either did or did not consider relevant phonological structures or phonetic patterns, and by reminding us of other research that either supported or contradicted the results and models proposed. By structuring the conference in this way we hoped to accomplish two things. First, we wanted to show the value of doing research in this area between phonology and phonetics, and second, we wanted to provoke phonologists and phoneticians into talking to each other and into thinking about how the methods and aims of the two fields could be united in a hybrid laboratory discipline tuned specifically to doing this sort of research. After the conference, we commissioned both sets of participants to develop their presentations into the papers which we have grouped in this volume so that the commentary papers follow immediately upon the paper to which they are reacting.

The specific topics that these groups of papers address fall into several large categories. First are papers which focus on suprasegmental phenomena in language: 2. Where phonology and phonetics intersect: the case of Hausa intonation, Sharon Inkelas and William R. Leben; 3. Metrical representation of pitch register, D. Robert Ladd; 4. The status of register in intonation theory: comments on the papers by Ladd and by Inkelas and Leben, G. N. Clements; 5. The timing of prenuclear high accents in English, Kim E. A. Silverman and Janet B. Pierrehumbert; 6. Alignment and composition of tonal accents: comments on Silverman and Pierrehumbert's paper, Gösta Bruce; 7. Macro and micro f_0 in the synthesis of intonation, Klaus J. Kohler; 8. The separation of prosodies: comments on Kohler's paper, Kim E. A. Silverman; 9. Lengthenings and shortenings and the nature of prosodic constituency, Mary E. Beckman and Jan Edwards; 10. On the nature of prosodic constituency: comments on Beckman and Edwards's paper, Elisabeth Selkirk; 11. Lengthenings and the nature of prosodic constituency: comments on Beckman and Edwards's paper, Carol A. Fowler; 12. From performance to phonology: comments on Beckman and Edwards's paper, Anne Cutler.

(p. 16) The next group of papers addresses the question of the relationship between phonological representations and phonetic structures more generally: 13. The Delta programming language: an integrated approach to nonlinear phonology, phonetics, and speech synthesis, Susan R. Hertz; 14. The phonetics and phonology of aspects of assimilation, John J. Ohala; 15. On the value of reductionism and formal explicitness in phonological models: comments on Ohala's paper, Janet B. Pierrehumbert; 16. A response to Pierrehumbert's commentary, John J. Ohala.

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The last group of papers addresses various aspects of segmental organization and coordination among segmental tiers: 17. The role of the sonority cycle in core syllabification, G. N. Clements; 18. Demisyllables as sets of features: comments on Clements' paper, Osamu Fujimura; 19. Tiers in articulatory phonology, with some implications for casual speech, Catherine P. Browman and Louis Goldstein; 20. Toward a model of articulatory control: comments on Browman and Goldstein's paper, Osamu Fujimura; 21. Gestures and autosegments: comments on Browman and Goldstein's paper, Donca Steriade; 22. On dividing phonetics and phonology: comments on the papers by Clements and by Browman and Goldstein, Peter Ladefoged; 23. Articulatory binding, John Kingston; 24. The generality of articulatory binding: comments on Kingston's paper, John J. Ohala; 25. On articulatory binding: comments on Kingston's paper, Louis Goldstein; 26. The window model of coarticulation: articulatory evidence, Patricia A. Keating; 27. Some factors influencing the precision required for articulatory targets: comments on Keating's paper, Kenneth N. Stevens; 28. Some regularities in speech are not consequences of formal rules: comments on Keating's paper, Carol A. Fowler.

The papers in this volume [...] represent a wide range of views on the issue of the relationship between phonology and phonetics. We trust that they also reflect the excitement and congenial argumentation that characterized the conference. And we hope that they will spark further inquiry into and discussion about topics in laboratory phonology.

Notes:

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This chapter is a condensed and mildly edited version of the original first chapter to *Papers in Laboratory Phonology 1: Between the Grammar and Physics of Speech*. The condensing was done by removing the paragraphs that introduced each of the other twenty-seven chapters of the original volume. These paragraphs have been replaced by listings of the chapter titles and authors. All other edits are corrections of typos in the original.

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Mary E. Beckman, Ohio State University, mbeckman@ling.osu.edu, "Language-specific and language-universal aspects of lingual obstruent productions in Japanese-acquiring children" (with Kiyoko Yoneyama and Jan Edwards) *Journal of the Phonetic Society of Japan* 7:18-28. (2003) The ontogeny of phonological categories and the

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primacy of lexical learning in linguistic development. (with Jan Edwards) *Child Development* 71:240-249. (2000) Japanese tone structure. (with Janet B. Pierrehumbert) Cambridge, Mass.: MIT Press. (1988)

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