SYMPOSIUM NO. 1: PHONETIC UNIVERSALS IN PHONOLOGICAL SYSTEMS AND THEIR EXPLANATION

(see vol. II, p. 5-59)

Moderator: John J. Ohala

Panelists: Thomas V. Gamkrelidze, André-Georges Haudricourt, Robert K. Herbert, Jean-Marie Hombert, Björn Lindblom, Kenneth N. Stevens, and Kenneth L. Pike

Chairperson: Bertil Malmberg

JOHN J. OHALA's INTRODUCTION

Phonetic universals is such a large subject that the members of this symposium despaired of being able, in the short time allotted, to give adequate consideration to any of the general aspects of the theory or practice of the field or to solve any of its "great problems". It was decided, therefore, that the moderator would make a few brief general comments about some of these larger issues, more or less "for the record", but that most of the time of the symposium be devoted to the discussion of one very specific problem in the area of phonetic universals.

General Problems and Issues in Phonetic and Phonological Universals

(In this report I will use the shorter phrase 'phonological universals' for the longer, somewhat unwieldy expression 'phonetic universals in phonological systems', the official topic for this symposium.)

1. Before beginning this discussion, we should define what we mean by *phonological universals.* As this term has come to be used, it means *systematic patternings of speech sounds cross-linguistically.* This definition does not require that the pattern be manifested in every human language, merely that it have sufficient incidence in the languages of the world such that its occurrence could not be attributed to chance. It is assumed, though, that all languages, indeed, all human speakers, are potentially subject to whatever "forces" create these patterns, but an overt manifestation of these forces may or may not occur and if it does occur, may take different forms. For example, to consider a case discussed extensively by Professor Gamkrelidze, it is presumably the same universal factors which are responsible for the asymmetrical gap in the voiced velar stop position (/g/)

in the segment inventories of Dutch, Czech, and Thai, as are responsible for the disproportionately low incidence of /g/ in the lexicon or in running speech of many languages. Likewise, whatever causes the asymmetrical absence of /p/ in Arabic, Nkom, and Chuave, is also responsible for the limited distribution of /p/ in Japanese, i.e., it only appears intervocalically and as a geminate.

2. The concern with phonological universals in our field has both theoretical and practical consequences. Some 100 years ago our intellectual forefathers, Ellis, Sweet, Passy, Lepsius, Jespersen, and others, provided us, in the phonetic alphabet and the descriptive anatomical and physiological terms accompanying it, the equivalent of the Linnean system of classification in biology or Mendeleev's periodic table of the elements in chemistry. Today, I believe it safe to say that we have reached the stage equivalent to that which Bohr's model of the atom represented in physics and chemistry. We have a framework within which to observe, to describe, and to establish natural classes of phonetic and phonological entities and processes in all human languages. We are also able, with obvious limitations, to predict and explain the behavior of speech sounds. Commendably, in many cases, these explanations are based on empirically-supported models of parts of the speech communication process. Although it is obviously the case that as we deepen our understanding of some of the basic physical, physiological, and psychological mechanisms serving speech, we also are better able to explain many phonological universals; it is also true that in many cases *it is our observation of phonological universals which leads to a greater understanding of speech mechanisms*. The literature in phonological universals is even now causing us to critically re-examine some of the most fundamental concepts in phonetic and phonological theory, for example, the notions of 'segment', of 'distinctiveness', etc., and to explore in considerable detail in the laboratory basic acoustic, aerodynamic, and auditory mechanisms in speech.

In the practical realm phonological universals can aid us in the analysis and understanding of the phonologies of individual languages: they tell us what to look for and they help us to choose alternative scenarios for the history of sound changes in the language. I personally believe that phonological universals

can also aid us in such cases of *applied phonology* as speech synthesis, automatic speech recognition, speech pathology, speech therapy, and language teaching. It must be said, however, that at present there has been very little penetration of universals in these areas.

3. Phonological universals are found in many different forms, e.g., segment inventories, segmental sequential constraints ("phonotactics"), allophonic variation, sound change, morphophonemic variation, dialect variation, patterns of sound substitution by first and second language learners, frequency of occurrence of sounds in the lexicon and in connected speech, conventional and esthetic use of speech sounds in onomatopoeia, poetry, jokes, singing, etc. Can we bring all of these disparate phenomena under one theoretical umbrella, using one of these as the base or primitive from which the others may be derived, or, possibly, deriving them from some separate principle external to all of them?

4. Another general issue concerns the problem of how to obtain a truly representative sample of sound patterns from a variety of languages such that the sample is not biassed by including too many or too few languages having certain genetic, typological, or geographical linkages. The many pitfalls of attempting a quantification of phonological data from large samples has been discussed previously, including such concerns as how one differentiates a language from a dialect, whether one should look at the behavior of phones or phonemes and if phonemes, whose conception of the phoneme, etc? The fact is, most works on phonological universals ignore this issue and seem to rely on the investigator's intuitive "feel" for what constitutes a proper sample. Is there any way to make this process objective? How can we create an unbiassed sample; how large should it be?; what criteria should we apply in admitting a language to the sample? Once we have the supposedly unbiassed sample, what type of statistical analysis should we apply to it in our attempts to prove or disprove universal tendencies?

My own solution to this problem, a solution which has parallels in other scientific disciplines, is to make sure that any posited universal is supported both *inductively* -- that is with lots of examples (and few counterexamples) - and *deductively* --

that is, by what we know to be the underlying operating principles of speech production and perception.

5. A related issue is whether or not some of the claims made about phonological universals may be distorted by observer bias, i.e., be self-fulfilling prophecies. It has been claimed, for example, that all languages code speech in terms of phonemes. But I know of no universally-accepted algorithm which discovers phonemes. And if there were, do we now have any evidence that phonemes and all the properties attributed to them, have psychological and/or physical reality?

A very clear example of the perils of observer bias surrounds claims about universals of syllable structures. It has been claimed that within a syllable, one should not find a transition from voiced to voiceless to voiced. Upon being presented with an apparent counterexample such as [itv], the claimant would protest that there is a syllable boundary between the [t] and [v]! The potential for similar circularity enters into any claim which contains terms that cannot be objectively defined. And this, unfortunately, is true of a very large number of terms used in phonetics and phonology, including terms such as consonant, vowel, segment, syllable, sonority, strength, lenition, etc.

Would we find a different set of universals if we adopted the parallel, hierarchic system such as Professor Pike advocates? Would we have a different, more interesting set of universals if we included in the description of sounds, as Professor Stevens proposes, the sensory information each sound gives rise to?

<u>A Specific Problem in Phonological Universals</u>

The problem selected for special attention during this symposium is by no means a small one and it is doubtful that it will be solved very quickly, certainly not in the short time allotted us. Nevertheless, it is a problem that intersects with the particular interests of most members of the symposium and is a matter to which many members of the audience can contribute. The problem is stated in a deliberately provocative way in order to stimulate discussion.

The notion of a vowel "space" has been used in phonetics for about 2 centuries but it is only recent evidence which points to this space having acoustic-auditory correlates. The research of Lindblom and his colleagues suggests that the placement of vowels

in this space in various languages is dictated by the principle of maximal perceptual difference, i.e., that however many vowels there are in the system, they tend to arrange themselves in the available space in such a way as to maximize their distance from each other. This principle seems to adequately predict the arrangement of systems with approximately 7 or 8 vowels. It would be most satisfying if we could apply the same principles to predict the arrangement of consonants, i.e., posit an acoustic-auditory space and show how the consonants position themselves so as to maximize the inter-consonantal distance. Were we to attempt this, we should undoubtedly reach the patently false prediction that a 7 consonant system should include something like the following set:

ɗ, k', ts, ɬ, m, r, ʇ,

Languages which do have few consonants, such as the Polynesian languages, do not have such an exotic consonant inventory. In fact, the languages which do possess the above set (or close to it), such as Zulu, also have a great many other consonants of each type, i.e., ejectives, clicks, affricates, etc. Rather than maximum differentiation of the entities in the consonant space, we seem to find something approximating the principle which would be characterized as "maximum utilization of the available distinctive features". This has the result that many of the consonants are, in fact, perceptually quite close -- differing by a minimum, not a maximum number of distinctive features.

Does this mean that consonant inventories are structured according to different principles from those which apply to vowel inventories? Could it mean that the "spaces" both consonants and vowels range in, are limited by the auditory features (= parameters) recognized by the particular language? Or does it mean that we are asking our questions about segment inventories in the wrong way?

COMMENTS FROM THE PANELISTS

<u>K.N. Stevens</u>: In an acoustic representation of connected speech we find certain regions where there are rapid (10-30 msec) changes in a number of acoustic parameters, e.g., amplitude, periodicity, and spectrum. A hypothesis that has emerged from our and Chistovich's research, is that the attention of the listener is drawn

to these regions, more so than to other regions where changes are less rapid. These regions are, first of all, markers of consonants, but additional information can also be packaged in them along several orthogonal dimensions. We believe languages therefore tend to "select" a consonant inventory that uses up most of these dimensions. These primary dimensions are: [± voice] (presence/absence of periodicity), [± nasal] (presence/absence of low-frequency murmur), [± continuant] (unbroken/interrupted sound), [± grave] (low-/high-frequency tilt to the spectrum), [± compact] (energy spread out/concentrated). After processing the information in these regions of rapid change (= high rate of information transfer), the listener's attention may focus on the remaining regions and here lie the cues for such dimensions as palatalization, pharyngealization, clicks, etc. It logically follows that the learning of (or introduction of) such distinctions will *follow* the learning of distinctions coded in the regions to which primary attention is directed.

B. Lindblom: We have recently followed up and improved on our early work on predicting vowel inventories and I think the research strategy we have used could be applied to consonant inventories, too. Briefly, our procedure is to 1) specify a physiological model of the vocal tract and use it to define 2) the range of humanly possible vowels and from this derive 3) the (universal) human acoustic vowel space, a continuum, and, finally, 4) to employ an auditory model to define a perceptual space to accommodate a specified number of vowels. The last step consists of convolving an input power spectrum (of a given vowel) with an auditory filter derived from masking data, thus yielding a hypothetical auditory excitation pattern. We assume that, other things being equal, the probability of any two vowels being confused, that is, their perceptual closeness, will be related to the overlap area enclosed by their excitation patterns. We believe vowel systems evolve so as to make vowel identification efficient and this is done by making perceptual differences between vowels (quantified as mentioned above) maximally or, perhaps, sufficiently large. This new measure of perceptual distance yields much more reasonable predictions about vowel placement; in particular, it eliminates the excessive number of high central vowels that plagued previous models.

A preliminary typological study of diphthongs shows that [a^{i}] and [a^{u}] are the most favored. This result is compatible with the new properties of our model's perceptual space and provides evidence for a principle of perceptual differentiation applying not only paradigmatically, but also sequentially. Consonant inventories can be studied within a paradigm such as this.

K. Pike: My own approach to phonetic analysis is a bit different from that of most of my fellow panelists. Although I have often been helped by acousticians when I have brought my phonetic problems to them, I would rather argue that the reductionism, so necessary in the laboratory, is detrimental to linguistic analysis in the field. I can illustrate this with an examination of a short poem by E.E. Cummings. [Text and detailed commentary omitted.] Although one can point out puns, details of orthography, prosody, and even cultural allusions which contribute to the overall effect, the poem, like language, functions as a whole. I am encouraged by the enlarged scope of phonological inquiry demonstrated at this congress, e.g., the work on syllables. The study of vowel spaces should also be enlarged to include what I call 'pharynx space' (changes in vowel quality by modifications of pharyngeal width and larynx height) and by taking into consideration the psychological reality of vowel structure.

J.-M. Hombert: A surprising number of people I have met at this congress are quite skeptical about the existence of phonological universals. Although one can cite countless examples of cross-language similarities in sound inventories, sound changes, and phonological processes, there are, of course, always counterexamples to almost any generalization one might make. Perhaps the answer to this is to pay more attention to the diachronic aspect of universals: the counterexamples may just be unstable transitional states between more natural states. Moreover, it is often possible to find that certain cited counterexamples cease to be so if one looks into the details more closely, e.g., in cases of tonal development from obstruents, a voiced stop giving rise to a high tone runs counter to the usual patterns, but if it was found that the voiced stop had first become an implosive, an expected development, then the case is no longer a counterexample.

Concerning the sampling problem, mentioned by the moderator, it is particularly acute in the case of perceptual data. This can be solved if we start discovering ways to take our laboratories into the field and thereby gather perceptual data from a wide variety of languages.

R. Herbert: A consideration of the factors constraining the introduction into a consonant inventory of complex sound types, e.g., affricates, pre- and post-aspirated consonants, and especially prenasalized consonants, may provide insight into the constraints on consonant inventories as a whole. Obviously, the parts of such complex segments must be sufficiently different from each other so that they may both be perceptually salient within the time span of a single segment, e.g., the nasal/oral distinction used in prenasalized stops. It must also be possible to articulate the parts within this same time span. Thus there are limits on the number of components in single segments: usually 2, but 3 in the case of pre-nasalized affricates, and rarely more. Most such complex sounds involve at least quasi-homorganic components, and thus nasal and stop combinations are frequently encountered but lateral and stop combinations less so since laterals, unlike nasals, have limited capacity for homorganicity. We might also speculate that the relative ordering of the components in complex segments is governed by the same factors that determine optimal syllable codas: the first element is generally the more common syllable coda, it being understood that optimal syllable codas are drawn first from the opposite ends of the sonority hierarchy, e.g., glides, nasals, [ʔ], and voiceless stops, before involving segment types from the middle, e.g., laterals, voiced stops, fricatives.

A.-G. Haudricourt: The search for phonological universals seems to me to be like the quest for the philosopher's stone. As for phonetic changes, it is more profitable to look at the conditions for the appearance of the phenomena rather than for their existence. Language is a social phenomenon and one of its main functions, communication, causes the development of new phonemes. Sindhi provides an example: its whole series of voiced stops, when long, has become preglottalized in order to remain distinctive. Language also has a socio-ethnic function and so preglottalization may appear without any phonological conditioning, as happens in Vietnamese and the Henan dialect of Chinese. In these cases, one or two preglottalized consonants are sufficient for the social function and it is normal that they should be the easiest to articulate (ɓ, ɗ). Likewise, preglottalized consonants can disappear for a variety of reasons. The loss of these sounds in Vietnamese was in part due to the presence of tones (which made the voicing superfluous) but has also been aided by the sociolinguistic environment in, e.g., Saigon. These facts are outside the domain of instrumental phonetics.

T.V. Gamkrelidze: I believe an understanding of the principles governing the structure of consonant and vowel inventories will come from typological phonology and experimental phonetics. An important task for typological phonology today is the establishment of constraints or relations of markedness or dominance between certain bundles of co-occurring features. For example, as detailed in the printed version of my paper, in the subsystem of stops and fricatives, $\begin{bmatrix}\text{+voice}\\ \text{+labial}\end{bmatrix}$ is dominant (unmarked) with respect to the co-occurring features $\begin{bmatrix}\text{+voice}\\ \text{+velar}\end{bmatrix}$. Thus, among voiced stops, /b/ is dominant, /g/ is recessive. Also, among voiceless stops, /k/ is dominant, /p/ is recessive. These relations stem from the specific acoustic and articulatory properties of the features involved. In the examples mentioned, the volume of the air chambers plays a part. Gaps in the paradigmatic system of obstruents will generally reflect these dominance/recessiveness relations. These relations can therefore help us to better understand sound change and to do language reconstruction more realistically. In light of this, the classical reconstruction of the Indo-European occlusive phonemes appears to be linguistically improbable in that (among other things) it assumes the series with the missing labial were voiced stops. Reinterpreting this series as ejectives brings the IE obstruent system into full conformity with typological studies.

J.J. Ohala: I would speculate that a universal vowel and consonant space does not exist. Each language "chooses" some restricted set of features or dimensions for these spaces. It is common knowledge, for example, that a native speaker of one language is 'deaf' to certain features used in other languages. It is true that the Lindblom model does have a remarkable degree of success in predicting the structure of systems with a small number of vowels. But it is significant that it breaks down when a large number of vowels are involved, very likely because one or two dimensions other than those used in the model are also involved, e.g., vowel duration, diphthongization, voice quality. It could be that vowel spaces, unlike consonant spaces, have rather few possible dimensions and that most languages make some use of the most salient dimensions (those based on spectral shape). In consonant systems, it is well known that there are more possible dimensions to choose from and so the discrepancy between reality and the predictions of a maximum-perceptual-distance model are more evident. Thus, the differences between vowel and consonant systems in this respect are only apparent. What is more remarkable --to me, at least -- is the highly symmetric nature of consonant proliferation. The mechanism of proliferation is reasonably clear, e.g., stop plus [ʔ] yields a glottalized series of stops or ejectives, but why should proliferation almost always yield a whole new row or column of such consonants?

DISCUSSION

K.N. Stevens: It is true, as Professor Gamkrelidze notes, that aerodynamic factors contribute to the asymmetries in obstruent systems, but auditory factors are important, too. The noise or burst of a voiceless velar will give a very clear indication of compactness -- more so than a voiced velar, whereas a voiced labial will reveal the feature [+grave] better than a voiceless labial.

J. Ohala and K. Stevens discussed the need, in the search for the most salient auditory dimensions, of finding the perceptual cues for such striking sounds as ejectives.

K. Pike and J. Ohala mentioned specific instances of vowel and consonant systems utilizing voice quality as a distinctive dimension, e.g., certain languages of Nepal, various Nilotic languages, Korean, Javanese, Cambodian, Gujarati.

B. Lindblom: It is possible, in principle, to include other dimensions in the vowel space, but it is better at this stage of research to make our models precise and quantitative. At present then, it is better to restrict the investigation to spectrally-based dimensions. I agree with Ohala that listeners react to vowel stimuli in language-specific ways. In fact, some of our own research shows that Swedish listeners put more subjective distance between the vowels in the crowded front region of the Swedish vowel space than would have been predicted by our model's spectrum-based metric. But let us not be too hasty in discarding the notion of a universal vowel space. After all, this may be what the child brings to the language-learning task.

J. Ohala: I concede that I overstated my position. There undoubtedly is a universal vowel space and each language chooses a subspace within it. No doubt there is some order according to which features are chosen first.

T.V. Gamkrelidze: The greater proliferation of consonants as opposed to vowels is due to the greater number of possible dimensions in consonant systems. In theory, of course, an infinite number of vowels could be produced, but practically the number is small due to auditory and articulatory constraints.

A. Haudricourt: (In response to a question from J.-M. Hombert) The search for phonological invariants and for culture-specific phenomena is not incompatible, but they are two different problems. First we must investigate the *function* of language and only then look at its phonetic realization.

B. Lindblom: Given the well known *discreteness* of language, it might be asked why, in our model, we start with a *continuous* vowel space. The answer is that we do not yet have a theory that predicts that language should have discrete units such as distinctive features. The theory of distinctive features we do have is based on induction. I think the discreteness has to be deduced or derived as a consequence of more fundamental principles. Even so, a totally discrete model will still not explain why, in languages with few vowel contrasts, the extreme corner vowels tend to be phonetically less extreme (as noted by Crothers).

(To Prof. Stevens:) The quantal phenomena you find in the articulatory-to-acoustic transformation cannot be the only source of phonological discreteness. Surely, memory mechanisms must be involved as well (cf. the work of G. Miller and I. Pollack on elementary auditory displays).

K. N. Stevens: I agree with all of your points. I would just say that in the vowel space there are some regions which are more stable (or discrete) than others in that a wide range of articulations would give rise to the same acoustic signal. So the vowels will be within these regions, the exact location determined by factors such as your model incorporates. It is possible, too, that the whole space may shift in one direction or another due to different so-called 'basis of articulation' of various languages.

B. Lindblom: Isn't this a denial of the possibility for a universal framework?

K.N. Stevens: I don't think so. I view these shifts as being fairly small. The high front vowels in various languages may not be phonetically identical, but they are still high front vowels.

K. Pike: It won't work to say it is either 'discrete' or 'continuous'. We need 'particle' or 'wave' descriptions, both of which are observer-related, *and* a 'field' view which describes it in terms of an overall system.

C.J. Bailey and T.V. Gamkrelidze expressed differing views on how much weight to give to typological evidence as opposed to comparative (within-family) evidence when doing reconstructions.

C. Scully: A propos of pre-nasalized stops, I have found in airflow traces that the velum closes very late during the closure portion of post-pausal voiced stops, almost as if some aspects of speech are begun while certain acts of respiration (open velum) are still in play. This may be a good example of a mechanically determined feature of pronunciation that might become generalized and taken up as a linguistic feature.

S. Anderson: I wish to take issue with the assumptions (or by Ohala, an explicit proposal) that claims about phonological structures must be verifiable in terms of substance in some other domain, typically phonetic. At the Phonology session of this congress I sketched a rather different approach to phonology which assumes that there is a systematic domain which is relevant to the nature of language but which isn't directly reducible to other domains. According to this view, the facts that are directly susceptible of phonetic explanations are, in a sense, exactly what is irrelevant to phonology.

F. Longchamp: (To Hombert) You haven't made a clear case for the decreased saliency of the centralized vowels. The vowels that behaved oddly in your study seem to be the one-formant vowels. Of course, subjects can give labels to these vowels but this may have no relevance to natural speech.

H.-H. Jeng: I think child language studies can provide evidence relevant to the questions on the elaboration of segment inventories. In the early speech of my son the consonant system used only the features for $\pm$ stop and those for different places of articulation. Later on, features were added to differentiate nasality, aspiration, frication, etc. In the case of vowels, only height features were used at first. Later, front-back and rounding were differentiated. I think these early segment systems represent the universal core upon which further elaborations of the system can be built.

N. Waterson: I question the phonemic basis used in work on universals. There is much evidence that the proper domain of many phonological processes is something more like the word. In sound change the position of the sound in the word and its phonetic context is very important. Children will often produce the correct degree of vowel openness in vowels in a 2-syllable word but not the correct frontness or rounding feature. Thus, when looking for universals we should look for patterns in the domain of the whole syllable or word.

H. Andersen: I don't see how Lindblom's model will accommodate vowel mergers which are very common diachronically. Nor can this problem be solved as recommended by Hombert by assigning the merged vowels to an unnatural transitional state which will eventually revert to a stable natural state. How is one to identify transition as opposed to stable state? The solution, I think, is to recognize that the vowel (as well as the consonant) space is used for more than just diacritic purposes: they also carry information about their consonant environment, about the style of speech used by the speaker as well as his age and social class membership. Thus when the vowels slide around it must be because these subsidiary functions lose their value and are re-interpreted as basic values of the vowel phonemes themselves. This notion is fully in accord with the views expressed here by Profs. Pike and Haudricourt.

L. Jacobson: I can provide some more details on the vowel systems of certain Nilotic languages (alluded to by Ohala) and and at the same time show that they are compatible with Lindblom's model. My own acoustic analysis of the 9 vowel system of Luo shows that many of the non-low vowels show great overlap in an F1 x F2 x F3 space. They can be separated, however, by adding a dimension of voice quality (or pharynx size): breathy voice vs. normal or creaky voice. When this is done, all the vowels are still maximally distant from the other vowels *on the same plane.*

I. Maddieson: It was mentioned (by Lindblom) that high vowels in systems with few vowels tend to be less peripheral. This is a crucial fact and suggests that *maximal* dispersion of entities in an auditory space isn't required. I find supporting evidence for this view in the structure of tonal spaces: words borrowed from a 2 level-tone language into a 3 level-tone language reveal that the high tone of the 2-tone language is equal to the mid-tone of the 3-tone

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L. Lisker: Is the search for universals a viable enterprise if we can't be sure that we are aware of all the features that human languages make use of? New ones are discovered all the time. Also, when making generalizations about segment inventories, we should be clear what we're talking about: the /g/ in English is not the same 'beast' as the /g/'s in Spanish or French, for example. The problem is that the C's and V's we count are invariably the product of the phonologist who uses other than purely phonetic criteria in deciding how to classify sounds.

H. Galton: Considering cases like Ubykh,a Caucasian language with 80 consonants and no more than 2 vowels, and English with about 1/3 as many consonants and many more vowels, I wonder if Prof. Gamkrelidze would accept the tentative universal that is there a kind of balance between a language's consonant and vowel inventories, i.e., that one develops at the expense of the other?

T.V. Gamkrelidze: The number of consonants always exceeds that of vowels since the possibilities for auditory and articulatory contrasts is greater for consonants.

J. Ohala: Regarding the relative merits of a formalist vs. a physicalist research strategy in phonology, the issue raised by Prof. Anderson, I suggest this be decided by examining the 'track record' of the two approaches in providing explanations in phonology.

Reflecting on several of the comments made here, I would suggest we consider the possibility that the single multi-dimensional perceptual space that *both* consonants and vowels range in is not simply defined by the various spectral features (F1, F2, F3), amplitude, periodicity, etc., but rather the first derivative --the rate of change-- of those features. R. Port at Indiana as well as Lindblom have explored this possibility. In this case, the units would no longer be phonemes as such, but rather the transitions between them. These units (more numerous than phonemes) tend to be more invariant, too.