Feature Economy as a Phonological Universal

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ABSTRACT

This paper compares two approaches to the study of sound inventories, one phonological and the other phonetic. The first maintains that speech sounds tend to be organized by a principle of *feature economy*, according to which languages maximize the combinatory possibilities of a few phonological features to generate large numbers of speech sounds. The other holds that sound systems are organized by a principle of *maximal dispersion,* according to which speech sounds tend to be maximally dispersed in perceptual space. A comparison of these two principles with respect to the UPSID-92 data base of phoneme inventories provides strong support for the first.

1 INTRODUCTION

This paper addresses the question: what principles underlie the structure of sound systems? Much discussed in the earlier structuralist literature, this question lay dormant during most of the generative era, only to reemerge in the more recent literature on linguistic universals. It is perhaps paradoxical that this question, first raised by phonologists, is now most vigorously discussed in phonetic circles. Yet the question is of fundamental interest to phonology as it concerns the basic architecture of the sound systems from which each language draws its characteristic sound patterns.

This question was raised in the earliest literature in phonology. One of the first observations was that phonemes tend to occur in correlated series such as “voiced vs. voiceless stops” or “oral vs. nasal vowels” [18]. To explain this trend, *feature economy* was proposed as a basic organizational principle of phoneme systems, first by de Groot [6] and more extensively by Martinet [14]. According to this principle, languages tend to maximize the combinatory possibilities of a few distinctive features to generate a much larger number of phonemes. In other words, features used once in a system tend to be used again. However, as pointed out by Martinet, feature economy is subject to functional phonetic constraints tending to disfavor articulatory complexity and to favor perceptual salience.

A more recent trend in the study of universals has involved the notion of *maximal dispersion.* While feature economy predicts that sound systems tend to be organized around a small number of feature parameters, maximal dispersion predicts that the speech sounds of a language tend to be maximally distant in perceptual space [6:121, 14:62, 7, 8]. The total dispersion of a system is defined as the sum of the perceptual distances between each pair of sounds in the system. (Maximal dispersion is to be distinguished from *sufficient dispersion* [8, 9, 10]. Sufficient dispersion requires pairs of sounds to be auditorily distinct enough to be easily identified and distinguished. This relatively uncontroversial principle is not at issue here.)

The maximal dispersion principle has been most often applied to the study of vowel systems. In regard to consonants, Ohala [15] has pointed out that maximal dispersion makes the “patently false” prediction that a 7-consonant system should include something like the set / ɖ k’ ts ɬ m r | /. He observed that languages with very few consonants do not have such an exotic consonant inventory; instead, languages which do possess such consonants, such as Zulu, also have a great many other consonants of each type, e.g. ejectives, clicks, affricates, etc.

The present study compares the predictions of feature economy and maximal dispersion as they apply to the structure of consonant inventories, and tests them against a sample of the world's languages.

2 PREDICTIONS OF FEATURE ECONOMY AND MAXIMAL DISPERSION

The basic insight underlying feature economy is that if a feature is used once in a system, it will tend to be used again. Thus a strong prediction is that sounds will tend to attract other sounds bearing the same features. This prediction may be stated as follows:

> **Prediction A** (Mutual Attraction): A given sound will have a higher than expected frequency of occurrence in languages having other sounds bearing one or more of its features.

Thus, for example, [v] should be more frequent in languages that have other distinctively labial, voiced, or continuant sounds, and [b] should be more frequent in languages having other distinctively voiced stops such as [d]. Sounds *not* sharing distinctive features should show no positive interactions.

The maximal dispersion principle makes precisely the opposite claim: sounds should be disfavored in systems containing other sounds that are similar to it. (The tolerated degree of similarity will depend on the number of sounds in the system, larger systems allowing greater similarity.) There are many methods for defining perceptual similarity (e.g. [1, 16]). For present purposes it will be sufficient to assume that two sounds sharing a distinctive feature F are more similar than two otherwise identical sounds not sharing F. For example, [b] and [d], which share voicing, are more similar than the otherwise similar [b] and [t], which do not. It follows that [b] should be less frequent in languages having [d] as well. (Effects of system size on tolerated degree of similarity should cancel out across the sample as a whole.) As the predictions of feature economy and maximal dispersion are contradictory, evidence in favor of one of these principles constitutes evidence against the other.

These predictions were tested using the method described more fully in [3, 4]. The main features of this method are the following:

1. The data base used for the study is UPSID-92, a balanced sample of 451 phoneme systems from the world's languages [11,13].
2. Speech sounds in the data base were coded in terms of a current model of distinctive features, including [labial], [voice], [continuant], etc.
3. Frequencies of compared sounds were arrayed in contingency tables and the resulting distributions were tested for significance by the chi square (χ^2) test.
4. Observed frequencies (F_O) were compared with expected frequencies (F_E). Significant associations between two sounds were coded as positive if $F_O > F_E$, and as negative otherwise.

3 TESTING THE PREDICTIONS

Preliminary results have already confirmed Prediction A for several comparisons [3, 4]. For example, it was found that [v] is more frequent in languages having [z], with which it shares the features [+voice] and [+continuant], than in languages not having [z], and that the frequency of [v] increases in proportion to the number of other labial obstruents present in the system.

To further test this prediction, comparisons were made between pairs of stops differing in place but sharing all manner features, as shown in Table 1. By feature economy (Prediction A) we expect all associations to be positive, while by maximal dispersion we expect them to be negative. The top three cells in this table compare voiceless aspirated stops, voiceless ejective stops, and nasal stops, respectively, while the bottom three cells compare plain, breathy, and implosive voiced stops.

P^h vs. T^h P^h vs. K^h T^h vs. K^h	P’ vs. T’ P’ vs. K’ T’ vs. K’	M vs. N M vs. NG N vs. NG
B vs. D B vs. G D vs. G	B^h vs. D^h B^h vs. G^h D^h vs. G^h	$B^{<}$ vs. $D^{<}$ $B^{<}$ vs. $G^{<}$ $D^{<}$ vs. $G^{<}$

Table 1: Comparisons among pairs of stops sharing manner features but differing in place. Upper-case symbols stand for articulator-defined places of articulation: labial (P, B, M), coronal (T, D, N), or dorsal (K, G, NG).

All comparisons proved positive at a very high level of significance ($p < .0001$): languages having one member of each pair tended overwhelmingly to have the other. This result strongly supports Prediction A. (It must be noted, however, that voiced aspirates and implosives are not widely distributed among the world's languages, so the results for these sounds may not reflect broadly-based typological characteristics.)

A further set of comparisons was made between plain voiced stops and stops differing both in place and in phonation type, as shown in Table 2.

B vs. T B vs. K	B vs. T^h B vs. K^h	B vs. T’ B vs. K’
D vs. P D vs. K	D vs. P^h D vs. K^h	D vs. P’ D vs. K’
G vs. P G vs. T	G vs. P^h G vs. T^h	G vs. P’ G vs. T’

Table 2: Comparisons among pairs of stops differing in one or two phonation type features.

In this table, voiced stops B D G are compared with plain voiceless stops P T K in column 1, with voiceless aspirates P^h T^h K^h in column 2, and with voiceless ejectives P’ T’ K’ in column 3. As these pairs share no features of place or phonation type, feature economy predicts no positive associations among them (unless by virtue of the shared unmarked feature [-continuant], see below). In contrast, since these pairs are more distant from each other than those in Table 1, differing by one phonation type feature (e.g. B vs. T) or by two (B vs. T^h, B vs. T’), maximal dispersion theory would predict these pairs to be relatively favored.

However, *all* comparisons in Table 2 proved negative, many significantly so, including all but B vs. T in column 1; the presence of a voiced stop tends to disfavor the presence of a plain, aspirated or ejective voiceless stop. As far as the pairs examined in Tables 1 and 2 are concerned, then, only feature economy makes the correct predictions.

Further comparisons were made between maximally distinct obstruents and nonobstruents (liquids, nasals, glottals), as shown in Table 3. These pairs of sounds are highly dissimilar in terms of features, and could be expected to favor each other under maximal dispersion. In contrast, feature economy predicts no positive associations among them.

P vs. liquids P vs. dorsal nasals P vs. glottals	S vs. labial glides S vs. labial nasals S vs. glottals*
V vs. liquids V vs. dorsal nasals V vs. glottals	G vs. liquids G vs. labial nasals G vs. glottals

Table 3: Comparisons between obstruents and non-obstruents. Just one comparison (shown by the asterisk) proved significant.

In this table, P represents the class of voiceless labial stops, V the class of voiced labial fricatives, S the class of voiceless coronal fricatives, and G the class of voiced dorsal stops. Glottals include H-sounds and glottal stops.

Only the comparison between S and glottals showed a statistically significant association (χ^2 = 43.880, $p<.0001$), and this was positive. A closer study of this effect shows that it is due entirely to the subset of voiceless H-sounds, which associate with voiceless fricatives by virtue of the shared features [+continuant] and [-voice]. The results in Table 3 are thus fully in agreement with the predictions of feature economy, but not with those of maximal dispersion theory.

4 FEATURE ECONOMY INVOLVES DISTINCTIVE FEATURES ONLY

Not all features exert economy effects. Table 1 revealed economy effects for the features [spread glottis], [constricted glottis], [+nasal], and [+voice], all of which tend to be distinctive in stops. Shared features which are *nondistinctive* throughout a class of sounds do not generally give rise to feature economy effects. For example, though most of the pairs compared in Tables 2 and 3 share such features as [-sonorant] and [+consonantal], these do not create economy effects. These features are rarely distinctive, but typically serve the role of defining the classes of sounds within which other features are distinctive. For example, [±voice] is often distinctive in the class of [-sonorant] sounds, but not in the class of [+sonorant] sounds. Similarly, though P, liquids and glottals in Table 3 share such features as [-nasal] and [-strident], these features are typically nondistinctive and phonologically inactive in these classes of sounds.

If such features are permanently absent in representations [2], they will not be present in these sounds and so cannot give rise to feature economy effects.

A further feature that does not give rise to economy effects is [-continuant], shared by all stops compared in Table 2, as well as by the stops and nasals in Table 3. Unlike those just discussed, this feature is typically distinctive in obstruents, where it distinguishes stops from fricatives. Preliminary results [3, 4] suggest that feature economy effects may be strongest in marked feature values, understood as those which designate the less frequent member of a contrast. As stops are more frequent than fricatives across languages, [-continuant] is the unmarked value of [±continuant].

It thus appears that only *marked distinctive features* give rise to robust feature economy effects. This observation argues that feature economy operates at a higher cognitive level than that of prelinguistic auditory processing or motor control, i.e. that it directly accesses feature representations in which marked, distinctive values have a special status.

5 SUMMARY AND DISCUSSION

This paper has brought to light statistically strong feature economy effects among certain classes of consonants, showing that marked distinctive features, if present in one sound, tend to be present in others. We have found no evidence supporting the opposed principle of maximal dispersion in the comparisons examined here. Instead of dispersing, speech sounds show a tendency to concentrate along just a few feature dimensions in any language.

As noted earlier, the maximal dispersion principle has not been without its critics. Its failure to apply to consonant systems has long been noted, and is now accepted by proponents of adaptive dispersion theory [10]. Its role has also been questioned in the study of vowel systems, where it was first applied. Thus Maddieson [11:16] points out that contrary to the predictions of dispersion theory in its strongest form, vowel systems tend to maximize the use of just a few acoustic dimensions:

> The most frequent vowel inventory is / i, e, a, o, u /, not / i, ẽ, a̤, o̰, uˤ / where each vowel not only differs in quality but is distinctively plain, nasalized, breathy, laryngealized and pharyngealized. Yet this second set of vowels surely provides for more salient distinctions between them and approaches maximization of contrast more than the first set whose differences are limited to only the primary dimensions conventionally recognized for vowel quality.

Maddieson elsewhere [12:637-9] cites data suggesting that small-inventory vowel systems show a concentration toward central values rather than dispersion toward extreme values. Independently, Schwartz et al. [17] have found that dispersion theory does not account for the symmetrical pattern of peripheral vowels, and suggest that it should be reinforced by a feature model in order to explain the "maximum utilization of the available distinctive features", another term for feature economy.

For such reasons, more recent work in dispersion theory has tended to constrain the predictions of maximal dispersion through the introduction of other, competing principles such as articulatory complexity [9, 10] and focalization [17]. Nevertheless, the principle of feature economy has still not been integrated into most accounts [8, 10, 17], though some suggestions to this effect are offered in [9]. The results discussed in this study call for a reassessment of dispersion theory in view of determining the proper role of maximal dispersion once feature economy, and eventually other relevant principles, are given their appropriate place.

There is some evidence that feature economy is not restricted to phonological features in the strict sense. Languages that have one contrastive geminate consonant tend to have several, even though gemination is usually thought to be represented by prosodic categories (such skeletal positions or moras) rather than features as such. Languages with dental [d] tend to have dental [t], even though dentality is a phonetic, not phonological category. In morphosyntax, languages that have one formally marked noun class, case, etc., tend to have several, and categories like [±plural] tend to generalize across all lexical items with which they are semantically compatible. It is possible, then, that feature economy reflects a more general principle of organization according to which the preferred categories of a language tend to be used to maximum effect.

ACKNOWLEDGEMENTS

I thank Cécile Fougeron for helpful comments on an earlier draft of this paper.

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