The difference between the distinctive features of contiguous bundles permits the division of a sequence into phonemes. This difference may be either complete, as between the last two phonemes /i/ and /ŋ/ in the word wing (which have no distinctive features in common) or partial, as between the last two phonemes of the word apt - /p/ and /t/ all of whose distinctive features are the same except one: /p/ is grave and /t/ is acute.

This suprasegmental extension of certain features such as interruptedness, diffuseness or non-nasality is selective: cf. such sequences as asp (continuant and interrupted), act (compact and diffuse) and ant (nasal and oral). On the other hand, strong (tense) and weak (lax) consonants cannot follow each other within a simple English word: cf. nabs/nabz/, nabbed/nabd/, and naps /naps/, napped/napt/. That is to say, in consonant sequences the tenseness and laxness features are suprasegmental.

Any one language code has a finite set of distinctive features and a finite set of rules for grouping them into phonemes and also for grouping the latter into sequences; this multiple set is termed phonemic pattern.

Any bundle of features (phoneme) used in a speech message at a given place in a given sequence is a selection from among a set of commutable bundles. Thus by commuting one feature in the first phoneme of the sequence pat we obtain a series bat - fat - mat - tat - cat. Any given sequence of phonemes is a selection from among a set of permutable sequences: e.g. pat - apt - tap. However, /tp'a/ not only does not, but could not exist as an English word, for it has an initial stop sequence and a single final vowel under stress, both of which are inadmissible according to the coding rules of contemporary English.

1.2 INVARIANCE AND REDUNDANT VARIATIONS

The consonants are quite different in the English coo and key or in the French coup and qui. In both languages a more backward (velar) articulation is used before /u/ and a more forward (palatal) articulation before /i/. The formants of the consonant are closely adapted to those of the following vowels, so that the frequency spectrum of /k/ before /u/ has a lower center of area and is closer to that of /p/ than is the case before /i/, where it has a higher center of area and is closer to that of /t/. Both in English and French, /p/ and /t/ are separate phonemes opposed to each other as grave and acute, whereas the two varieties of /k/ represent but a single phoneme. This seeming discrepancy is due to the fact that the opposition of /p/ and /t/ is autonomous, i.e. both /p/ and /t/ occur in identical contexts (pool - tool; pea - tea), while the difference between the two k-sounds is induced by the following vowel: it is a contextual variation. The retracted articulation and the low frequencies of one of these k-sounds and the more advanced articulation and high frequencies of the other are not distinctive but redundant features, since the distinction is carried by the subsequent vowels. In Roumanian, both k-sounds in question occur in one and the same context (e.g. before /u/: cu "with", with a backward articulation, and chiu "cry", with a more forward articulation) and, therefore, they represent two different phonemes.

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In the same way, the difference between the so-called "clear" and "dark" varieties of the English /l/ is redundant: the "clear" variant indicates that a vowel follows and the "dark" variant that no vowel follows; thus in lull, the initial /l/ is "clear" and the final, "dark". In Polish these two sounds may appear in one and the same context and form a distinctive opposition: cf. the "clear" /l/ in laska "cane" and the sound close to the English "dark" variety in łaska "grace."
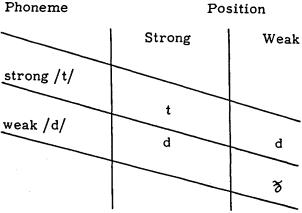
The relation between tart and dart, try and dry, and bet and bed represents in English one and the same minimal distinction regardless of the perceptible articulatory and acoustical difference between the three t-sounds cited. The invariant is the opposition of strength and weakness (for more precise data see 2.43). In English a regular concomitant factor of this opposition is the voicelessness of the strong consonants and the voicing of the weak ones. But this redundant feature may disappear occasionally; cf. the voiceless variants of /b d z/ observed by English phoneticians.

It is important to note that gradations in strength serve no distinctive purpose: they depend entirely upon the context. For instance, the heavy aspiration of the initial strong /p t k/ before a stressed vowel as in tart and, conversely, the lack of aspiration before other phonemes as in try are only contextual variants which cannot impede the identification of any /p t k/ as strong in contradistinction to the weak /b d g/.

Danish is another language that exhibits the opposition of strong and weak consonants. This opposition is implemented in different ways depending upon the position of the consonant in a word. Two positions are discernible in the Danish word - strong and weak. In monosyllabic words the strong position for a consonant is at the beginning of the syllable and the weak position, at its end. In strong position the strong stops are normally produced with a heavy aspiration, while their weak opposites appear as weak stops (differing from the English /b d g/ through voicelessness); e.g. tag "roof" - dag "day". In weak position the strong /t/ is weakened to the level of /d/, while its weak opposite is further weakened from /d/ to the weakest level /ð/ resembling somewhat the consonant of the English the; for example: hat [had] "hat" - had [hað] "hate". Consequently, the opposition of the strong and weak phoneme remains invariant in both positions; at the same time there is a redundant shift of both opposites induced by the weak position, which indicates that neither a stressed nor a long vowel follows. Although the weak phoneme in strong position and the strong phoneme in weak position overlap phonetically, in the strictly relational terms of distinctive features there is no overlapping:

"Two patterns are identical if their relational structure can be put into a one-to-one correspondence, so that to each term of the one there corresponds a term of the other" (3).

Hence, an automatic detector designed to distinguish between the two positions and between the two polar terms within each of them would unerringly "recognize" both the strong and weak phoneme:

Phoneme   Position

                    Strong   Weak

strong /t/

                       t

weak /d/

                       d   d

                                    ẕ

The instances cited show how the invariance of the minimal distinctions can be separated from the redundant features that are conditioned by the adjacent phonemes in the sequence.

The sequential arrangement of distinctive features does not generate the only type of redundancies. Another less analyzed though very important class of redundancies is conditioned by the superposition of simultaneous distinctive features. There are languages in which the velar [k] is in complementary distribution with the corresponding palatal stop or with a still more advanced prepalatal affricate (pronounced as in the English chew). For instance, the velar sound occurs only before back vowels and the palatal (or prepalatal) sound only before the front vowels. In such cases the former and the latter are considered two contextual variants representing a single phoneme. By the same reasoning, if in French we find the velar stop /k/, the palatal nasal /ɲ/ (as in ligne) and the prepalatal constrictive /ʃ/ (as in chauffeur), we must consider the difference between this velar, palatal and prepalatal articulation as entirely redundant, for this difference is supplementary to other, autonomous distinctions. All of these consonants are opposed to those produced in the front part of the mouth as compact vs. diffuse (see 2.41). When the features of interruptedness (stop), nasalization and continuancy are superposed upon the compactness feature, they are accompanied, in the French consonants, by the redundant features of velarity, palatality, and prepalatality respectively. Thus the French /p b/ and /t d/ bear the same relation to /k g/, as /f v/ and /s z/ do to /ʃ ʒ/, and as /m/ and /n/ to /ɲ/.

The redundant character of the velar and prepalatal feature of the English compact consonants can be demonstrated in a similar manner. In Czech or Slovak, however, the analogous difference between velars and palatals (including the prepalatals in the latter class) is distinctive, since these languages have velars and palatals, ceteris paribus. The velar stop /k/ is opposed to the palatal stop /c/ and the velar constrictive /x/ to the (pre) palatal /ʃ/. Consequently, in these languages the opposition grave vs. acute characterizes not only the relation of labials to dentals but also that of velars to palatals: /k/ is to /c/ as /p/ is to /t/.

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The multiplicity of distinctions traditionally accepted in the analysis of speech could be radically diminished were we to eliminate the redundancies linked to the relevant opposition of vowels and consonants. For example, it can be shown that the relation of the close to the open vowels, on the one hand, and that of the labials and dental consonants to consonants produced against the hard or soft palate, on the other, are all implementations of a single opposition: diffuse vs. compact (see 2.41); provided that the numerous redundancies contingent upon the fundamental difference between the vocalic and consonantal feature be eliminated. In their turn the relations between the back and front vowels, and between the labial and dental consonants pertain to a common opposition grave vs. acute (see 2.421).

While the relational structure of these features, which are common to consonants and vowels, manifests a definite isomorphism (one-to-one correspondence), the variations are in complementary distribution. That is to say, they are determined by the different contexts in which they appear: the variations are dependent upon whether the gravity-acuteness and compactness-diffuseness features are superposed upon a vowel or a consonant.

By successively eliminating all redundant data (which do not convey new information) the analysis of language into distinctive features overcomes the "non-uniqueness of phonemic solutions" (4). This pluralism, pointed out by Y. R. Chao, interfered with the analysis as long as the phoneme remained the ultimate operational unit and was not broken down into its constituents. The present approach establishes a criterion of the simplicity of a given solution, for when two solutions differ, one of them is usually less concise than the other by retaining more redundancy.

The principle of complementary distribution, which has proven most efficacious in speech analysis, opens many new possibilities when its ultimate logical implications are made explicit. Thus if certain phonemic distinctions possess a common denominator and are never observed to co-exist within one language, then they may be interpreted as mere variants of a single opposition. Furthermore, the question can be raised whether the selection of a given variant in a certain language is not connected with some other features proper to the same linguistic pattern.

In this way the inquiry succeeds in reducing the list of distinctive features ascertained in the languages of the world. Trubetzkoy (5) distinguishes the following three consonantal oppositions: first, the opposition of strong and weak consonants, the former characterized by a stronger resistance to the air flow and stronger pressure; second, the opposition of a stronger and weaker resistance alone, without accompanying pressure differences; third, the opposition of aspirated and non-aspirated. Since, however, never more than one of these three oppositions has been encountered functioning autonomously within any one language, all three should be regarded as mere variants of a single opposition. Moreover, this variation is apparently redundant because it depends upon certain other consonantal features present in the same pattern (see 2.43).

The extremely limited set of distinctive features underlying a language, the restrictions on their actual combinations into bundles and sequences and, finally, a high amount of redundancy, lighten the load imposed upon the participants of the speech event.

In the hierarchy of the sound features the distinctive features are of paramount importance. However, the role of the redundancies must not be underestimated. Circumstances may even cause them to substitute for the distinctive features. In Russian the distinction between the palatalized and non-palatalized consonants plays a significant part in differentiating words. Palatalization produces a slight rise of the formants (see 2.423). The phoneme /i/ is implemented as a back vowel [ɨ] after non-palatalized consonants, and as a front vowel [i] in all other positions. These variants are redundant, and normally for Russian listeners it is the difference between the non-palatalized [s] and the palatalized [ş] which serves as the means of discriminating between the syllables [sɨ] and [şi]. But when a mason telephoned an engineer saying that the walls [sɨr'ejut] "are getting damp" and the transmission distorted the high frequencies of the [s] so that it was difficult to comprehend whether the walls "were getting damp" or "turning gray" [şir'ejut], then the worker repeated the word with particular emphasis on the [ɨ] ,and through this redundant feature the listener made the right choice. In S. S. Stevens' formulation:

> ".....the fact of redundancy increases the reliability of speech communication and makes it resistant to many types of dis- ¹ tortion. By limiting the number of discriminations required of the listener and by assisting his choice through the redundant coding of information, we make talking to one another a resonably satisfactory business" (6).

1.3 IDENTIFICATION OF DISTINCTIVE FEATURES

Any distinctive feature is normally recognized by the receiver if it belongs to the code common to him and to the sender, is accurately transmitted and has reached the receiver.

Suppose that both participants of the speech event use the same kind of standard English and that the listener has received the vocables gip, gib and gid, which are unfamiliar to him, as to many other English speakers. He does not know that gip means "to clean (fish)", gib, "castrated tom-cat", and gid, "an animal disease." Yet the information he obtains from these three samples is that they may be English words, since none of the features and feature combinations contained in them contradict the English code. Moreover, the three samples convey the information that, if they are words, then each of them has a different meaning, for there is a duple distinction between gip and gid and two different minimal distinctions separate gib from gip and gid. Were the English-speaking listener to hear the following highly improbable sentence: "The gib with the gid shall not gip it", he would know from his knowledge of the rules of the English code, that /gib/ ≠ /gip/ ≠ /gid/. Were the samples to

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