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CHAPTER 14

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PHONOLOGY IN RELATION TO PHONETICS

I. THE FEATURE LEVEL OF LANGUAGE

1. DISTINCTIVE FEATURES IN OPERATION

Family names such as *Bitter, Chitter, Ditter, Fitter, Gitter, Hitter, Jitter, Litter, Mitter, Pitter, Ritter, Sitter, Titter, Witter, Zitter*, all occur in New York. Whatever the origin of these names and their bearers, each of these vocables is used in the English of New Yorkers without colliding with their linguistic habits. You had never heard anything about the gentleman introduced to you at a New York party. "Mr. Ditter", says your host. You try to grasp and retain this message. As an English-speaking person you, unaware of the operation, easily divide the continuous sound-flow into a definite number of successive units. Your host didn't say *bitter* /bítə/ or *dotter* /dátə/ or *digger* /dígə/ or *ditty* /díti/ but *ditter* /dítə/. Thus the four sequential units capable of selective alternation with other units in English are readily educed by the listener: /d/ + /i/ + /t/ + /ə/.

Each of these units presents the receiver with a definite number of paired alternatives used with a differentiating value in English. The family names, cited above, differ through their initial unit; some of these names are distinguished from each other by one, single alternative, and this minimal distinction is common to several pairs, e.g. /nítə/ : /dítə/ = /mítə/ : /bítə/ = nasalized *vs.* non-nasalized. /títə/ : /dítə/ = /sítə/ : /zítə/ = /pítə/ : /bítə/ = /kítə/ : *gítə* = tense *vs.* lax. Such pairs as /pítə/ and /dítə/ offer an example of two concurrentminimal distinctions: grave *vs.* acute together with tense *vs.* lax. The pair *bitter* /bítə/ and *detter* /détə/ presents two successive minimal distinctions: grave *vs.* acute followed by diffuse *vs.* compact. (For an acoustic and motor definition of the cited distinctions, see § III. 6).

2. STRUCTURE OF DISTINCTIVE FEATURES

Linguistic analysis gradually breaks down complex speech units into morphemes as the ultimate constituents endowed with proper meaning and dissolves these smallest semantic vehicles into their ultimate components, capable of differentiating morphemes from each other. These components are termed distinctive features. Correspondingly, two levels of language and linguistic analysis are to be kept apart: on the one hand, the semantic level involving both simple and complex meaningful units from the morpheme to the utterance and discourse and, on the other hand, the feature level concerned with simple and complex units which serve merely to differentiate, cement and partition or bring into relief the manifold meaningful units.

Each of the distinctive features involves a choice between two terms of an opposition that displays a specific differential property, diverging from the properties of all other oppositions. Thus grave and acute are opposed to each other in the listener's perception by sound-pitch, as relatively low-pitched and high-pitched; in the physical aspect they are correspondingly opposed by the distribution of energy at the ends of the spectrum and on the motor level by the size and shape of the resonating cavity. In a message conveyed to the listener, every feature confronts him with a yes-no decision. Thus he has to make his selection between grave and acute, because in the language used for the message both alternatives occur in combination with the same concurrent features and in the same sequences: */bítə/–/dítə/*, */fítə/–/sítə/*, */bíl/–/búl/*. The listener is obliged to choose either between two polar qualities of the same category, as in the case of grave *vs.* acute, or between the presence and absence of a certain quality such as voiced *vs.* voiceless, nasalized *vs.* non-nasalized, sharp *vs.* plain.

3. Opposition and contrast

Since in the listener's hesitation "Is it */bítə/* or */dítə/?*" only one of the two logically correlated alternatives belongs to the actual message, the Saussurian term "opposition" is suitable here, whereas the term „contrast" is rather to be confined to cases where the polarity of two units is brought into relief by their contiguity in sensory experience as, for instance, the contrast of grave and acute in the sequence */pi/* or the same contrast, but with a reversed order of features in the sequence */tu/*. Thus opposition and contrast are two different manifestations of the polarity principle and both of them perform an important role in the feature aspect of language (Cf. § III. 4).

4. Message and code

If the listener receives a message in a language he knows, he correlates it with the code at hand and this code includes all the distinctive features to be manipulated, all their admissible combinations into bundles of concurrent features termed "phonemes", and all the rules of concatenating phonemes into sequences – briefly, all the distinctive vehicles serving primarily to differentiate morphemes and whole words. Therefore, the unilingual speaker of English, when hearing a name like */zítə/* identifies and assimilates it without difficulty even if he has never heard it before, but either in perception or reproduction he is prone to distort, and to distrust as alien, a name such as */ktítə/* with its unacceptable consonantal cluster, or */xítə/* that contains only familiar features but in an unfamiliar bundle, or, finally, */mütə/*, since its second phoneme has a distinctive feature foreign to English.

5. Ellipsis and explicitness

The case of the man faced with family names of people entirely unknown to him was deliberately chosen because neither his vocabulary, nor his previous experience, nor the immediate context of the conversation give him any clues for the recognition of these names. In such a situation the listener cannot afford to lose a single phoneme from the message received. Usually, however, the context and the situation permit us to disregard a high percentage of the features, phonemes and sequences in the incoming message without jeopardizing its comprehension. The probability of occurrence in the spoken chain varies for different features and likewise for each feature in different contexts. For this reason it is possible from a part of the sequence to predict with greater or lesser accuracy the succeeding features, to reconstruct the preceding ones, and finally to infer from some features in a bundle the other concurrent features.

Since in various circumstances the distinctive load of the phonemes is actually reduced for the listener, the speaker, in his turn, is relieved of executing all the sound distinctions in his message: the number of effaced features, omitted phonemes and simplified sequences may be considerable in a blurred and rapid style of speaking. The sound shape of speech may be no less elliptic than its syntactic composition. Even such specimens as the slovenly */tem mins sem/* for 'ten minutes to seven', quoted by Jones, are not the highest degree of omission and fragmentariness encountered in familiar talk. But, once the necessity arises, speech that is elliptic on the semantic or feature level, is readily translated by the utterer into an explicit form which, if needed, is apprehended by the listener in all its explicitness. The slurred fashion of pronunciation is but an abbreviated derivative of the explicit clear-speech form that carries the highest amount of information. When analyzing the pattern of phonemes and distinctive features composing them, one must recur to the fullest, optimal code at the command of the given speakers.

II. THE VARIETY OF FEATURES AND THEIR TREATMENT IN LINGUISTICS

1. Phonology and phonemics

The question of how language utilizes sound matter, selecting certain of its elements and adapting them to its various ends, is the field of a special linguistic discipline. In English this discipline is frequently called "phonemics" (or, puristically, "phonematics)", since among the functions of sound in language the primary one is to serve as distinctive vehicle and since the basic vehicle for this function is the phoneme with its components.

The prevailing continental term "phonology" (launched in 1923 [8] and based upon the suggestions of the Geneva school) or the circumlocution "functional phonetics" is however preferable, although in English, the label "phonology" frequently designated other domains and especially served to translate the German *Lautgeschichte*. The advantage of the term "phonology" might be its easier application to the whole variety of linguistic functions performed by sound, while "phonemics" willy-nilly suggests a confinement to the distinctive vehicles and is an appropriate designation for the main part of phonology dealing with the distinctive function of speech sounds.

While phonetics seeks to collect the most exhaustive information on gross sound matter, in its physiological and physical properties, phonemics, and phonology in general, intervene to apply strictly linguistic criteria to the sorting and classification of the material gathered by phonetics.

2. The "inner" approach to the phoneme in relation to sound

For the connection and delimitation of phonology (especially phonemics) and phonetics, the crucial question is the nature of the

relationship between phonological entities and sound. In Bloomfield's conception, the phonemes of a language are not sounds but merely sound features lumped together "which the speakers have been trained to produce and recognize in the current of speech sounds – just as motorists are trained to stop before a red signal, be it an electric signal-light, a lamp, a flag, or what not, although there is no disembodied redness apart from these actual signals". The speaker has learned to make sound-producing movements in such a way that the distinctive features are present in the sound waves, and the listener has learned to extract them from these waves. This so-to-speak "inner", immanent approach, which locates the distinctive features and their bundles within the speech sounds, be it on their motor, acoustical or auditory level, is the most appropriate premise for phonemic operations, although it has been repeatedly contested by "outer" approaches which in different ways divorce phonemes from concrete sounds.

3. Types of features

Since the differentiation of semantic units is the least dispensable among the sound functions in language, speech participants learn primarily to respond to the distinctive features. It would be deceptive, however, to believe that they are trained to ignore all the rest in speech sounds. Beside the distinctive features, there are, at the command of the speaker, also other types of coded information-bearing features that any member of a speech community has been trained to manipulate and which the science of language has no right to disregard.

Configurative features signal the division of the utterance into grammatical units of different degrees of complexity, particularly into sentences and words, either by singling out these units and indicating their hierarchy (culminative features) or by delimiting and integrating them (demarcative features).

Expressive features put the relative emphasis on different parts of the utterance or on different utterances and suggest the emotional attitudes of the utterer.

While the distinctive and configurative features refer to semantic units, these two types of features, in turn, are referred to by the redundant features. Redundant features help to identify a concurrent or adjoining feature, either distinctive or configurative, and either one or a combination of them. The auxiliary role of redundancies must not be underestimated. Circumstances may even cause them to substitute for distinctive features. JONES cites the example of the English /s/ and /z/ which in final position differ from each other solely in the degree of breath force. Although "an English hearer will usually identify the consonants correctly, in spite of their resemblance to one another", the right identification is often facilitated by the concomitant difference in the length of the preceding phoneme: *pence* [*pɛn̆s*] — *pens* [*pɛn:z*].

Possession of a single specific denotation unites the redundant features with the configurative and expressive features and separates them from the distinctive features. Whatever the distinctive feature its denotation is always identical: any such feature denotes that the morpheme to which it pertains is not the same as a morpheme having another feature in the corresponding place. A phoneme, as SAPIR remarked, "has no singleness of reference". All phonemes denote nothing but mere otherness. This lack of individual denotation sets apart the distinctive features and their combinations into phonemes from all other linguistic units.

The code of features used by the listener does not exhaust the information he receives from the sounds of the incoming message. From its sound shape he extracts clues to identify the sender. By correlating the speaker's code with his own code of features, the listener may infer the origin, educational status and social environment of the speaker. Natural sound properties allow the identification of the sex, age, and psychophysiological type of the emitter and, finally, the recognition of an acquaintance.

4. THE "OUTER" APPROACHES TO THE PHONEME IN RELATION TO SOUND

a. *The Mentalist View*

An insight into the complexity of the informational content of speech sounds is a necessary prerequisite for the discussion of the various outer approaches to the phoneme in its relation to sound. In the oldest of these approaches the phoneme is a sound imagined or intended, opposed to the emitted sound as a "psychophonetic" phenomenon to the "physiophonetic" fact. It is the mental equivalent of an exteriorized sound. The unity of the phoneme, as compared with the variety of its implementations, is seen as a discrepancy between the internal impetus aiming at the same pronunciation and the involuntary vacillation in the fulfillment.

This conception is based on two fallacies: we have no right to presume that the sound correlate in our internal speech or in our speech intention is confined to the distinctive features to the exclusion of the configurative or redundant features. On the other hand, the multiplicity of contextual and optional variants of one and the same phoneme in uttered speech is due to the combination of this phoneme with diverse redundant and expressive features; this diversity, however, does not hamper the extraction of the invariable phoneme from among all these variations. Thus the attempt to overcome the antinomy between invariance and variability by assigning the former to the internal and the latter to the external experience distorts the two forms of experience.

b. *The Code-Restricting View*

Another attempt to locate the phoneme outside the uttered sounds confines the phonemes to the code and the variants to the message. A rejoinder to this view would be that the code includes not only the distinctive features, but also the redundant and configurative features which induce contextual variants, as well as the expressive features which underlie optional variations; the users of a language have learned to effect and apprehend them in the message. Thus phoneme and variants alike are present, both in the code and in the message.

A cognate tenet has opposed the phoneme to the variants as social value to individual behavior. This is hardly justifiable since not only the distinctive features but all the coded features are equally socialized.

c. *The Generic View*

Phoneme has frequently been opposed to sound as class to specimen. It has been characterized as a family or class of sounds related through a phonetic resemblance. Such definitions, however, are vulnerable in several respects.

First, the vague and subjective search for resemblance must be replaced by the extraction of a common property.

Second, both the definition and the analysis of the phoneme must take into account the logical lesson that classes can be defined by properties, but it is hardly possible to define properties by classes. In fact, when operating with a phoneme or distinctive feature we are primarily concerned with a constant which is present in the various particulars. If we state that in English the phoneme /*k*/ occurs before /*u*/, it is not the whole family of its various submembers, but only the bundle of distinctive features common to all of them, that appears in this position. Phonemic analysis is a study of properties, invariant under certain transformations.

Third, when dealing with a sound that in a given language figures in a definite position, under definite stylistic conditions, we are again faced with a class of occurrences and their common denominator, but not with a single, fleeting specimen. Whether studying phonemes or contextual variants ("allophones"), it is always, as the logician would say, the "sign-design" and not the "sign-event" that we define.

d. The Fictionalist View

According to the opinion most effectively launched by TWADDELL in 1935, but latently tinging writings of various authors, phonemes are abstractional, fictitious units. As long as this means nothing more than that any scientific concept is a fictional construct, such a philosophical attitude cannot affect phonemic analysis. Phoneme, in this case, is a fiction, in the same way as morpheme, word, sentence, language, etc. If, however, the analyzer opposes the phoneme and its components to sound as a mere contrivance having no necessary correlate in concrete experience, the results of the analysis will be distorted through this assumption. The belief that the choice among phonemes to which we assign the sound might, upon occasion, be made arbitrarily, even at random, threatens the objective value of phonemic analysis. This danger may, however, be avoided by the methodological demand that any distinctive feature and, consequently, any phoneme treated by the linguist, have its constant correlate at each stage of the speech event and thus be identifiable at any level accessible to observation. Our present knowledge of the physical and physiological aspects of speech sounds is sufficient to meet this demand. The sameness of a distinctive feature throughout all its variable implementations is now objectively discriminable. Three reservations, however, must be made.

First, certain features and combinations of features may be obliterated in the various kinds of phonemic ellipsis (cf. § I. 5). Second, features may be masked by abnormal, distorting conditions of sound production (whispering, shouting, singing, stammering), transmission (distance, filtering, noise) or perception (auditory fatigue). Third,

a distinctive feature is a relational property: the "minimum same" of a feature in its combination with various other concurrent or successive features lies in the essentially identical relation between the two opposite alternatives. No matter how the stops in *tot* may differ from each other genetically and acoustically, they are both high-pitched in opposition to the two labials in *pop*, and both display a diffusion of energy, as compared to a greater concentration of energy in the two stops of *cock*.

"Overlapping" of phonemes. The so-called overlapping of phonemes confirms the manifestly relational character of the distinctive features. A pair of palatal vowel phonemes, genetically opposed to each other through relative wideness and narrowness and, acoustically, through a higher and lower concentration of energy (compact/diffuse), may in some languages be implemented in one position as [*æ*] — [*e*] and in another position as [*e*] — [*i*], so that the same sound [*e*] in one position implements the diffuse, and in another, the compact term of the same opposition. The relation in both positions remains identical. Two degrees of aperture and, correspondingly, of concentration of energy – the maximal and the minimal – oppose each other in both positions.

e. The Algebraic View

The approach one might call "algebraic" aims at the maximal estrangement between phoneme and sound or, correspondingly, between phonemics and phonetics. The champion of this trend, HJELMSLEV, calls on linguistics to become "an algebra of language, operating with unnamed entities. i.e. arbitrarily named entities without natural designation" [6]. Particularly, the "expression plane" of language, as he christened the aspect named *signans* in Stoic and Scholastic tradition, and in the work of its reviver Ferdinand de Saussure, is to be studied without any recourse to phonetic premises.

Each venture, however, to reduce language to its ultimate invariants, by means of a mere analysis of their distribution in the text and with no reference to their empiric correlates, is condemned to failure. The comparison of two English sequences – /*ku*/ and /*uk*/ – will yield no information on the identity of the first segment in one of these samples with the second segment in the other sample, unless we bring into play sound properties common to initial and final /*k*/ and those common to /*u*/ in both positions. The confrontation of the syllables /*ku*/ and /*ki*/ does not authorize us to assign both initial segments to one phoneme /*k*/ as two variants appearing to their mutual exclusion before two different vowels, unless we have identified the common features, uniting the retracted and advanced variety of the phoneme *k* and differentiating it from all other phonemes of the same language. Only through such a test are we able to decide whether the retracted [*k*−] in /*ku*/ implements the same phoneme as the advanced [*k*+] in /*ki*/ and not the advanced [*g*+] in /*gi*/. Therefore, despite the theoretical requirement of an analysis totally independent of the sound substance, in practice "on tient compte de la substance à toute étape de l'analyse", as ELI FISCHER-JØRGENSEN exposed the troubling discrepancy [3].

As to the theoretical requirement itself, it arose from the assumption that, in language, form is opposed to substance as a constant to a variable. If the sound substance were a mere variable, then the search for linguistic invariants would indeed need to expunge it. But the possibility of translating the same linguistic form from a sound substance into a graphic substance, e.g. into a phonetic notation or into an approximately phonemic spelling system does not prove that the sound substance, like other "widely different expression substances" is a mere variable. In contradistinction to the universal phenomenon of speech, phonetic or phonemic writing is an occasional, accessory code that normally implies the ability of its users to translate it into its underlying sound code, while the reverse ability, to transpose speech into letters, is a secondary and much less common faculty. Only after having mastered speech does one graduate to reading and writing. There is a cardinal difference between phonemes and graphic units. Each letter carries a specific denotation – in a phonemic orthography, it usually denotes one of the phonemes or a certain limited series of phonemes, whereas phonemes denote nothing but mere otherness (cf. § II, 3). Graphic signs that serve to interpret phonemes or other linguistic units stand for these units, as the logician would say. This difference has far-reaching consequences for the cardinally dissimilar patterning of letters and phonemes. Letters never, or only partially, reproduce the different distinctive features on which the phonemic pattern is based and unfailingly disregard the structural relationship of these features.

There is no such thing in human society as the supplantation of the speech code by its visual replicas, but only a supplementation of this code by parasitic auxiliaries, while the speech code constantly and unalterably remains in effect. One could state neither that musical

form is manifested in two variables – notes and sounds – nor that linguistic form is manifested in two equipollent substances – graphic and phonic. And just as musical form cannot be abstracted from the sound matter it organizes, so form in phonemics is to be studied in relation to the sound matter which the linguistic code selects, readjusts, dissects and classifies along its own lines. Like musical scales, phonemic patterning is an intervention of culture in nature, an artifact imposing logical rules upon the sound continuum.

5. THE CRYPTANALYST'S AND DECODER'S DEVICES AS TWO COMPLEMENTARY TECHNIQUES

The addressee of a coded message is assumed to be in possession of the code and through it he interprets the message. Unlike this decoder, the cryptanalyst comes into possession of a message with no prior knowledge of the underlying code and must break this code through dexterous manipulations of the message. A native speaker responds to any text in his language as a regular decoder, whereas a stranger, unfamiliar with the language, faces the same text as a cryptanalyst. A linguist, approaching a totally unknown language, starts as a cryptanalyst until through a gradual breaking of its code he finally succeeds in approaching any message in this language like a native decoder.

The native or naturalized user of a language, when trained linguistically, is aware of the functions performed by its different sound elements and may utilize this knowledge to resolve the sound shape into its manifold information-bearing elements. He will employ various "grammatical prerequisites to phonemic analysis" as aids to the extraction of distinctive, configurative and expressive features [10].

On the other hand, the question raised by BLOCH as to the applicability of the cryptanalyst's technique to the inquiry into phonemic structure has great methodological importance: to what extent might a sufficient sample of accurately recorded speech enable a linguist to work out "the phonemic system without knowing what any part of the sample meant, or even whether any two parts meant the same thing or different things". Under such conditions, the extraction of redundant features is, in many instances, laborious but feasible. More difficult is the isolation of the expressive features but, in this regard also, the record may yield some information, given the difference between the markedly discrete, oppositional character of distinctive features and the more continuous "grading gamut" characterizing most of the expressive features. A still less manageable problem would be the cryptanalytical discrimination between distinctive and configurative features, especially word boundary signals.

III. THE IDENTIFICATION OF DISTINCTIVE FEATURES

1. Syllable

The distinctive features are aligned into simultaneous bundles called phonemes; phonemes are concatenated into sequences; the elementary pattern underlying any grouping of phonemes is the syllable. The phonemic structure of the syllable is determined by a set of rules and any sequence is based on the regular recurrence of this constructive model. A free form (a sequence, separable by means of pauses) must contain an integral number of syllables. Obviously, the number of different syllables in a language is a small submultiple of the number of free forms, just as the number of phonemes is a small submultiple of the number of syllables, and the number of distinctive features, a submultiple of the number of phonemes.

The pivotal principle of syllable structure is the contrast of successive features within the syllable. One part of the syllable stands out from the others. It is mainly the contrast vowel *vs.* consonant which is used to render one part of the syllable more prominent. There are languages where every syllable consists of a consonant and a succeeding vowel (CV): in such a case it is possible from any point of the sequence to predict the class of phonemes that is to follow. In a language with a greater variety of syllable types, the recurrence of a phonemic class presents different degrees of probability. In addition to CV, other schemes may be used: CVC, V, VC. In contradistinction to C, the part V can neither be omitted, nor figure twice in the syllable.

The contrast vowel/consonant is either unique or merely predominant: it can be sporadically substituted by other cognate contrasts. Both part C and part V may contain more than one phoneme. The phonemes constituting the parts V and C of the syllable are termed "crest" phonemes and "slope" phonemes respectively. If the crest contains two or more phonemes, one of them, termed the "peak" phoneme (or "syllabic") is raised over the others by the contrast compact *vs.* diffuse or vowel *vs.* sonorant.

The motor correlate of the phonemic syllable has been most adequately described by Stetson as "a puff of air forced upward through the vocal channel by a compression of the inter-costal muscles". According to this description, every syllable invariably consists of three successive factors: release, culmination and arrest of the pulse. The middle one of these three phases is the nuclear factor of the syllable while the other two are marginal. Both marginal factors – initiation and termination – are effected either by the mere action of the chest muscles or by speech sounds, usually consonants. If both marginal factors are effected by the action of the chest muscles alone, the nuclear phase of the syllable is the only audible one; if, however, the release and/or the arrest is effected by speech sounds, the nuclear phase of the syllable is the most audible. In other words, the nuclear part of the syllable is in contrast to its marginal parts as the crest to the slopes.

In the acoustic aspect, the crest usually exceeds the slopes in intensity and in many instances shows an increased fundamental frequency. Perceptually, the crest is distinguished from the slopes by a greater loudness, which is often accompanied by a heightened voice-pitch. As a rule, the crest phonemes are inherently louder than the slope phonemes of the same syllable: ordinarily the crest is formed by vowels, while the slopes contain the other phonemes; less frequently the contrast of crest and slope phonemes is displayed by liquids *vs.* pure consonants, or by nasals *vs.* oral consonants, and in exceptional cases by constrictives *vs.* stops (cf. § IV, 1*f*). If a slope is constituted by a whole cluster and if within such a cluster there is an inherently louder phoneme in less loud surroundings, its loudness is noticeably reduced, to preserve the unity of the syllable: e.g. Czech */jdu/*, */jsem/*, */rti/*, */lpi,/* or Polish monosyllable */krvi/* *vs.* Serbocroatian disyllabic */krvi/*.

2. Two kinds of distinctive features

The distinctive features are divided into two classes: (1) prosodic and (2) inherent. A prosodic feature is displayed only by those phonemes which form the crest of the syllable and it may be defined only with reference to the relief of the syllable or of the syllable chain, whereas the inherent feature is displayed by phonemes irrespective of their role in the relief of the syllable and the definition of such a feature does not refer to the relief of the syllable or of the syllable chain.

3. Classification of prosodic features

The three types of prosodic features, which, following Sweet, we term *tone*, *force* and *quantity*, correspond to the three main attributes of sensation – voice-pitch, voice-loudness and subjective duration (protensity). The dimensions of frequency, intensity and time are their closest physical correlates. Each of these three sub-classes of prosodic features presents two varieties: according to its frame of reference a prosodic feature may be either "intersyllabic" or "intrasyllabic". In the first case the crest of one syllable is compared with the crests of other syllables within the same sequence. In the second case, an instant pertaining to the crest may be compared with other instants of the same crest or with the subsequent slope.

a. Tone Features

In the intersyllabic variety of tone features, the "level" feature, different syllable crests within a sequence are contrasted by their register: higher and lower. The level feature may be split in two: either a neutral register is contrasted with an elevated register, on the one hand, and with a lowered one, on the other; or, finally, each of the two opposite registers, high and low, may appear in two varieties, raised and diminished. When the Jabo people transpose these four levels from speech into drum signals, they use for the two underlying oppositions two different pairs of terms: the opposites high and low are called "little bird" and "big bird", while the opposites raised and diminished are termed "smaller" and "larger", so that the four signals are distinguished – "smaller little bird", "larger little bird", "smaller big bird", and "larger big bird" [4].

The intrasyllabic variety of tone features, the "modulation" feature, contrasts the higher register of one portion of a phoneme with a lower register of another portion of the same phoneme, or the higher register of one component of a diphthong with the lower register of its other components, and this distribution of registers within the crest of the syllable is opposed to the reverse distribution, e.g. a rising modulation to a falling one, or both of them to an even intonation.

b. Force Features

The intersyllabic variety of the force features, the "stress" feature, is a contrast of a louder, stressed crest to the less loud, unstressed crests of other syllables within the same sequence, a difference produced by the sublaryngeal mechanism, in particular by the abdomen-diaphragmal movements.

In the intrasyllabic variety of the stress features, the so-called "stosston" (*stød*) feature, two contiguous fractions of the stressed phoneme are compared with each other. To an even distribution of loudness throughout the phoneme, another type is opposed: the initial portion of the phoneme presents the peak of loudness whereas in the final portion the loudness decreases. The decline of amplitude, often accompanied by a decrease of the fundamental frequency, is due to an abruptly decreasing innervation of the expiratory muscles.

c. Quantity Features

The intersyllabic variety of the quantity features, the "length" feature, contrasts a normal, short, unstretchable phoneme within the crest of the syllable with the long, sustained phonemes of the other syllables in the same sequence and/or a normal, short but steady phoneme with a punctual, reduced, transient one.

The second variety of the quantity features, the "contact" feature, is based on a different distribution of duration between the vowel and the subsequent consonant: in the case of the so-called close contact (*scharf geschnittener Akzent*), the vowel is abridged in favor of the following, arresting consonant, whereas at the open contact (*schwach geschnittener Akzent*), the vowel displays its full extent before the consonant starts.

d. The Interconnection between Stress and Length

Wherever there is a contrast of stressed and unstressed syllables, stress is always used as a configurative, namely culminative feature, whereas length never assumes this function. The culminative function of the stress is regularly combined either with the other variety of configurative functions, the demarcation (cf. § II, 3), or with the distinctive function. Languages where both length and stress appear as distinctive features are quite exceptional, and if the stress is distinctive, it is mostly supplemented by a redundant length.

The observation of force and quantity features in their intersyllabic variety seem to indicate that the prosodic distinctive features utilizing intensity and those utilizing time tend to merge.

4. Comparison of prosodic and inherent features

Any prosodic feature is based primarily on the contrast between two variables within one and the same time sequence: the relative voice-pitch, voice-loudness or duration of a given fraction is determined with respect to preceding and/or succeeding fractions. As Herzog has pointed out concerning the tone features, "the actualizations of the contrasts – given by successive distances between tone levels or by successive tone movements – do shift all the time [5]." Tone level, or tone modulation, stress degrees or its decrescendo (*Stosston*), are always purely relative and highly variable in their absolute magnitudes from speaker to speaker, and even from one utterance to another in the usage of the same speaker. Also the quantity of a vowel may be established only in relation to the quantity of the other vowels within the context or to the subsequent consonants (contact feature), while the absolute duration of the long or short vowels in the given language presents a considerable vacillation in speed, depending upon the speech-habits of the speaker and his expressive variations of tempo. A long vowel must be ceteris paribus longer than the surrounding short vowels. Similarly, nothing more is required of a stressed vowel than to be uttered with a louder voice than the unstressed vowels of the same chain; and the high register vowels must be of a higher voice-tone than the neighboring low register vowels. But the high register vowels of one, e.g. bass speaker, may be even deeper than the low register vowels of another, e.g. soprano speaker, and in the speech of one and the same person there may be passages with relative expressive lowering of both high and low register phonemes.

A prosodic feature involves two coordinates: on the one hand, polar terms such as high and low register, rising and falling pitch, or long and short, all may appear, ceteris paribus, in the same position in the sequence, so that the speaker selectively uses and the listener selectively apprehends one of the two alternatives and identifies the chosen alternative in relation to the rejected one. These two alternatives, the one present and the other absent in the given unit of the message, constitute a veritable logical opposition (cf. § I, 3). On the other hand, both polar terms are fully recognizable only when both of them are present in the given sequence, so that the speaker effects and the listener perceives their contrast. Thus, both alternatives of a prosodic feature co-exist in the code as two terms of an opposition and, moreover, co-occur and produce a contrast within the message.

If the message is too brief to include both contrasting units, the feature may be inferred from the substitutive clues offered by the sequence, *e.g.*, the quantity of a vowel in a monosyllabic message may be inferred from the relative duration of the surrounding consonants, and the register of a monophonemic message, from the modulation span in the onset and/or decay of the vowel.

The recognition and definition of an inherent feature is based only on the choice between two alternatives admissible in the same position within a sequence. No comparison of the two polar terms co-occurring within one context is involved. Hence, both alternatives of an inherent feature co-exist in the code as two terms of an opposition, but do not require a contrasting juxtaposition within one message.

5. General laws of phonemic patterning

The comparative description of the phonemic systems of manifold languages and their confrontation with the order of phonemic acquisitions by infants learning to speak, as well as with the gradual dismantling of language and of its phonemic pattern in aphasia, gives us important insights into the interrelation and classification of the distinctive features. The linguistic, especially phonemic progress of the child, and the regression of the aphasic, obey the same laws of implication. If the child's acquisition of distinction B implies his acquisition of distinction A, the loss of A in aphasia implies the absence of B, and the rehabilitation of the aphasic follows the same order as the child's phonemic development. The same laws of implication underlie the languages of the world both in their static and dynamic aspects. The presence of B implies the presence of A and, correspondingly, B cannot emerge in the phonemic pattern of a language unless A is there; likewise, A cannot disappear from a language as long as B exists. The more limited the number of languages possessing a certain phonemic feature or combination of features, the later is it acquired by the native children and the earlier is it lost by the native aphasics.

a. Restrictions in the Over-all Inventory of Distinctive Features

The progressing phonemic investigation of infants and aphasics along with the ever increasing number of discovered laws, moves into the foreground the problem of the universal rules underlying the phonemic patterning of languages. In view of these laws of implication and stratification, the phonemic typology of languages is becoming an ever more feasible and urgent task. Every step in this direction permits us to reduce the list of distinctive features used in the languages of the world. The supposed multiplicity of features proves to be largely illusory. If two or more allegedly different features never co-occur in a language and if they, furthermore, yield a common property that distinguishes them from all other features, then they are to be interpreted as different implementations of one and the same feature, each occurring to the exclusion of the others and consequently presenting a particular case of complementary distribution. The study of invariances within the phonemic pattern of one language must be supplemented by a search for universal invariances in the phonemic patterning of language.

Thus, no language simultaneously displays two autonomous consonantal oppositions – pharyngealized/non-pharyngealized and rounded/unrounded. The back orifice of the mouth resonator (pharynx) is involved in the first instance and the front orifice (lips) in the second, but in both cases a narrowed orifice of the mouth resonator, producing a downward shift in the resonances, is opposed to the absence of narrowing. Hence these two processes (narrowed back slit und narrowed front slit) are to be treated as two variants of one and the same opposition, which on the motor level may be defined as narrowed *vs.* wider slit (cf. § III, 6*b*). The relation of retroflex to the dental consonants proves to be a mere variety of the opposition of pharyngealized and non-pharyngealized dentals. Four consonantal features listed by TRUBETZKOY – the tension feature, the intensity or pressure feature, the aspiration feature and the pre-aspiration feature – also turn out to be complementary variants of one and the same opposition that by virtue of its common denominator may be termed tense/lax.

Double stops (in particular clicks) with two closures in rapid succession, followed by two distinct releases in the same order, appear to the exclusion of other types of clusters in the same positions and present simply a different implementation of ordinary consonantal sequences.

6. THE TWO CLASSES OF INHERENT FEATURES

The inherent distinctive features which have so far been discovered in the languages of the world and which, along with the prosodic features, underlie their entire lexical and morphological stock, amount to twelve oppositions, out of which each language makes its own selection. All the inherent features are divided into two classes that might be termed "sonority" features and "tonality" features, the former akin to the prosodic force and quantity features and the latter to the prosodic pitch features. The sonority features utilize the amount and concentration of energy in the spectrum and in time. The tonality features involve the ends of the frequency spectrum.

a. Sonority Features

i. V o c a l i c / n o n-v o c a l i c:

acoustically – presence *vs.* absence of a sharply defined formant structure;

genetically – primary or only excitation at the glottis together with a free passage through the vocal tract.

ii. C o n s o n a n t a l / n o n-c o n s o n a n t a l:

acoustically – low (*vs.* high) total energy;

genetically – presence *vs.* absence of an obstruction in the vocal tract.

Vowels are vocalic and non-consonantal; consonants are consonantal and non-vocalic; liquids are vocalic and consonantal (with both free passage and obstruction in the oral cavity and the corresponding acoustic effect); glides are non-vocalic and non-consonantal.

iii. C o m p a c t / d i f f u s e:

acoustically – higher (*vs.* lower) concentration of energy in a relatively narrow, central region of the spectrum, accompanied by an increase (*vs.* decrease) of the total amount of energy and its spread in time;

genetically – forward-flanged *vs.* backward-flanged. The difference lies in the relation between the shape and volume of the resonance chamber in front of the narrowest stricture and behind this stricture. The resonator of the forward-flanged phonemes (wide vowels, and velar and palatal, including post-alveolar, consonants) has a shape of a horn, whereas the backward-flanged phonemes (narrow vowels, and labial and dental, including alveolar, consonants) have a cavity that approximates a Helmholtz resonator.

iv. T e n s e / l a x:

acoustically – more (*vs.* less) sharply defined resonance regions in the spectrum, accompanied by an increase (*vs.* decrease) of the total amount of energy and its spread in time;

genetically – greater (*vs.* smaller) deformation of the vocal tract away from its rest position. The role of muscular strain, affecting the tongue, the walls of the vocal tract and the glottis, requires further investigation.

v. Voiced/voiceless:
acoustically – presence *vs.* absence of periodic low frequency excitation;
genetically – periodic vibrations of the vocal cords *vs.* lack of such vibrations.

vi. Nasal/oral (nasalized/non-nasalized):
acoustically – spreading the available energy over wider (*vs.* narrower) frequency regions by a reduction in the intensity of certain (primarily the first) formants and introduction of additional (nasal) formants;
genetically – mouth resonator supplemented by the nose cavity *vs.* the exclusion of the nasal resonator.

vii. Discontinuous/continuant:
acoustically – silence (at least in the frequency range above the vocal cord vibration) followed and/or preceded by a spread of energy over a wide frequency region (either as burst or as a rapid transition of vowel formants) *vs.* absence of abrupt transition between sound and "silence";
genetically — rapid turning on or off of source either through a rapid closure and/or opening of the vocal tract that distinguishes plosives from constrictives or through one or more taps that differentiate the discontinuous liquids like a flap or trill /*r*/ from continuant liquids like the lateral /*l*/.

viii. Strident/mellow:
acoustically – higher intensity noise *vs.* lower intensity noise;
genetically – rough-edged *vs.* smooth-edged: supplementary obstruction creating edge effects (*Schneidenton*) at the point of articulation distinguishes the production of the rough-edged phonemes from the less complex impediment in their smooth-edged counterparts.

ix. Checked/unchecked:
acoustically – higher rate of discharge of energy within a reduced interval of time *vs.* lower rate of discharge within a longer interval (lower *vs.* higher damping);
genetically – glottalized (with compression or closure of the glottis) *vs.* non-glottalized.

b. Tonality Features

x. Grave/acute:
acoustically – concentration of energy in the lower (*vs.* upper) frequencies of the spectrum;
genetically – peripheral *vs.* medial: peripheral phonemes (velar and labial) have an ampler and less compartmented resonator than the corresponding medial phonemes (palatal and dental).

xi. Flat/plain:
acoustically – flat phonemes are opposed to the corresponding plain ones by a downward shift or weakening of some of their upper frequency components;
genetically – the former (narrowed slit) phonemes, in contradistinction to the latter (wider slit) phonemes, are produced with a decreased back or front orifice of the mouth resonator, and a concomitant velarization expanding the mouth resonator.

xii. Sharp/plain:
acoustically – sharp phonemes are opposed to the corresponding plain ones by an upward shift or strengthening of some of their upper frequency components;
genetically – the former (widened slit) phonemes, in contradistinction to the latter (narrower slit) phonemes, are produced with a dilated back orifice (pharyngeal pass) of the mouth resonator and a concomitant palatalization restricting and compartmenting the mouth cavity.

7. Stages of the Speech Event

Each of the distinctive features has been defined above both on its acoustical and articulatory level. The communication network, however, comprises a higher number of stages. The initial stage in any speech event – the intention of the sender – is not yet open to a precise analysis. The same may be said of the nerve impulses sent from the brain to the effector organs. The work of these organs – the motor stage of the speech event – is at present quite accessible to observation, especially with the progress of X-rays and other tools that reveal the activities of such highly important parts of the speech apparatus as the pharyngeal, laryngeal and sublaryngeal mechanisms. The status of the message between the bodily pathways of the speaker and listener, the transmitted vibrations in the air, are being ever more adequately mastered, owing especially to the rapid advance of modern acoustics.

The translation of the physical stimulus, first into aural and then into neural processes is about to be charted. The search for the models of distinctive features used by the auditory system is a timely task. As to the transformation of speech components by the nervous system, we can, for the time being, at best only hazard what psychophysiologists have intimated as "a mere speculative assertion" [12]: sonority features seem to be related to the amount, density and spread of nervous excitation, while the tonality features relate to the location of this excitation. The present development of research on the neural responses to sound stimuli promises, however, to supply a differential picture of distinctive features on this level as well.

The psychological study of sound perception has endeavored to isolate the diverse subjective attributes of sound and to determine the discriminatory capacity of the listeners for each of the dimensions of the stimulus. The expansion of this investigation to speech sounds is likely to illuminate the perceptual correlates of the diverse distinctive features in view of their phenomenal autonomy. The initial experiments on English consonants transmitted with frequency distortion and with random masking noise have actually confirmed that the perception of each of these features is relatively independent of the perception of the others, as if "separate, simple channels were involved rather than a single complex channel [9]."

To a psychologist, each attribute is defined through a differential reaction to a stimulus by a listener under a particular set (*Aufgabe*). In application to speech sounds this set is determined by the decoding attitude of the listener to the message received and to each of its constituents. The listener correlates the incoming message with the code common to himself and the speaker. Thus the role of sound components and combinations in the linguistic pattern is implicit in the perception of speech sounds. To find out what motor, acoustic and perceptual elements of sounds are utilized in a given language, we must be guided by its coding rules; an efficacious physiological, physical and psychological analysis of speech sounds presupposes their linguistic interpretation.

a. *The Use of Different Stages in the Study of Distinctive Features*

In order to decode the message, its receiver extracts the distinctive features from the perceptual data. The closer we are in our investigation to the destination of the message, the more accurately can we gauge the information conveyed by the sound-chain. This determines the operational hierarchy of levels in their decreasing pertinence: perceptual, aural, acoustical and motor (the latter carrying no direct information to the receiver except for the sporadic help of lip-reading). The auditory experience is the only aspect of the encoded message actually shared by the sender and the receiver since the speaker normally hears himself.

In the process of communication there is no single-valued inference from a succeeding to a preceding stage. With each successive stage the selectivity increases; some data of an antecedent stage are irrelevant for any subsequent stage and each item of the latter stage may be a function of several variables from the former stage. The measurement of the vocal tract permits an exact prediction of the sound wave, but one and the same acoustical effect may be attained by altogether different means. Similarly, the same attribute of the auditory sensation may be the result of different physical stimuli.

The theoretically unlikely surmise of a closer relationship between perception and articulation than between perception and its immediate stimulus finds no corroboration in experience: the kinaesthetic feedback of the listener plays a very subordinate and incidental role. Not seldom do we acquire the ability to discern foreign phonemes by ear without having mastered their production, and a child learning language often discriminates phonemes of adults long before he uses them in his own speech.

The specification of distinctive oppositions may be made with respect to any stage of the speech event, from articulation to perception and decoding, on the sole condition that the invariants of any antecedent stage be selected and correlated in terms of the subsequent stages, given the evident fact that we speak to be heard and need to be heard in order to be understood.

The distinctive features have been portrayed only on the motor and on the acoustic level, because these are the only two aspects for which we so far possess detailed information. Either of these two patterns must give the complete picture of all the ultimate, further irreducible distinctions. But since articulation is to acoustic phenomenon as means to effect, the classification of motor data must be made with reference to the acoustic patterns. Thus, the difference among four articulatory classes of consonants – velar, palatal, dental and labial – dissolves itself on the acoustic level into two binary oppositions: on the one hand, labials and velars concentrate their energy in the lower frequencies of the spectrum in contradistinction to dentals and palatals, which concentrate their energy in the upper frequencies – the grave/acute opposition. On the other hand, velars and palatals are distinguished from labials and dentals by a greater concentration of energy – the compact/diffuse opposition. The gravity of the labials and velars is generated by a larger and less divided mouth cavity and the acuteness of dentals and palatals by a smaller and more compartmented cavity. Thus, on the motor level, the decisive difference is between the stricture in a medial region of the mouth – dental or palatal – and a stricture in a peripheral region – labial or velar. An identical articulatory difference opposes the velar to palatal vowels (back – front) as acoustically grave *vs.* acute. A larger volume of the resonating cavity in front of the point of articulation and a smaller volume of the cavity behind this point distinguishes velar from labial consonants and palatal from dental consonants and engenders the compactness of velars and palatals. The same articulatory factor determines the compactness of the wide vowels *vs.* the diffuseness of the narrow vowels. It would have been much more difficult to extract the common denominator of the distinctions between labial and dental consonants and velar and palatal consonants of vowels, as well as the common denominator of the distinctions between velars and labials, palatals and dentals, wide and narrow vowels, if the striking acoustical and perceptual oppositions grave/acute and compact/diffuse had not been taken into account.

Although it was evident to observers that among plosives, the labio-dental, alveolar (hissing), post-alveolar (hushing) and uvular affricates are opposed by their noisy friction to the bilabial, dental, palatal and velar stops, nonetheless a similar opposition between the corresponding constrictives was usually overlooked, notwithstanding that all these affricates and the homorganic constrictives are distinguished by a special kind of turbulence due to forcing the air stream over a supplementary barrier (the edge of the teeth or uvula) or by directing the stream toward the obstacle at a right angle. In the spectrogram, the random distribution of black areas in these strident consonants, as compared with the considerably more regular patterns in the mellow consonants, is the only differentiating clue for all such pairs, and this clue, common to all the pairs in question, reveals a distinct binary opposition.

b. Nomenclature of Distinctive Features

Traditional terminology resorted indiscriminately to different stages of the speech event: terms such as nasal, palatalized, rounded, glottalized, referred to the motor level; other labels (voiced, high, falling, pitch, lenis, liquid) referred partly to the acoustical, partly to the perceptual aspect; and even when a figurative term was used, it had some basis in phenomenal experience. Insofar as the feature we define has a traditional term, we use the latter regardless of the stage of the speech event to which it relates, e.g. nasal/oral, tense/lax, voiced/voiceless, stressed/unstressed. A traditional articulatory term is retained as long as it points to an important criterion of division with respect to the sound transmitted, perceived and decoded. In several cases, however, there is no current phonetic term to cover the feature we define. For such features we take over terms from acoustics or psycho-acoustics. But since each of these features is definable and has actually been defined both on the acoustic and on the motor level, any of them could with equal right bear a newly-coined articulatory designation such as forward-flanged/backward-flanged instead of compact/diffuse, rough-edged/smooth-edged instead of strident/mellow, peripheral/medial instead of grave/acute, narrowed slit/wider slit instead of flat/plain and widened slit/narrower slit instead of sharp/plain.

We are not concerned with substituting an acoustic classification for an articulatory one but solely in uncovering the most productive criteria of division valid for both aspects.

IV. PHONEMIC PATTERNING

1. Stratification

a. The Nuclear Syllable

Ordinarily child language begins, and the aphasic dissolution of language preceding its complete loss ends with what psychopathologists have termed the "labial stage". In this phase speakers are capable only of one type of utterance, which is usually transcribed as /*pa*/. From the articulatory point of view the two constituents of this utterance represent polar configurations of the vocal tract: in /*p*/ the tract is closed at its very end while in /*a*/ it is opened as widely as possible at the front and narrowed toward the back, thus assuming the horn-shape of a megaphone. This combination of two extremes is also apparent on the acoustic level: the labial stop presents a momentary burst of sound without any great concentration of energy in a particular frequency band, whereas in the vowel /*a*/ there is no strict limitation of time and the energy is concentrated in a relatively narrow region of maximum aural sensitivity. In the first constituent, there is an extreme limitation in the time domain but no ostensible limitation in the frequency domain, whereas the second constituent shows no ostensible limitation in the time domain but a maximum limitation in the frequency domain. Consequently, the diffuse stop with its maximal reduction in the energy output offers the closest approach to silence, while the open vowel represents the highest energy output of which the human vocal apparatus is capable.

This polarity between the minimum and the maximum of energy appears primarily as a contrast between two successive units – the optimal consonant and the optimal vowel. Thus the elementary phonemic frame, the syllable, is established. Since many languages lack syllables without a prevocalic consonant and/or with a postvocalic consonant, CV (Consonant + Vowel) is the only universal model of the syllable.

b. The Role of the Nasal Consonant

The choice between /*pa*/ and /*a*/ and/or /*pa*/ and /*ap*/, may become the first carrier of meaning in the very early stages of child language. Usually, however, the infant preserves for a time a constant syllable scheme and splits both constituents of this syllable, first the consonant and later the vowel, into distinctive alternatives.

Most frequently, the oral stop, utilizing a single closed tract, obtains a counterpart in the nasal consonant, which combines a closed main tract with an open subsidiary tract and thereby supplements the specific traits of a stop with a secondary vocalic characteristic. Before there appeared the consonantal opposition nasal/oral, consonant was distinguished from vowel as closed tract from open tract. Once the nasal consonant is opposed to the oral as presence to absence of the open tract, the contrast consonant/vowel is revalued as presence *vs.* absence of a closed tract.

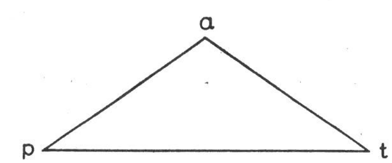
Various further oppositions, modifying and attenuating the primary optimal contrast of consonant and vowel follow. All these later formations reshape in some way the mouth resonator, while nasalization merely adds a secondary resonating cavity to the mouth resonator without changing its volume and shape.

The opposition of nasal and oral consonant, which belongs to the earliest acquisitions of the child, is ordinarily the most resistant consonantal opposition in aphasia and it occurs in all the languages of the world except for some American Indian languages.

c. The Primary Triangle

The opposition nasal *vs.* oral stop, however, may be preceded by the split of the stop into two opposites, labial and dental. After the appearance of the contrast CV, founded upon one attribute of sound, loudness, the utilization of the other basic attribute, pitch, is psychologically inferrible. Thus the first tonality opposition is instituted: grave/acute, in other words, the concentration of energy in the lower *vs.* upper frequencies of the spectrum. In /*p*/ the lower end predominates, while in /*t*/ the upper end is the stronger one. It is quite natural that the first tonality feature should affect not the vowel /*a*/, with its maximal concentration of energy in a narrow central region of the spectrum, but the consonant /*p*/, with its maximal diffusion of energy over a wide frequency band.

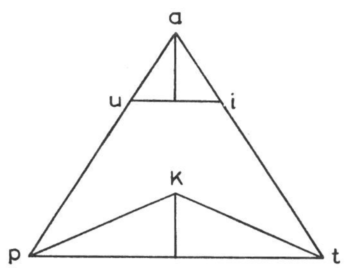
At this stage the pole of high and concentrated energy /*a*/ contrasts with the low energy stops /*p*/ and /*t*/. Both stops are opposed to each other by a predominance of one or the other end of the frequency spectrum, as the gravity and acuteness poles. These two dimensions underlie a triangular pattern of phonemes (or at least of oral phonemes if the nasality feature has already emerged):



d. The Split of the Primary Triangle into Two Triangles, Consonantal and Vocalic

The rise of the consonantal tonality feature is followed by the first vocalic split. The polarity of two successive units, CV, based on the contrast of reduced and full energy is supplemented by a polarity of two alternative vowels, founded on the opposition of lower and higher concentration of energy. The single compact /*a*/ finds its opposite in a diffuse vowel. Henceforth, both the consonantal and the vocalic section of the primary triangle construct each its own linear pattern – the grave/acute consonantal axis and the compact/diffuse vocalic axis. The consonants duplicate this originally vocalic opposition, and the consonantal base-line of the over-all triangle is complemented by a consonantal apex – the velar stop.

The tonality opposition, originally consonantal, may in turn be extended to the vocalic pattern: it is naturally the diffuse vowel that splits into grave and acute, complementing the vocalic apex of the over-all triangle by a *u* – *i* base-line. In this way the originally single primary triangle is partitioned into two autonomous two-dimensional patterns – the consonantal and the vocalic triangle.



e. Patterning of Oral Resonance Features

Both the vocalic and the consonantal pattern may subsequently pass from the triangular to the quadrangular pattern by superimposing the distinction between velar and palatal upon the wide vowels and/or upon the consonants. In this way the grave/acute feature spreads to the compact vowels and/or consonants. In the languages of the world, however, the triangular pattern prevails over the quadrangular for vowels and even more so for consonants: it is the minimum model, both for the vocalic and for the consonantal patterns, with the very rare exceptions when either the vocalic or the consonantal pattern – but never both – is linear. In the rare cases of a linear patterning, the vowels are confined to the feature compact/diffuse and the consonants, almost unfailingly, to the tonality feature. Thus no language lacks the oppositions grave/acute and compact/diffuse, whereas any other opposition may be absent.

The alternation in volume and shape of the mouth resonator is used for the grave/acute opposition. In the early stages of child language, in the advanced stages of aphasia and in numerous languages of the world, this alternation is reinforced by the variation in the size of one or both orifices of the mouth cavity. The restriction of the back and front orifices, together with an expanded and unified oral cavity,

serve to lower the resonance frequencies, whereas the combined action of the dilated orifices and of a restricted and compartmented cavity raise the resonance frequencies. But the change in the size of each of these orifices may achieve an autonomous status and set in operation secondary tonality features (flatting and/or sharping).

f. Sonority Features in Relation to the Optimal Consonant and Vowel

The reduced concentration of energy in the diffuse vowel moves it away from the optimal, compact vowel in the direction of the consonants and, conversely, the reduced spread of energy in the compact consonant diverts it from the optimal, diffuse consonant in the direction of the vowel.

In the nasal consonants the addition of the new, open resonator superimposes sharply-defined nasal formants upon the spectrum of the oral stop. Nasal resonance brings consonants closer to vowels and, on the other hand, when superimposed upon a vocalic spectrum, damps the other formants and deflects the vowel from its optimal pattern.

The optimal, stop consonant finds its opposite in the constrictive that attenuates the consonantal reduction of energy. Stops are an earlier acquisition of children and a later loss of aphasics than constrictive phonemes. There are in the world several languages without constrictives but no languages without stops.

The appearance of liquids which combine the clear cut formant structure of a vowel with the consonantal reduction of energy, changes the contrast consonant/vowel into two autonomous oppositions, consonantal/non-consonantal and vocalic/non-vocalic. While the consonantal feature, reduction of energy, is optimally represented by the stop, which tends toward a single pulse, the non-vocalic feature, absence of sharply-defined formant structure, is optimally manifested by the strident consonant which tends toward white noise. Therefore, the emancipation of the two features from each other, discontinuous/continuant on the one hand, and strident/mellow on the other, implies the acquisition of a liquid that combines two autonomous features, the vocalic and the consonantal. Actually, mellow constrictives opposed to strident constrictives, or strident plosives (affricates) opposed to mellow plosives (stops proper) do not appear in child language before the emergence of the first liquid, and under aphasia, vanish when the liquids are lost.

Strident plosives, in contradistinction to mellow plosives, attenuate the consonantal reduction of energy. The mellow constrictives deviate from the non-vocalic optimum embodied in the strident constrictives, namely from their markedly noisy pattern. One and the same split of the consonantal feature, on the one hand, and of the non-vocalic feature, on the other, is manifested both in the appearance of the liquids and of the strident stops. This explains the "strange but widespread" interchangeability of strident stops and liquids, especially laterals, that have been noted in Manchu-Tungus and in Paleosiberian languages [1].

Since nasality, by superimposing a clear-cut formant structure upon the consonantal pattern, brings consonants closer to vowels, and since liquids combine the consonantal with the vocalic feature, it is advantageous to range these two related classes of phonemes under a common heading of sonorants. The consonantal character of these two classes is again reinforced in such relatively rare phonemes as the discontinuous nasals (the so-called prenasalized stops) and the strident liquids (the sibilant laterals or vibrants).

The oral phonemes with an obstructed vocal tract have a noise source at the obstruction and may use voice – if ever – only as a supplementary source, whereas for the phonemes with an open tract, the voice is the main source. While the optimal consonant is voiceless and the optimal vowel voiced, the voicing of consonants or, in very rare instances, the unvoicing of vowels, may be utilized as one of the various attenuations of the maximum contrast CV.

Since the consonant is primarily characterized by reduction of energy, the optimal consonant is lax but may be subsequently opposed by a tense consonant that attenuates the contrast between consonant and vowel. Normally, however, the voiced consonant is of lower energy than the voiceless and therefore, in the opposition of tense and lax consonants, the laxness is frequently accompanied by voicing and the tenseness, by voicelessness, so that the consonant, optimal in one respect – reduction of energy – deviates from the consonantal optimum in another way – the presence of voice. If both oppositions act autonomously in a language, the doubly optimal consonant, lax and voiceless, is opposed by two phonemes, one, a voiceless tense and the other, a voiced lax, both of which, though in different ways, shift the structure of the consonant toward that of the vowel. A further move in this direction is a consonant endowed with the distinctive features of tenseness and voicing, such as /*d*‘/ in some languages of India.

Normally, the total energy of a vowel increases along with the concentration of energy (compactness), but in a tense vowel, as compared with the corresponding lax vowel, the total energy increases, whereas the concentration of energy decreases. This reversal separates the tense vowels from the vocalic optimum.

While reducing the time, the checked consonants increase their energy and thus attenuate the consonantal optimum. If a language possesses the two oppositions, checked/unchecked and tense/lax, then the optimal consonant, lax and unchecked, is opposed by two phonemes, the one checked (glottalized), the other tense. A double attenuation of the consonantal optimum may be further presented by the rare combination of two distinctive features, tense and checked within one and the same phoneme, such as the Avar /*K*'/.

Thus, all the inherent distinctive features actually rest upon two axes. On the one hand, the oppositions bearing upon the sonority axis display various fissions and attenuations of the primary contrast between optimal consonant and optimal vowel, and thus give rise to more minute and specific distinctions. On the other hand those oppositions that involve the tonality axis, perpendicular to the sonority axis, emerge originally as the counterpart and corollary of the contrast, "optimal vowel *vs.* optimal consonant" and, subsequently, as the corollary of the opposition, "optimal, compact vowel *vs.* attenuated, diffuse vowel" or "optimal, diffuse consonant *vs.* attenuated, compact consonant".

2. The dichotomous scale

In their recent, quite autonomous development, phonemic analysis and the mathematical theory of communication arrived at fundamentally similar and mutually complementary conclusions, making possible a most productive cooperation on both sides. Any spoken message presents the listener with two complementary alignments of information: on the one hand the chain of phonemes yields sequentially encoded information, on the other hand every phoneme is composed of several distinctive features. The totality of these features is the minimum number of binary selections necessary for the specification of the phoneme. In reducing the phonemic information contained in the sequence to the smallest number of alternatives, we find the most economical and consequently the optimal solution: the minimum number of the simplest operations would suffice to encode and decode the whole message. When analyzing a given language into its ultimate constituents, we seek the smallest set of distinctive oppositions which allow the identification of each phoneme in the messages framed in this language. This task requires an isolation of distinctive features from concurrent or adjoining redundant features.

If in a language, one and the same phoneme is implemented as a palatal stop before */i/*, as a post-alveolar affricate before */e/* and as a velar stop in all other positions, the invariant must be determined as a compact (forward-flanged) consonant, distinct from the diffuse (backward-flanged) consonants */p/* and */t/* of the same language. While in such a case the redundant features are conditioned by the diverse distinctive features of the following phoneme, a striking example of redundant features linked with concurrent distinctive features may be found in the French consonantal pattern. Here, the compactness of the consonant is implemented by a velar articulation when lumped with plosiveness in */k/* and */g/*, by a palatal articulation when lumped with nasality in */ɲ/*, and by a post-alveolar articulation when lumped with constrictiveness in */ʃ/* and */ʒ/*.

Such a delimitation of distinctive and redundant features not only permits an identification of all the phonemes involved but is the unique solution, since any different analysis of these five phonemes deviates from the optimal solution. All fifteen French consonant phonemes in the proposed test require only five binary decisions: nasal/oral, and if oral then continuant/discontinuous and tense/lax; compact/diffuse, and if diffuse then grave/acute. Each French consonant contains from two (compact nasal) to five distinctive features. If one deems the point of articulation distinctive, and the difference between constrictive and stop redundant, then the six French voiceless consonants – velar */k/*, post-alveolar */ʃ/*, alveolar */s/*, dental */t/*, labiodental */f/* and bilabial */p/* – would require, for their identification, fifteen distinctions instead of three, according to the elementary mathematical formula cited by TWADDELL: "If x is the maximum number of significant phonological differentiations within a given articulatory range in a language, then $2x = n(n-1)$, where n is the maximum number of phonemes in that range." Some of the minute differences in the point of articulation have, moreover, the disadvantage of being acoustically hardly recognizable by themselves. Finally, such distinctions as */s/ vs. /f/* and */t/ vs. /p/* present an identical differential criterion, namely the opposition of an acute and grave consonant due to the same difference in the size and shape of the mouth resonator. Also */k/ vs. /t/* and */ʃ/ vs. /s/* display (acoustically as well as genetically) one and the same opposition, due to a parallel relation of the front and back resonators, so that the operation with both pairs, as if they were distinguished by two separate features, introduces superfluous redundancies.

The reduction of language into distinctive features must be consistent. If, for instance, the Czech */l/*, which can occur in identical positions with each of the 32 other phonemes of the language, is declared "an unanalyzable distinctive unit", its distinction from the other 32 phonemes would require 32 unanalyzable relations, whereas the dissolution of the *l* bundle into its three features – vocalic, consonantal and continuous – reduces its relation to all other phonemes of the pattern to three binary selections.

The maximum elimination of redundancies and the minimum amount of distinctive alternatives is a principle that permits an affirmative answer to the focal problem raised by CHAO as early as in 1934 on whether the task of breaking down a given language into its ultimate components yields a unique solution. Not less crucial is his recent question [2] on whether the dichotomous scale is the pivotal principle which the analyzer can profitably impose upon the linguistic code or whether this scale is inherent in the structure of language. There are several weighty arguments in favor of the latter solution.

First, a system of distinctive features based on a mutually implicating relation between the terms of each binary opposition is the optimal code and it is unwarranted to assume that the speech participants in their encoding and decoding operations use a more complicated and less economical set of differential criteria. Recent experiments have disclosed that multidimensional auditory displays are most easily learned and perceived, when "binary-coded" [11].

Second, the phonemic code is acquired in the earliest years of childhood and, as psychology reveals, in a child's mind the pair is anterior to isolated objects [13]. The binary opposition is a child's first logical operation. Both opposites arise simultaneously and force the infant to choose one and to suppress the other of the two alternatives.

Third, almost all of the distinctive features show an unquestionably dichotomous structure on their acoustical and, correspondingly, on their motor level. Among the inherent features, only the vocalic distinction compact/diffuse often presents a higher number of terms, mostly three. For example, */æ/* is to */e/* as */e/* is to */i/*: the geometric mean */e/* is non-compact in relation to */æ/* and non-diffuse in relation to */i/*.

Psychological experiments that obtained /e/ through the mixture of /æ/ and /i/, confirm the peculiar structure of this vocalic feature [7]. Parallel experiments in mixing vowels situated on the tonality axis showed that grave and acute vowels, when sounded simultaneously are not perceived as a single vowel: /u/ and /i/ do not merge into /ü/. The feature grave/acute is a patently binary opposition.

Finally, the application of the dichotomous scale makes the stratified structure of the phonemic patterns, their governing laws of implication, and the conclusive typology of languages so transparent that the inherence of this scale in the linguistic system is quite manifest.

3. The spatio-temporal pattern of phonemic operations

If there is a difference between the linguistic patterns of two speech communities, interlocution between members of the two communities demands an adjustment of the listener to the speaker and/or of the speaker to the listener. This adjustment may involve all aspects of language or only a few of them. Sometimes the phonemic code is the only one affected. Both on the listener's and on the speaker's side there are different degrees of this adjustment process, neatly called "code switching" by communication engineers. The receiver trying to understand the sender, and/or the sender in trying to make himself understood, concentrate their attention on the common core of their codes. A higher degree of adjustment is represented in the effort to overcome the phonemic differences by switching rules, which increase the intelligibility of the message for its addressee. Having found these clues, the interlocutor may try to use them not only as a listener, but also more actively, in adapting his own utterances to the pattern of his addressee.

The phonemic adjustment may cover the whole lexical stock, or the imitation of the neighbor's phonemic code may be confined to a certain set of words directly borrowed from the neighbor or at least particularly stamped by his use of them. Whatever the adjustments are, they help the speaker to increase the radius of communication, and if often practiced, they are likely to enter into his everyday language. Under favorable circumstances they may subsequently infiltrate into the general use of the speech community, either as a particular speech fashion or as a new pattern fully substituted for the former norm. Interdialectal communication and its influence on intradialectical communication must be analyzed from a linguistic and, particularly, from a phonemic point of view.

The problem of bridging space stops neither at the borders of distant and highly differentiated dialects, nor at the boundaries of related or even unrelated languages. Mediators, more or less bilingual, adapt themselves to the foreign phonemic code. Their prestige grows with the widening radius of their audience and may further a diffusion of their innovations among their monolingual tribesmen.

Not only the interdialectal, but also the interlingual adjustment may affect the phonemic code without limitation to borrowed words or even without any lexical borrowing. In all parts of the world, linguists have been surprised, as Sapir confesses, to observe "the remarkable fact that distinctive phonetic features tend to be distributed over wide areas regardless of the vocabularies and structures of the languages involved." This far-reaching phenomenon still awaits systematic mapping and study in connection with the equally urgent inquiry into the typology of phonemic patterns.

The other possibility of phonemic adjustments to a different dialect or foreign language is a partial or total preservation of its phonemic structure in borrowed words. As noted repeatedly in the phonemic literature, and particularly emphasized by Fries and Pike, "the speech of monolingual natives of some languages is comprised of more than one phonemic system". Such a coexistence of two systems within one language is due either to a phonemic difference between the original vocabulary and unassimilated loanwords, or to the use of two patterns, one native and the other imitative, as different styles of speech. Thus phenomena of space, namely interdialectal or interlingual isoglosses, especially isophones, may be projected into the framework of a single dialect, individual or social.

The same statement, *mutatis mutandis*, may be made about the time factor in language, particularly in the phonemic field. Any sound change, at its proceeding, is a synchronic fact. Both the start and the finish of a change coexist for a certain length of time. If the change differentiates the younger generation from the older, there is always some intercourse between the two generations, and the receiver belonging to one is accustomed to decode messages from a sender of the other. Furthermore, the initial and the final stage may co-occur in the use of one and the same generation as two stylistic levels: on the one hand, a more conservative and solemn, on the other, a more fashionable way of talking. Thus synchronic analysis must encompass linguistic changes and, vice versa, linguistic changes may be comprehended only in the light of synchronic analysis.

The decisive factor in phonemic changes and in the diffusion of phonemic phenomena is the shift in the code. The interpretation of events in time and space is primarily concerned with the question in what respect the structure of the code is affected by such shifts. The motor and physical aspects of these innovations cannot be treated as self-sufficient agents, but must be subordinated to the strictly linguistic analysis of their role in the coding system.

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