Notes on sonority and segmental strength

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This paper deals with sonority and segmental strength as parameters of the universal phonetic space. It is shown how sonority corresponds to hierarchic feature configurations in terms of geometric models of segment structure, and how specific strength scales of the major phonetic gestures interact with each other and enrich the configurational multiformity of the feature tree.

So-called Major Class Features are shown to be dispensable elements of segment representations, since all relevant qualities of segments follow directly from the configurational structure of the hierarchic representation in terms of class nodes and gestures.

Unidimensional scales of relative segmental strength are discarded in favour of multidimensional scales of initiatory, phonatory, velopharyngeal, and articulatory strength.

The ontological reliability of the traditional binary valued distinctive features is questioned.

0.1. Since the trailblazing work of Jakobson, Fant and Halle (1952), phonetically interpretable distinctive features have been recognized as the basic atoms of phonological representations. The phonological analysis of a given language reduces the sound shape of words to bundles of distinctive features on the basis of which the rules and processes occurring in that language are formulated. The phonetic substance of features is universal, but their implementation as distinctive features is a matter of actual phonological systems. Thus, apart from language-specific analyses, we conceive of phonological theory as a model of the sound-processing capabilities of man with respect to language as a semiotic activity of articulation and perception. From this 'anthropophonic' point of view, we conclude that a universal set of potentially distinctive features defines the universal phonetic space on the basis of which individual phonological systems of the languages of the world are constructed. All phonological systems must fit this space, but it follows from the notion of potential distinctivity that they do not have to use this space exhaustively (in fact, they never do).

0.2. The descriptive and explanatory capacity of a feature-based model is considerable: many important phonological relations such as natural classes of sounds, context-sensitive phonological processes, phonotactic constraints,

 (ricevuto nel febbraio 1990)

etc., are definable in terms of distinctive features. However, there are other atomic phonological relations which are difficult to express in terms of distinctive features. Two such relations which we will examine in this paper are sonority and segmental strength.

0.3. It is widely assumed that relative sonority and segmental strength are merely two reciprocal expressions for one and the same phenomenon, designating both ends of a universal scale that correspond roughly to the dichotomy of vowels and consonants:

(1) *Vowels* *Approximants* *Nasals* *Obstruens*

- strength <-------------------------------> + strength

+ sonority <-------------------------------> - sonority

According to this interpretation, maximal sonority and maximal segmental strength would be incompatible for one single segment, but optimal as constituents of a syllable. Thus, the most natural syllable type is !C!V, whereby !C stands for 'most consonantal (= strongest) consonant' and !V stands for 'most vocalic (= sonorous) vowel'. However, the incompatibility of relative sonority and consonantal strength seems to be restricted to the left side of the above scale, since there is a class of sounds with a low degree of sonority, but also a low degree of consonantal strength, namely the so called laryngeals (variants of [h] and [ʔ]).

0.4. Based on these assumptions, we will present in this paper an integrated model of phonological description in which concepts such as sonority and strength will be defined as configurations of the universal phonetic space. The descriptive model that we use is the geometrical model as proposed by Clements (1985) and developed in Halle (1986), Sagey (1986), Dogil (1988) and others (cf. contributions to van der Hulst & Smith [eds.] 1988).

0.4.1. In the first section we will show the way in which individual distinctive features are grouped into complex feature classes which ultimately make up the tree configuration defining the universal phonetic space.

0.4.2. In the section on 'Natural Classes of Sounds' we will show how the parts of the configuration defined in section 1. may be used as definitions of the natural classes of sounds. We will argue that tree configurations help us to remove the *major class features* from phonetic and phonological descriptions.

0.4.3. In the section on 'Sonority and Syllable Preference Laws', we will show that the relative sonority of segments can be derived from the geometrical representation of the tree, and we will illustrate the use of the concept of sonority in accounting for various preference laws in syllabification.

0.4.4. Finally, in the section on 'Segmental Strength', we will show how the sonority hierarchy defined in section 3. may be made more delicate by accounting for 'strength' relations which are opened under the complex nodes of the geometrical representation of universal phonetic space. We will further motivate these strength scales by giving examples of diachronic substitution processes which are not adequately described by pure feature models.

1. *Classes of features.*

1.1. We assume that the universal set of distinctive features should include at least the following binary oppositions: [1]

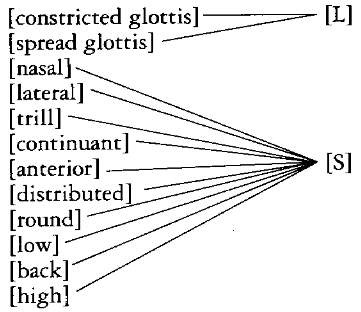
(2) [constricted glottis]
[spread glottis]
[nasal]
[lateral]
[trill]
[continuant]
[anterior]
[distributed]
[round]
[low]
[back]
[high]

This set is uncontroversial, and all the features included in it are motivated in the studies on phonetic perception and invariance as well as in the studies of phonological systems of various languages of the world (cf. Keating 1987, Stevens & Keyser 1989). What this set fails to express is the fact that certain features are independent of each other to different degrees. Both from the phonetic and the phonological point of view some features tend to function as units or classes.

1.2. Speech production is essentially componential in nature. The two main components in the widely accepted source-filter model of vowel production are the LARYNGEAL [L] (source) and the SUPRALARYNGEAL [S] (filter) components. We propose to represent this fact in the feature notation by allowing the two separate classes to be dominated by separate 'class nodes'. Consider the illustration in (3).

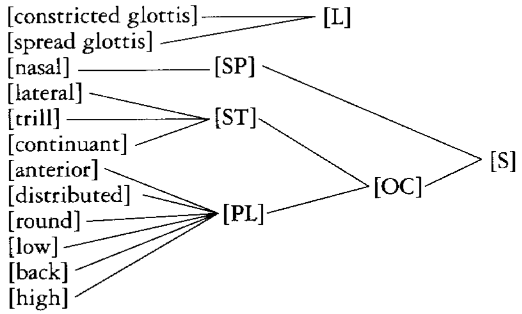
[1] Cf. Dogil (1988) for the motivation for this particular feature set.

(3)



1.3. SUPRALARYNGEAL features are not uniform. Their function depends on the type of oral cavity stricture, [2] the oral/nasal cavity participation and the place where an active and a passive articulator meet. We can encode this fact directly into the feature notation by letting the 'class nodes' ORAL CAVITY [OC], SOFT PALATE [SP], STRICTURE [ST] and PLACE [PL] dominate the features which represent these independent filtering functions. Consider the representation in (4).

(4)

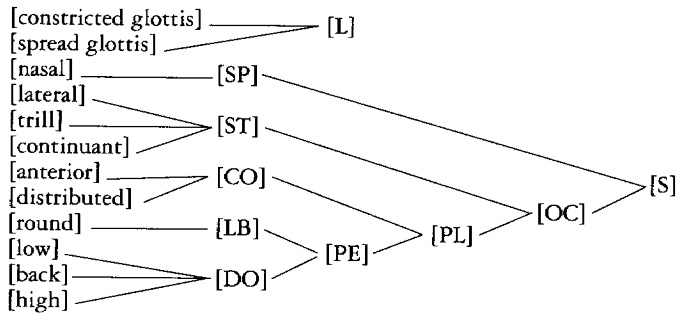


1.4. Halle (1986) noted that vowels in all languages are executed with tongue body and thus are DORSAL [DO]. The lips also participate in the production of certain vowels, which are specified as LABIAL [LB]. The participation of the tongue blade in the production of vowels (as opposed to consonants) is quite rare: the 'retroflex' vowels of American English, Danish, Tarascan (Foster 1969), Mandarin and of some Dravidian languages (cf. Emeneau 1939) are the only attested cases of vowel sounds that are CORONAL [CO]. In our feature notation the fact that the lips and the tongue body go together as against the tongue blade is expressed by letting the PLACE node dominate the independent PERIPHERAL [PE] and CORONAL [CO] nodes. Further motivation for the CORONAL/PERIPHERAL distinction comes from the consideration of the acoustic patterns of consonants. The consonants described by

[2] In case of consonants (particularly the fricatives) stricture may also be considered a source feature.

Jakobson, Fant & Halle's feature [+grave] were all non-coronals, and grouping them under the PERIPHERAL node accounts for this observation. The PERIPHERAL node is even more general than the feature [grave], because it may naturally subsume the uvular and pharyngeal articulations, [3] which were unspecified for [grave] in the Jakobson, Fant & Halle system. Phonological rules which refer to labials and velars, but not to coronals can be quoted from a number of languages. For example, in Polish /j/ is inserted after labials and velars but not after coronals (Rubach 1984: 177). In Old English, the voiced stops /b g/ had fricative allophones intervocalically, but not the stop /d/. Similar asymmetries in the historical development of 'peripherals' versus 'coronals' are reported for Proto-Uralic, Ostyak and Middle Korean. Moreover, in some languages (Rumanian, Tamil) changes within the class of peripherals have been noted (k - p in Rumanian; x - v in Tamil), and according to Christdas (1988: 30), such changes are more common than changes between coronal and dorsal, or coronal and labial. Christdas also quotes examples of rules which look like typical cases of PERIPHERAL spreading. In Fe?fe?-Bamileke there is a vowel alternation after non-coronal consonants, and in Danish low vowel /a/ becomes back (and rounded) before a tautosyllabic non-coronal consonant (Christdas 1988: 29-30). Beside that PERIPHERAL is useful in the classification of labio-velars, which also may spread independently of coronals. Hence, the interdependence between the labial and the dorsal parameters is expressed by placing them together under the PERIPHERAL node. Consider the representation in (5).

(5)

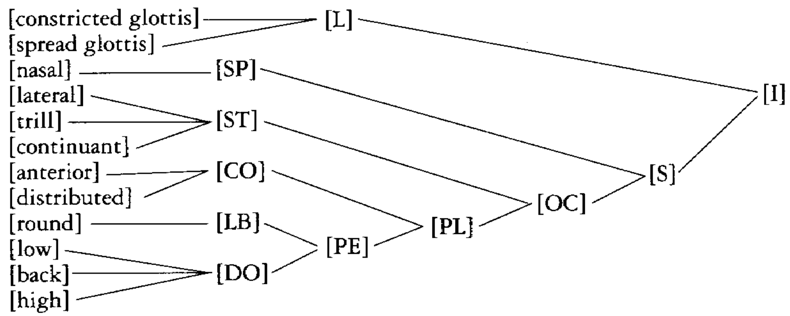


1.5. In the preceding paragraphs we adopted, in somewhat modified fashion, the suggestion by Mascaró (1983), Mohanan (1983), Halle (1986), Clements (1985, 1987) that individual features are grouped into classes and organized under hierarchically superordinate nodes. In the standard geometrical model (Clements 1985), the classes of features represented by the class nodes are rooted in a single abstract node, the ROOT node. Following our 'anthropophonic' approach to feature notation we choose not to use abstract

[3] Cf. Dogil (1988: 84, 88-89) for a suggestion of such a representation. Palatal consonants, which are [-grave], may be subsumed under the CORONAL node, as was suggested by Czaykowska Higgins (1988: 41ff).

nodes in the representation of the universal phonetic space. Our suggestion is to replace the ROOT by the three complementary INITIATOR [I] nodes (PULMONIC, GLOTTALIC and VELARIC). [4] This is a logical consequence of our enterprise, since the initiation of speech makes the differentiation of the whole system possible. The introduction of the INITIATOR node has also phonological consequences. Note that the ROOT node was originally motivated by phonological rules of total assimilation. The prediction of our model is that there would not be total assimilation processes between the segments of different initiation type (e.g. clicks & ejectives or pulmonic & glottalic sounds). Feature structures with ROOT as the highest node do not have this restriction. The complete representation of the phonetic space that we will build upon is given in (6).

(6)



1.6. The representation in (6) contains a formal reflection of the fact that features correlate with independent class nodes which are interpretable as gestures of the speech production system, such as LARYNGEAL, LABIAL, CORONAL, etc. Language particular sound patterns tend to show use of these gestures for locating distinctive places of constriction (e.g. expressed by the feature [±anterior] under the CORONAL gesture). Linguistic rules, on the other hand, tend to treat features of the same node as bundles. Thus, the structure as in (6) allows representation of significant and phonetically interpretable sound contrasts as well as phonological processes. In the following section we will argue that this representation is also suitable for grouping sounds into natural classes.

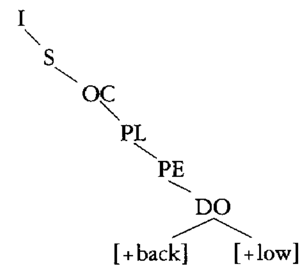
[4] In the following we will consider mainly the sounds by means of pulmonic initiation. Thus, the [I] node will be equivalent to pulmonic node [IP]. For clicks the [I] node would represent the velaric initation [IV], and for implosives (glottalic suction) and ejectives (glottalic pressure) it will represent complementary glottalic initiations [IGs], [IGp]. Such a classification of initiation types appears necessary, because there are languages in which segments are minimally distinguished by means of initiation. One such example is Uduk (cf. Ladefoged 1971: 27), which has not only [b p pʰ], but also [ɓ] and [p'], and a similar alveolar series. This differentiation will be used in the consideration of varying initiation strength (section 4.).

2. *Natural classes of sounds.*

2.1. In the phonological description of a particular sound pattern the universal phonetic space is exhausted only as far as it contributes to the expression of all relevant contrasts within this pattern. Segments do not have to be specified for features which contribute nothing to their contrastive value. In particular, the class nodes (LARYNGEAL, CORONAL, etc.) are specified only when the distinctive features controlled by them are used contrastively within the described sound system. We will use this distinctiveness of nodes as a defining criterion for natural classes.

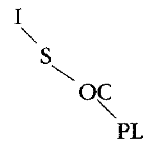
2.2. A non-redundant representation of simple vowels, for example [a], requires the specification of the SUPRALARYNGEAL, ORAL CAVITY, PLACE, PERIPHERAL and DORSAL nodes only. Consider the representation of a vowel [a] in (7).

(7)



This is so, because the simple (unmarked) vowels do not contrast in features which are specified under the LARYNGEAL, STRICTURE and SOFT PALATE nodes. In most languages vowels are also distinguished by the degree of lip rounding, [5] and, hence, have to be specified as LABIAL. The 'marked' types of vowels, like retroflex, nasal and breathy vowels, are represented by additional CORONAL, SOFT PALATE and LARYNGEAL nodes respectively (cf. Dogil 1988: 41-51). The most general representation of vowels should express the fact that there is an undisturbed airflow (allowing for spontaneous voicing) up to and beyond the main articulator node (the PLACE node). Such a representation is the one given in (8).

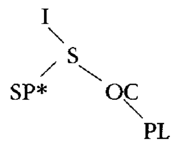
(8)



[5] This, however, is not universal. Trubetzkoy (1939) provided data from Caucasian languages (Adyge, Kabardian and Abaza) where the lips play no role in differentiating vowels.

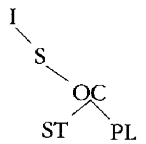
We are assuming that such most general, unmarked and highly underspecified representations of natural classes of sounds are provided at the highest (universal) level of phonological representation. We will show that such unmarked configurations are essential for the assignment of sonority values and for the expression of the sonority-cued syllable assignment (section 3).

The marked distinctive values (e.g. nasality or breathiness in vowels) are inserted at the language specific component of feature assignment, and hence will not interfere with the universal sonority and syllabification assignment rules. We suggest representing such marked cases with the starred (*) nodes in the tree, the nodes which are not available to sonority assignment algorithm. Consider such a representation for a nasal vowel in (9).

(9)


2.3. Unlike for vowels, in the production of consonants the airflow is modified or disturbed before the main articulation node (PLACE) is reached. There are various degrees of this modification, and in accordance with this variation, several natural classes of consonants may be distinguished.

2.3.1. The natural class of consonants with the slightest modification of the airflow is the class of approximants. The main parameter distinguishing approximants from vowels is the narrower articulatory channel (cf. Catford 1977: 119-123). The width of the articulatory channel in our model is expressed by the STRICTURE node. Hence, the approximants receive their class specification under this node in the feature structure representation. Consider the class representation for approximants in (10).

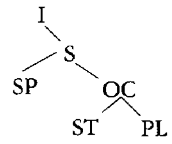
(10)


Approximants are not specified for the LARYNGEAL class node, because they do not use the features [constr. glottis] and [spread glottis] contrastively. [6] In the unmarked case approximants are voiced and non-breathy (unaspirated).

[6] The situation in Sedang (Smith 1968), where the approximant /r/ contrasts with the voiceless and breathy rhotics, and in Gilyak where there is an approximant and voiceless /r̥/, may be accounted for by the interaction of the approximant with the underlyingly adjacent laryngeals. See the analogical analysis of voiceless and breathy nasals in the next section.

The class node SOFT PALATE does not have to be specified either, as approximants are non-nasal in the unmarked case. [7]

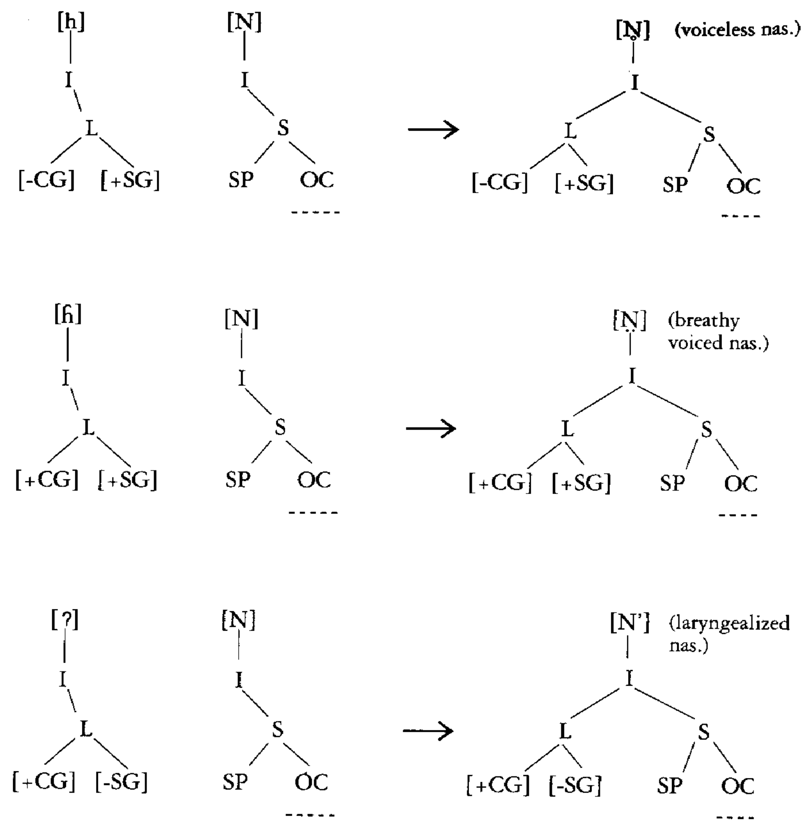
2.3.2. Nasal consonants are produced by lowering the velum and creating a closure in the oral cavity in front of the velic opening. In one respect nasals are similar to approximants. The constriction that the outwardly flowing air has to pass through is not sufficiently narrow to produce greater turbulence. Thus in terms of STRICTURE nasals are similar to approximants. Their primary characteristic, however, is the activity of the SOFT PALATE. The basic feature-structure for nasals will look like in (11):

(11)


Nasals are not specified for the LARYNGEAL complex because they are unmarkedly voiced and non-breathy (non-murmured). Voiceless nasals are rare but do occur in some Southeast Asian and North American languages (e.g. in Burmese, Hmong, Iaai, Kwanyama). Their description will be amended by the [+spread glottis] specification under the LARYNGEAL component. Similarly, the still rarer breathy voiced nasals (noted in Hindi, cf. Kelkar 1968) and laryngealized nasals (in Klamath, Barker 1964) will be represented as [+constr. glottis, +spread glottis] and [+constr. glottis, -spread glottis] under the additional LARYNGEAL node. These are, however, very clearly the marked cases and in some circumstances voicelessness, breathiness and laryngealization are redundant (and not contrastive) features of nasals. Such cases can be described as spreading of the LARYNGEAL features from the laryngeal sound in the neighborhood. We will argue later in this section that laryngeal sounds ([h,ɦ,ʔ]) are not specified for any of the supralaryngeal features. Hence if a nasal, which has no LARYNGEAL specification, and a laryngeal, which has no SUPRALARYNGEAL specification, come together, their complementary nodes may merge under the unified tree. Consider the derivations in (12).

[7] For details of representation of the particular glides, laterals and rhotics see Dogil (1988: 53-63).

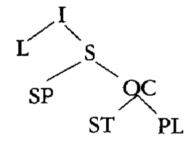
(12)



If this analysis were acceptable for all cases of nasals with the surface LARYNGEAL specification, the representation like the one in (11) could be seen as underlying all nasals, and the marked cases would be accounted for by the postulated presence of one of the laryngeals in the neighborhood of the nasal. At least in some cases such an analysis should be clearly preferred (e.g. Columbian Salish reported by Ladefoged and Maddieson 1986, 38-39). In languages where there are no synchronic reasons for such a spreading-analysis (e.g. Klamath, Clements (personal communication)), there will be a *-starred LARYNGEAL node additionally specified for nasals. For many other cases "..the documentation is not yet very extensive" (Ladefoged and Maddieson 1986, 39). However, for the overwhelming majority of nasals the LARYNGEAL specification does not play any role.

2.3.3. Obstruents are specified for all components provided by the feature representation which defines the universal phonetic space. That is, their non-redundant tree will mention all the class nodes. Consider the representation in (13).

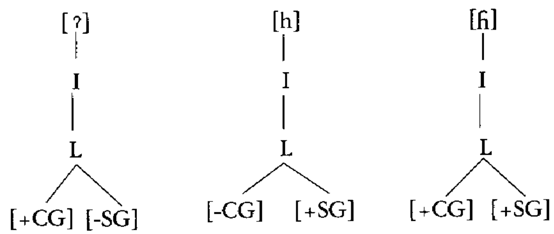
(13)



The detailed description of the feature structure of various types of obstruents and for most of the obstruent sounds listed in the IPA (1979), Maddieson (1984) and Ladefoged & Maddieson (1986) has been given in Dogil (1988: 70-99). These details are not essential to the discussion of the main issues of this paper. It is, however, essential to remember that obstruents show the most complex feature-structure of all the natural classes of sounds that have been discussed so far in this study.

2.3.4. There are only three sounds generated in the larynx which can be used contrastively - the 'glottal stop' [ʔ], the 'fricative' or 'approximant' [h], and its voiced variant [ɦ]. Glottal stops are characterized by a constricted glottis; [h] and [ɦ] are produced with spread arytenoid cartilages, and with increased and decreased vocal-fold stiffness, respectively (cf. Stevens, 1977). In terms of feature geometry laryngeals may be uniformly specified as the class of sounds in which only the LARYNGEAL complex is involved. Consider the representations in (14).

(14)



The laryngeal sounds are 'defective' in many ways. Even when they occupy a timing slot of their own, they do not behave like complete segments. This is due to the fact that the only component of feature-structure that they are specified for is the phonatory one. The articulatory components, those specified under the SUPRALARYNGEAL node, are completely missing. [8] Hence it is common to find descriptions of languages in which [h] is described as 'the voiceless counterpart of the following vowel' (Ladefoged 1975: 55), and [ʔ] as an abrupt beginning ('fester Ansatz') of the vowel that follows. We believe that the representations in (14) express this 'faulty' character of laryngeals fairly closely. Laryngeals share with obstruents the property of being the only sound classes underlyingly specified for the LARYNGEAL node. This property

[8] Actually, as we will argue in sec. 4., the best way to account for laryngeals is in terms of conflation of phonatory and articulatory gestures.

makes these two classes function together with respect to some phonological rules. For example, in Slovak (Rubach 1989) a voiced laryngeal [ɦ] and voiced obstruents cause voicing assimilation, by L spreading. Sonorants and vowels, which are not underlyingly specified for the LARYNGEAL node do not participate in this process. However, what sets laryngeals aside from all other sound classes is the fact that they are not specified for the SUPRALARYNGEAL node. The underspecified representation of laryngeals will also play an important role in the account of sonority. As a fact to be described let us just state that the laryngeals turn up only as extreme syllable-margin units.

2.4. In this section we have shown how the distinctiveness of the class nodes may be used as a defining feature of the major classes of sounds such as vowels, approximants, nasals, obstruents and laryngeals. Interestingly, the result of these definitions are varied, systematic to configurations of the feature structure representation. Hence vowels are not branching, and consonants show branching to a different degree. Obstruents are underlyingly characterised for all of the left branches, and sonorants only for some of them. Notice that in our account of natural classes of sounds we make no reference to *major class features* like [consonantal], [syllabic] or [sonorant], which were traditionally used for this purpose. This is a welcome result from the point of view of feature geometry, because exactly these features do not show the kind of autosegmental behaviour (e.g. stability, spreading) which would licence their inclusion in the tree. We will show in the sections to follow how these formal differences may be exploited in defining other atomic concepts of phonology, particularly sonority and strength.

3. *Sonority and Syllable Preference Laws.*

3.1. The issue of sonority and strength has a long history, [9] and the interest in the problem can currently be observed in the literature. [10] The interest and the diversity of accounts provided for these phonological atoms stems from the fact that, unlike other distinctive features, neither sonority nor strength can be accounted for in terms of physically measurable properties.

3.1.1. Ohala and Kawasaki state plainly: '*no one has yet come up with any way of measuring sonority*' (1985: 122), and indeed the definitions of sonority which are based on the consideration of some measurable parameter are not long lived.

[9] Cf. Murray (1988: 6-103), for an extensive review of ideas.

[10] Cf. Hankamer and Aissen (1974) , Hopper (1976), Basbøll (1977), Foley (1977), Price (1980), Kiparsky (1981), Steriade (1982), Lindblom (1983), Keating (1983), Selkirk (1984), van der Hulst (1984), Dogil (1988), Murray (1988), Vennemann (1988), Clements (in press), Puppel (in press); to mention just a few of the major studies on this subject.

3.1.2. The articulatory parameters are not very reliable. For example, Lindblom (1983) found a correlation between jaw height and linguistically predicted sonority value in his experiments on the articulation of Swedish nonsense syllables. The observed tendency was that "open" consonants occurred with more frequency closer to vowels. However, Keating (1983), who replicated Lindblom's experiment for English, obtained very different results. She found that: 'virtually any segment order can be accommodated by the jaw' (1983: 405).

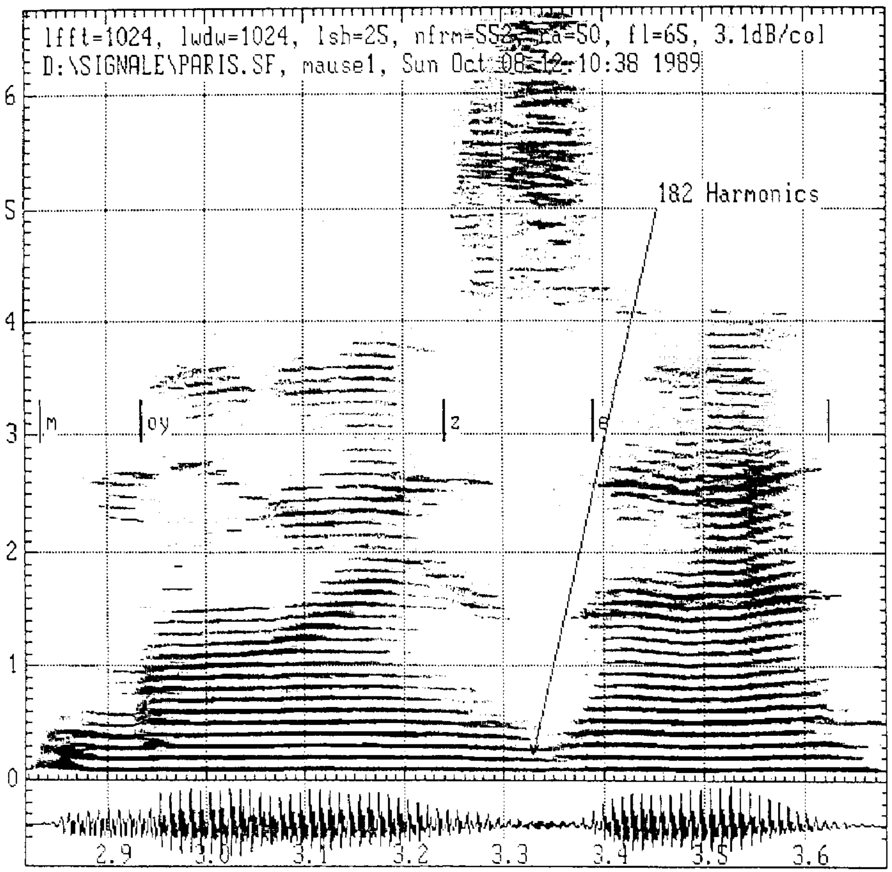
3.1.3. The acoustic definitions based on phonetic power, such as Ladefoged's definition of sonorants as 'sounds (which) have comparatively large amount of acoustic energy' (1975: 264) are difficult to quantify. Additionally, acoustic measurements of phonetic power (cf. Fletcher 1953, Stevens 1987) vary substantially across languages and speakers, and the results that they yield stray considerably from the linguistically motivated sonority accounts. Thus, according to Fletcher's measurements, sibilants are higher in sonority than nasals, and [k] ranks higher than fricatives and voiced stops (cf. Clements in press, fn.11).

3.2. The substantive uncertainty in finding universal phonetic correlates of sonority and strength has led many researchers to refer to a gradual scale – the sonority hierarchy – which is not definable in phonetic terms. Hankamer & Aissen (1974) claimed (based on evidence from a highly 'deviant' sonority scale in Pāli) that sonority is a psychological construct, with no direct relation to the phonetic facts, which may vary greatly from language to language. Hooper (1976) gave a functional interpretation to the sonority (actually strength) scales, suggesting that they may be established only by the analysis of the particular phenomenon and language at stake. The non-phonetic 'scale' approach culminated in a highly controversial work of Foley's (cf. Foley 1977), who claimed that not only sonority but all of the features have to be analyzed in abstract (arbitrary) terms.

3.3. Basbøll (1977), Lekach (1979), Clements (in press), Puppel (in press), attempt to derive sonority from the hierarchical combination of distinctive features describing the universal phonetic space. However, at least the first three authors use the major class features in deriving the sonority hierarchy. [11]

[11] Basbøll's (1977) basic features are [consonantal], [sonorant] and [voice], Lekach (1979) uses the features of Kean's markedness hierarchy (cf. Kean 1975) where [sonorant] plays an important role, and Clements (in press) employs [vocoid] (identical to consonantal), [approximant] and [sonorant] to derive the sonority hierarchy. Puppel (in press) is a notable exception here as his sonority scale is derived from the dependency of the features [voiced] and [continuant], which are supposed to mirror the source-filter model of articulation. Puppel elegantly embeds his analysis in the Dependency Phonology framework. However, his solution falls short of accounting for laryngeals which, incidentally, are not accounted for under any of the other analyses either.

As we pointed out in section 2., major class features should not be accommodated in the tree geometry model as they do not show the kind of behaviour required of autosegmental features. Moreover, major class features are notoriously difficult to define from the phonetic point of view. For example, the aerodynamic definition of the feature [sonorant] in the Sound Pattern of English, 'sonorants are sounds produced with a vocal tract cavity configuration in which spontaneous voicing is possible' (Chomsky & Halle 1968: 302), has to be abandoned due to the fact that laryngeals [h] and [ʔ] would be



Narrow band spectrogram of a german word *Mäuse* (mice). Note the continuity of the spectrum amplitude in the region of the first and second harmonics.

classified as [+sonorant]. The acoustic definition of this feature, provided by Stevens & Keyser (1989: 87): 'A consonantal segment with the feature [+sonorant] is characterized by continuity of spectrum amplitude at low frequencies in the region of the first and second harmonics – a continuity of amplitude that extends into an adjacent vowel without substantial change', seems impracticable because voiced obstruents (particularly fricatives) also possess high energies in the lower harmonics. Consider Figure 1., which shows continuity of spectrum amplitude across the low frequencies of the narrow band spectrogram. Hence, the voiced fricative [z] which was pronounced in this word would have to be classified as [+sonorant].

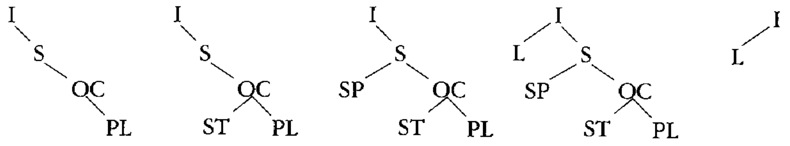
A similar type of phonetic indeterminacy is characteristic of other major class features. The feature [consonantal] is meant to correlate with presence of constriction at some point along the length of the vocal tract. The acoustic effect of a constriction is a rapid movement of formants in the vicinity of [+consonantal] sounds (Stevens & Keyser 1989: 89). However, as Repp & Lin (1989) and Dogil & Wokurek (1989) have shown, the formants of the release transients in plosives are actually followed by the formants of the following vowel. Thus, even plosives might be considered [-consonantal] given the results of these measurements. This suggests that major class features do not possess a core of invariant acoustic and articulatory properties [12] which would licence their use as underlying parameters for sonority.

3.4. There is no doubt that sonority and strength must be determined by some general (possibly universal) parameter. Otherwise, there would be no way of explaining the universal distribution of sonority and strength constraints across languages. It is a well established fact that the phonotactics and the context-free sound substitutions of a vast number of meticulously studied languages rest on principles which refer directly to sonority and strength scales. The differences in phonotactics and historical development point out that parametrization of the general principles is at stake too. But if there is parametrization there must be some underlying parameter.

3.5. In our model *sonority is derived from the branchedness of the feature structure.* More specifically, it is inversely proportional to the number of nodes that have to be consulted on the way to the first articulator node (i.e. the PLACE node). Notice that segments with the highest sonority – the vowels – have the most straightforward path from the INITIATOR node to the PLACE node. Approximants, which are specified for one left-branch (the STRICTURE node), are lower in sonority than the vowels. The nasals are lower in sonority than the approximants. This is expressed directly in the model, where nasals have two left-branching nodes. Thus a complex path must be consulted before the PLACE node is reached. Nasals are still higher in sonority than the obstruents, for

[12] This is even more true of the feature [syllabic], which, however, has disappeared from distinctive feature lists after the first studies on autosegmental phonology.

which all complex nodes have to be consulted. Laryngeals are specified for just one component, and they are *not* specified for the articulator nodes at all. From this point of view they must be lowest in sonority. We defined sonority as inversely proportional to the number of nodes that have to be consulted on the way to the first articulator node (the PLACE node), and if this articulator node is absent, sonority must be missing too. This seems actually to be the case, as the laryngeal sounds occupy extreme satellite positions in the syllables. Hence, the 'complete' sonority scale which can be derived from the branchedness condition of the feature structure is as in (15):

(15)


vowels --------- approximants ------- nasals ------ obstruents --- laryngeals

The defining criterion for this hierarchy is strictly formal – sonority is the degree of branchedness of the feature-structure. Notice, however, that this formal definition has straightforward substantive support. The sounds, the representations of which include more branches, automatically involve more components in their production, and, the more components involved, the less sonorant the sound is.

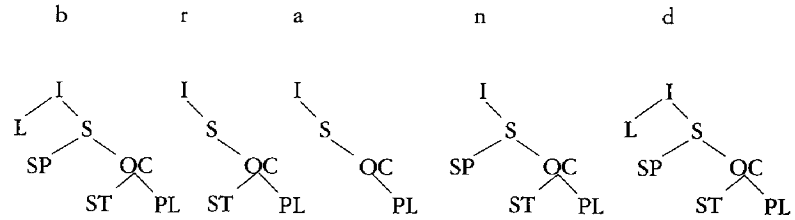
3.5.1. The scale in (15) is fairly uncontroversial, and crosslinguistic studies of sonority (cf. Greenberg 1978) give full support to this kind of sonority scale. Further subdivisions of the scale (e.g. approximants subdivided into glides and liquids; liquids into rhotics and laterals; obstruents into fricatives and stops) do not find such a universal motivation. We will refer to such language-specific subdivisions later in this study.

3.5.2. Actually, crosslinguistic studies of sonority are usually based on the study of the distribution of various sound types within the syllable. Rules that refer to sonority scale are supposed to explain why certain sounds constitute syllabic peaks and other sounds only function as satellites. This highly consistent phenomenon of increasing and decreasing sonority within the syllable has led phonologists to propose the so-called 'Sonority Sequencing Generalization'. In the model proposed in this study this generalization is formulated as follows:

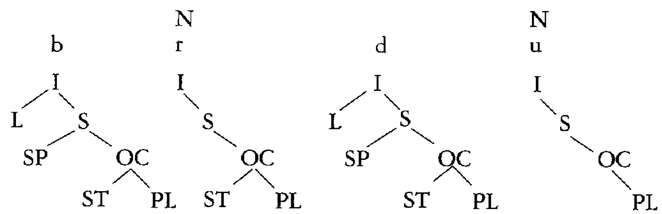
(16) Sonority Sequencing Generalization (SSG)

In any syllabe, a segment with the lowest degree of branchedness constitutes a sonority peak that is preceded and/or followed by segments normally with increasing, but never decreasing, degree of branchedness

Consider the sonority sequencing in a monosyllabic word like *brand*. The segment of the lowest degree of feature structure branching is the vowel /a/, and this sound will constitute the peak of the syllable (Nucleus Placement Rule). The sound immediately preceding and following the /a/ in *brand* – the approximant /r/ and the nasal /n/ – have a higher degree of branchedness, and thus, may be assigned as satellites to /a/. The /b/ and /d/ have still higher degree of branchedness than the /r/ and the /n/, and are aligned with the margins of the syllable. In this way any well formed syllable may be analyzed by the Sonority Sequencing Generalization, with sonority defined by the branchedness of the feature structure. The complete representation of the syllable 'brand' is given in (17).

(17)


Notice that the rules which distribute sounds in the syllable (e.g. Nucleus Placement Rule) do not have to look at any abstract features ([cons] & [son] in the SPE-type models), or nodes (V-node in the CV model), but refer simply to the configuration of sound representation. In this way syllabic consonants do not have to be marked as such at any level of representation, but emerge in the nucleus position due to their inherent branchedness and the configurational properties of the neighbouring sounds. Consider the Czech word *brdu* (stroll) in (18). /r/ is lower in branchedness than its immediate environment, and this is the only reason that it will be assigned the status of the 'syllabic' consonant. [13]

(18)


[13] In other languages, e.g. Polish, the sonorants do not become syllabic in the obstruent environment (e.g. *krwi* [krfi] 'blood'). This is due to the language specific restriction, which prohibits the sonorants to become syllabic.

3.5.3. Sequences of segments with equal number of branches, so-called 'sonority plateaus', do not violate the generalization in (17). Thus the syllables like English *apt*, *act*, *sphere*, or Polish *kto* (who), *tka* (he webs), *ptak* (bird) are not exceptional in our model. Also many cases of the apparent 'sonority reversals' [14] like, for example, Polish *spać* (to sleep) and *psuć* (to spoil), or even *źdźbło* [ʑdʑbwo] 'blade', *przęstępstw* [pʃestew̃pstf] 'crimes', and *bwźdźwiągwa* [bvʑdʑviaw̃.gva] (a sort of a synthesizer) can be accommodated into the model as syllables which do not violate the SSG. This is due to the fact that the universal sonority hierarchy derived from the degree of branchedness of class nodes does not allow for subdivisions of the major natural classes. Obviously, there are languages where consonant combinations of this Polish sort are prohibited, but this is a language specific matter and should not be sanctioned by a constraint which refers to the universal sonority scale. [15] We will suggest in section 4 that language specific scales may be derived from the strength hierarchies defined for individual class nodes.

3.6. A number of phonologists have observed that when a medial consonant or a consonant cluster may be analyzed as either a margin of the preceding syllable (coda) or a margin of the following syllable (onset), it is the onset analysis which prevails. For example, the Polish word *iskra* 'spark', may be syllabified in 3 different ways – all of which are in conformity with the Sonority Sequencing Generalization: a) *i.skra*, b) *is.kra*, c) *isk.ra*. Although all of these syllabifications are permissible (given the Sonority Sequencing Generalization), only the ones in a) and b) are correct. [16] A syllabification like *i.skra* is possible, because Polish contains a number of words which begin with the /skr/ cluster (e.g. *skruszyć* 'pulverize', etc.). The Maximal Onset Principle (cf. Kuryłowicz 1948) expresses this generalization.

(19) Maximal Onset Principle
Word medial onsets are preferred, to the extent that they do not differ from the word initial onsets in a particular language.

We will incorporate this principle into the system, and allow it to function as a sort of 'filter' or language specific 'repair device' superimposed on the universal Sonority Sequencing Generalization.

3.7. In some cases the reference to word-initial onsets does not lead to the optimal syllabification. 'In French for example, a greater range of onset types is available for word-initial syllables than for syllables placed elsewhere in the

[14] Cf. Clements (in press) for an illustrative list.
[15] A typical example of such a language specific constraint is the "Obstruent Sequencing Principle", which Rubach & Booij (1990) proposed to account for the indeterminacy of obstruent sequences in Polish.
[16] Examples like the one from Polish may be cited for any language which has word medial clusters (cf. Selkirk 1982: 355ff, van der Hulst 1984).

word. So while /sl/ or /ps/ are permissible onsets in *slave* or *psychologie*, within the word they must belong to separate syllables: *Is.lande*, *cap.sule*' (Selkirk 1982: 359). Similarly in Icelandic, word-initial #*pl* and #*kl* are reanalyzed as heterosyllabic in word-medial position as in *ep.li* 'Apple', *ek.la* 'the lack of' (cf. Vennemann 1972: 3). The reason for this is that some consonants make a better 'contact' across the syllable boundary than others do. Our formulation of the Syllable Contact Principle in terms of the model where sonority is defined in terms of the feature structure branchedness is the following:

(20) Syllable Contact Principle
Consonants which differ minimally in branchedness of the feature structure form good syllable contacts. There is a preference for the offset segment (coda) to exceed the onset segment in sonority.

This principle has a number of interesting consequences. For example in 'problematic' cases like French *cap.sule* mentioned above, the syllable contact between the /p/ and the /s/ is optimal, as in terms of the feature structure they show exactly the same degree of branchedness. The Polish example *iskra* may also be syllabified as *is.kra*, and this syllabification is optimal from the point of view of the Syllable Contact Principle. The /s/ and the /k/ show the smallest difference in branchedness of all the segments in this word. The empirical content of the Contact Principle is the prediction of the syllabification of such complex consonant clusters.

3.7.1. Vennemann (1986, 41ff, 1988: 50-55) [17] has shown that the Syllable Contact Principle has consequences in the account of diachronic processes. For example, West-Germanic Consonant Gemination may be argued to have this principle as its causing factor. In this process consonants (except /r/) are geminated in front of a semi-vowel. Consider the following changes:

(21)

Proto-Germanic		West-Germanic
satjan	→	settian
skapjan	→	skeppian
kunjis	→	kunnies
halja	→	hellia
farjan	→	ferian

[17] The phenomenon of syllable contact has been thoroughly described by Vennemann (cf. Vennemann 1972, 1986, 1988; Murray and Vennemann 1983), who postulated accounting for it with the Contact Law (1988: 40). Vennemann's predictions are different from the predictions that our Syllable Contact Principle makes. Although the second clause of our principle expresses the same idea as Vennemann's Contact Law, the first clause allows us to achieve a greater degree of generalization. Not only can we accommodate all of the syllable contact changes (cf. Vennemann 1988: 50-55), but additionally we can account for cases like the French one mentioned above and also for English ones like *chapter*, *abdomen*, *napkin*, etc., for which Vennemann has to consult other principles.

Why does /t/ geminate while /r/ does not? The difference is in the branchedness of the feature structure. The /t/, which is specified for all the complex nodes, is very different in degree of branchedness from /j/, in which only one right-branch (STRICTURE) is specified. Thus, the syllable contact between the /t/ and the /j/ is bad, and, consequently has to be repaired by gemination. In the case of the contact between the /r/ and the /j/ the situation is quite different because they have the same number of branches in the feature structure. Hence, syllable contact is good, and it does not have to be repaired. [18]

3.8. The Sonority Sequencing Generalization and the principles of preferred syllabification (Maximal Onset Principle and Syllable Contact Principle) are all expressible within the configurational approach to sonority. They allow us to formulate many interesting generalizations about syllable structure, which are motivated both in phonotactics and in sound change. What we are lacking in this model is an account of preferred syllable types.

3.8.1. The prototypical syllable consists of a single consonant (preferably a laryngeal or an obstruent) followed by a vowel. There is plenty of phonological and phonetic evidence for this prototype. For example:

– there is no language which does not have CV syllables, but there are many languages which have only CV syllables (Maddieson 1984).

– CV syllables are acquired first in the process of language acquisition (Allen 1981; Moskovitz 1971; Ingram 1978; Locke 1983).

– CV syllables are preserved even in the most severe forms of motor aphasia (Dogil 1984b).

– historical syllabic restructuring rules tend towards the creation of CV syllables (Kisseberth 1970; Ohala & Kawasaki 1984).

– when subjects are asked to synchronize clicks with syllables it turns out that the clicks are aligned at a point, called the P-CENTRE (or 'perceptual centre'), which is close to the CV transitions of the syllable (Marcus 1981).

– listeners can classify stops by place better than chance when they are given only the first 10-46 msec. of CV syllables (Blumstein & Stevens 1981), but the classification is much worse in VC syllables.

– the parameters of initial and final transition segments of vowels are not symmetrical in symmetrical syllables (*pap*, *bab*, etc.). The parameters of initial transitions may be successfully used as features of the adjacent consonant place of articulation, but the parameters of final transitions are useful as features only in few particular cases (Tsemiel 1971; Tsemiel & Krinov 1974).

[18] A careful reader will have noticed the problem here. If /r/ in *farjan* does not geminate, why does the /l/ in *halja*? In feature structure representation they are both approximants, and have the same number of branches in the feature structure representation. Still the lateral geminates and the trill does not. In such cases one has to consider language specific strength relations. In West-Germanic trills are higher in sonority than laterals, which can be observed in contrasts like *Kerl* vs. *Keller* with schwa insertion.

– when place of articulation cues are different at VC and CV transitions, listeners tend to follow the CV cues (Wang 1959; Fujimura *et al.* 1978).

– speakers try to create temporally more well defined, more precise, articulations near the CV as opposed to VC interface (Tuller *et al.* 1982).

– listeners can recover missing speech fairly accurately if only the CV cues (Pivots) are preserved (Dogil & Braun 1988).

3.8.2. The degree of distance from this optimal syllable type is also predictable. Kaye & Lowenstamm (1981) observed that complex syllable rimes (nucleus + coda) imply even more complex syllable onsets. Thus, languages which allow for root syllables closed by a single consonant (VC) must also allow for complex onsets (CC). The general implication is illustrated in (22):

(22) ONSET RIME

$$C_1 \ldots C_n \subset VC_1 \ldots C_{n-1}$$

3.8.3. This asymmetry of consonants which precede and follow the vowel in a single syllable is not only quantitative in nature. Complex syllables tend to resemble the prototypical CV syllable also in distribution of sonority. In languages which allow for complex syllables the inventory of syllable final consonants is much more restricted than the inventory of syllable initial consonants. Moreover, the consonants of higher sonority (approximants and nasals) are strongly preferred to obstruents and laryngeals in syllable offset position. [19] Thus, contrary to the 'mirror image' picture of the syllable presupposed by the Sonority Sequencing Generalization, optimal syllables are asymmetrical in nature. The beginnings of syllables favor maximal and evenly distributed rise in sonority and syllable endings prefer minimal and instant sonority falls.

3.9. Clements (in press) proposed to give a formal expression to this generalization in form of the Sonority Cycle Principle. In our model this principle has to be so formulated as to contain crucial reference to the configuration approach to sonority and syllabicity. Consider a proposal for such a formulation in (23).

(23) Sonority Cycle Principle

The sonority profile of a syllable tends to rise maximally (and slowly) towards the peak (associated with the feature structure of the lowest degree of branchedness), and to fall abruptly (in the limit case not at all) and minimally after the peak.

[19] Laryngeals are nearly absent in syllable-final position (cf. Holmberg & Gibson 1979). Obstruents in this position are rare, and they often reflect morphological endings (e.g. syllable final coronal obstruents in German). Approximants and nasals, on the other hand, are often the only consonant types which can close the syllable (e.g. West African languages, Japanese).

We agree with Clements in that the Sonority Cycle Principle should replace the Sonority Sequencing Generalization as the basic expression of the distributional properties of sounds within the syllables. The Sonority Cycle, in the limit case, reflects the prototypical status of CV syllables. In the extended case it reflects the asymmetries observed crosslinguistically for complex syllables. It also renders the Maximal Onset Principle and the second clause of the Syllable Contact Principle derivative. The preference for slow rises at the beginning of a syllable accounts for maximal onsets, and the preference for minimal sonority drops at the end of a syllable accounts for the tendency of syllable offsets to exceed syllable onsets in sonority.

3.9.1. Clements, from whom we took the Sonority Cycle Principle and whose approach to syllabic asymmetries has influenced us substantially, proposes to account for these with a Dispersion Principle (cf. Clements, in press, section 5.2.). The measure of dispersion in sonority is rather complex, and due to the limitations of space, can not be discussed here. It can be, however, incorporated into our model, because the sonority hierarchy which Clements bases this on is very similar to the sonority hierarchy argued for in this study. [20] However, the ways of arriving at this hierarchy are very different. Whereas we claim that sonority is a property derivable from the conceptual framework of geometrical phonology (branchedness of the feature structure), Clements derives sonority from the interplay of binary 'major class features' [vocoid (consonantal), approximant, sonorant].

3.9.2. The approach to feature configurations provided in this study renders all the 'major class features' derivative. The feature [vocoid] (=[consonantal]) has a configurational definition based on the branchedness of the feature structure. Consonants have a branching structure between the INITIATOR and the PLACE node, whereas vowels have a straight path from INITIATOR to PLACE. The feature [approximant] is unnecessary, because approximants, just as other natural classes, are defined as sounds with a particular feature configuration (cf. section 2.3.1.). The sonority (scale) is derivable from considerations of branchedness of the feature structure (the more branches between the INITIATOR and the PLACE, the less sonorant the sound is), and syllabicity is derivable from the Sonority Cycle Principle. We can categorically claim: [21] "*the major class features of the standard feature system do not exist*". In the geometrical model of phonology they are not phonological primes, but a derivative property of the configurational representation of phonetically interpretable distinctive features. The 'major class features' never conformed to the theory of nonlinear phonology. These features are inert, and do not engage in spreading. There is no evidence that features like [sonorant], [consonantal], [approximant], behave as though they occupied an autosegmental tier (or node) of their own. By accounting for them in configurational terms we eliminate this paradox from nonlinear phonology.

[20] The treatment of laryngeals (underspecification of the supralaryngeal complex) is identical in both models (cf. Clements, in press, section 7.3), and glides are nonsyllabic vowels. Clements explicity distingushes between liquids and glides, and uses the feature [vocoid] for this purpose. We do not make this distinction, and so are not able to account for the asymmetries between the OLV and OGV initial (demi)syllables, and VGO vs. VLO final (demi)syllables – the asymmetries, which are predicted by Clements' model. However, context free substitutions of glides for liquids is common in language acquisition, aphasia and dialect variation (cf. Dressler 1984).

[21] As Hankamer & Aissen did already in 1974: 140).

3.9.3. In this section we have argued that there is a universal sonority scale, which is a theoretical construct deeply determined by the conceptual framework of the multidimensional theory of representing speech. We have also shown that the configurational way of defining the sonority scale may be extended to stating general preference laws for syllabification. Our sonority scale is fairly crude and many refinements are necessary before a complete account of such problematic issues as ambisyllabicity, interdependence between syllabicity and stress, morpho(no)logical conditioning of syllable boundaries may be presented. These issues, however, are highly language specific, and they can be incorporated into the model without much damage to its basic principles. A concrete proposal for the extension of the model which we present in the final section of our study is the account of the strength scales for particular class nodes (gestures) of the feature structure which we proposed in the first section. We will show that segmental strength can be represented as a degree of magnitude of individual gestures.

4. *Segmental Strength.*

4.1. The complementary notions of 'strengthening' and 'weakening' have pertained to the conceptual furniture of diachronic phonology since its very beginning. Additionally, the general idea that phonological change is processual in nature can be traced back to such 'proto-phonologists' as Rudolf von Raumer, who provided an interpretation of the Germanic Consonant Shift (Grimm's Law) in terms of strength-relations as early as 1837.

4.1.1. A deductive theory of sound changes encompassing the notion 'strength' was first presented in 1876. However, Eduard Sievers, to whose *Grundzüge der Lautphysiologie* we are alluding, restricted the relation of strength to the gesture of articulation, so that for him only obstruents could contrast in strength (e.g. Swiss German / p,b̥;t,d̥;k,g̊ /) whereas sonorants and vowels were subject to 'syllable strength', which was, per definitionem, not a segmental feature (Sievers 1901: 69-72). This confinement of consonantal strength as a rather concrete phonetic parameter underlying the opposition of 'fortis' and 'lenis' obstruents is still common in traditional descriptive phonology.

4.1.2. Grammont (1933) discerned 'mechanic' and 'psychic' aspects of segmental strength, both of which were entirely dependent on such factors as stress, syllable position, and morphological context.

4.1.3. Thus, segmental strength had not been recognized as an intrinsic quality of speech sounds by phonologists and phoneticians when Wilhelm Geiger discovered that consonantal assimilations in Middle Indic reflected a hierarchy according to which /r/ would always be totally assimilated to a neighboring consonant, be it preceding or following, whereas plosives would always 'win', assimilating all other consonants adjacent to them. On the basis of his material, Geiger worked out the following hierarchy:

(24) Plosives Sibilants Nasals l v y r
<------------------------------------>
strong weak

The interpretation of this hierarchical behavior was that plosives were the strongest segments, since they were assimilantia, i.e. they preserved their features and expanded them to adjacent consonants, while the sonorants were weak, figuring as assimilata, i.e. losing their identity in favor of the stronger segments.

4.1.4. Although the nature of such language specific hierarchies is highly interesting (for more examples, see Drachman 1977), they can hardly be generalized for universal purposes, since one single, unidimensional hierarchy would predict too few results for the huge number of possible phonological processes.

4.1.5. Some recent theoretical approaches to phonology have attempted to reduce as many phenomena as possible to an abstract parameter of strength (often inversely synonymous to sonority, see 0.3.), which is then expanded over the whole range of speech sounds and seems to be inspired by Geiger's and other's findings. More or less differentiated implementations of this idea have proven to over-determine reality, perhaps because of premature axiomatization of results based on insufficient empirical material. [22]

4.1.6. Other authors have tried to categorize speech sounds exclusively according to a concrete physiological parameter of 'articulatory force', aiming at the explanation of diachronic processes in terms of 'narrowing' and 'widening' (e.g. Straka 1964, 1965), [23] but their criteria were too inflexible with respect to the plurality of phenomena (see also Goman 1981).

[22] See Foley (1977) and the critiques in Brakel (1979), Katamba (1979), Rennison (1979), Smith (1981), Brasington (1982), Bauer (1983), answered in part in Foley (1983); cf. also the discussion in Istre (1981).

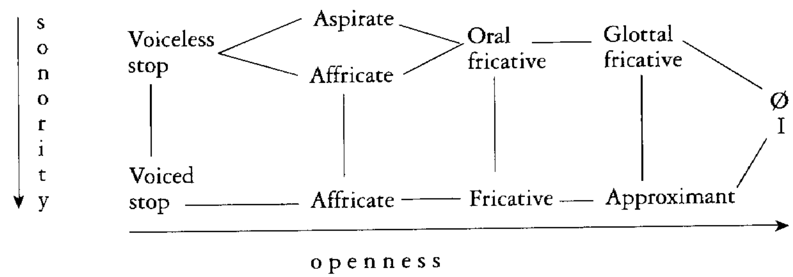
[23] Straka arrives at classifying palatalization as strengthening, because the area of contact of the articulators is larger for palatalized than for nonpalatalized consonants (cf. fn. 42).

4.1.7. So the history of strength as a phonological prime vacillates between two extremes: sometimes it is treated as a minor feature or a shallow 'accidens' determined by a segment's position within the prosodic structure of an utterance and sometimes as a fundamental scale accounting for syllable structure, directionality of processes and other things (see Vennemann 1988).

4.2. In view of the obvious inadequacies of unidimensional strength scales, some authors have proposed two-dimensional 'floating scales' composed of such parameters as voicing and stricture. Let us briefly look at those proposed by Lass (1984) and Hock (1986, 1991).

4.2.1. Lass (1984: 177) states that 'perhaps the best way to look at lenition/fortition overall is in terms of two strength scales, one of openness and one of sonority: movement down the first involves decreased resistance to airflow, movement down the second an increase in the output of periodic acoustic energy. And a segment can, as we will see, move from one hierarchy to another. So:

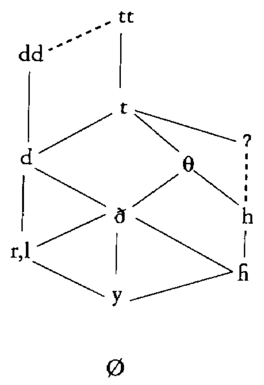
(25)



4.2.2. Hock (1991) presents a weakening hierarchy that is 'largely defined by a combination of increased voicing and sonority' (see 26): 'The changes apply from top to bottom (...). A broken line indicates a possible, but not actually observed change. For notational convenience, dentals have been chosen to represent the different segments classes (as in *t* = voiceless stops), flaps are included among the liquids, and lines leading to Ø have been omitted. (Excepting the geminates, probably all segment classes can go directly to Ø, without having to go through intermediate segmental stages).' (Hock 1986: 82).

4.2.3. It is interesting to observe how one and the same matter is viewed differently by two authors. While Lass relies on the parameters of 'opening' and 'voicing' (the latter being inadequately termed 'sonorization'), Hock renounces any such systematicity, allowing the processes to move freely between archetypical segment classes. Without going into too much detail, (e.g. one might ask for common segment types like voiced aspirates, ejectives, implosives etc.), we observe that both models are distressingly unsatisfying just from a descriptive point of view.

(26)



4.2.4. Consider Lass' placing of aspirates parallel to affricates as a possible intermediate stage in the development of stops to fricatives. There are at least three questions we have to ask with respect to this arrangement:

(a) Does aspiration usually occur in environments typical of weakening processes?

(b) Why are voiceless aspirates unlikely to undergo voicing?

(c) Where are aspirated affricates located in this hierarchy?

We believe that it is impossible to answer these and many further questions in terms of such one- and two-dimensional hierarchies, but we are also convinced that this is no reason to abandon the concept of segmental strength entirely.

4.3. A theory of segmental strength that is compatible with our geometric model of the phonetic space must be refined into a multidimensional framework. As a consequence, we propose that strength should not be conceived as a primary quality of a whole phonological segment, but that it should refer to individual nodes of the hierarchical representation and to individual phonetic gestures. The gestures are: the initiatory, phonatory, velopharyngeal, and articulatory gesture, which correspond to the nodes labelled I, L, SP, and ST, respectively, of the feature tree. An extension of our theory to the place node, which refers mainly to the articulatory gesture, is beyond the scope of our approach, since the place of the articulation gesture is not directly connected with the degree of its execution. We are well aware of the preferences that exist in this respect, but are unable to tackle the difficulties of incorporating this dimension at present. [24]

4.3.1. A phonetic gesture is defined as a relatively independent, homogeneous motoric action forming part of the production of a speech sound. For

[24] Much more phonetic detail would have to be incorporated in such an enterprise, as is exemplified with respect to place of articulation preferences of nasals by Recasens (1991).

instance, the raising of the soft palate with concomitant contraction of the velopharyngeal sphincter is a mandatory gesture in the production of oral as opposed to nasal sounds. According to this view, a phonological process is to be classified as a strengthening or weakening process, if it amounts to strengthening or weakening of such a gesture. Since gesture-specific scales of strength are graded, they allow for a more subtle account of phonetic properties than would a representation in terms of binary features.

4.3.2. Before we discuss the phenomenology of the four 'cardinal' gestures, we must examine their status in phonological theory. There are basically two ways to look at gestures and their execution: from a synchronic-derivational point of view, a gesture is a phonetic execution of a part of the underlying representation of a phonological segment. By the application of phonological processes, this execution can be changed in the course of phonological editing. If these changes are motivated by the structure of the underlying representations of neighboring sounds, we can classify these processes as weakening processes, since they represent a deviation from the execution of one or more gestures as prescribed by the underlying representation. [25] In other words, a segment can be said to undergo weakening because its identity is injured due to environmental impact. This is roughly the way in which processes are classified in Natural approaches to phonological theory (Dressler 1984, 1985). [26] In diachrony, however, it is ultimately the underlying representation itself that is changed, and the diachronic strengthening and weakening processes have to be classified in a less relativistic manner by reference to the phonetic gestures themselves. Thus, gestures are *anthropophonically constant parameters defining the possible range of underlying representations*. Because of this panchronic perspective we will rely heavily on typological evidence in the remainder of this section.

4.3.3. Hierarchical relations of the internal structure of segments are already expressed in terms of gestures by geometric representation. The further ramification of (sub)gestures with their relative strength values distinguishes, inter alia, [27] our approach from the representations of gestures in Dependency Phonology (cf. Anderson & Ewen 1987: Part II) and in

[25] What is weakened in a synchronic weakening process is primarily the iconic mapping relation between the underlying segments and their surface realizatons, not necessarily the gestures involved in the production of the segments. If 'weakening' referred to the gestural alternation of a segment in the course of an assimilation (e.g. /mp/ → [mb]), the same process could as well be termed a strengthening, since the gesture of the dominant segment is expanded to the same extent as the gesture of the segment that undergoes the assimilation is reduced.

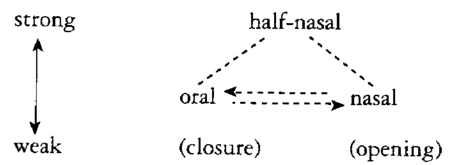
[26] Luschützky (1988) criticizes the current process typologies and proposes a functional dichotomy of adaptive vs. evolutive processes. Both process types can involve strengthening or weakening of gestures.

[27] There are many differences, e.g. concerning the association of gestures to phonological features. For example, Anderson & Ewen (1987: 193ff.) treat aspiration as a matter of initiation (but cf. 4.4.3. here below). We will not enter any polemics in the present article but confine ourselves to the exposition of our own conceptions.

Articulatory Phonology (cf. Browman & Goldstein 1986). The gradation of strength allows much more subtle description of phonological processes. As a paraphrase of what has been noted in 0.1. concerning the geometrical representation of phonetic space, all phonological systems must make use of cardinal gestures, but they do not have to exploit their gradation exhaustively (in fact, they never do).

4.4. From a purely phonetic angle, it would be natural to start our presentation of cardinal gestures with initiation and articulation, since 'from the organic-aerodynamic point of view the production of speech sounds involves (with trivial exceptions) two basic functional components: *initiation* (also called 'air-stream mechanism') and *articulation*.' (Catford 1977: 15). But since we want to develop our notion of cardinal gestures step by step, from the most simple to the most elaborate gesture, we will first deal with the potential of motoric actions related to the SP-node of the feature tree.

4.4.1. The velopharyngeal gesture could be termed a bipolar one, since in most languages segments are underlyingly specified as either oral or nasal. However, there is a tertium comparationis in languages with nasalized obstruents. In hierarchical representation, the only difference between, say, a plain /d/ and a prenasalized /ⁿd/ would be the feature value [+ nasal] instead of a specification as [- nasal] for the former. [28] Furthermore, prenasalized obstruents are distinguished from 'true' nasals by their specification for the L-node, which is absent in the latter. According to the procedure of deriving sonority from the branchedness of the feature structure (as exemplified in 3.3.), plain voiced obstruents and prenasalized obstruents would thus be equivalent with respect to the strength of the velopharyngeal gesture, as can be seen from the representation of this gesture in (27):

(27)


4.4.1.1. The term 'half-nasal' (cf. French *mi-nasal(e)*) refers to three phonetically distinct categories of speech sounds: (a) prenasalized obstruents, (b) postnasalized stops, (c) nasalized obstruents. Since no language contrasts two or all three types of half-nasals, there is no need to establish a further distinction in the representation of the velopharyngeal movement. The

[28] There is almost general agreement that prenasalized obstruents should not be analyzed as clusters of nasal+obstruent (but see Herbert 1986: chapters 3-6). Many African languages have this type of clusters in addition to a series of prenasalized obstruents. The problems associated with not treating prenasalized segments as in some way asymmetrical are amply discussed in Ewen (1983: 38-46).

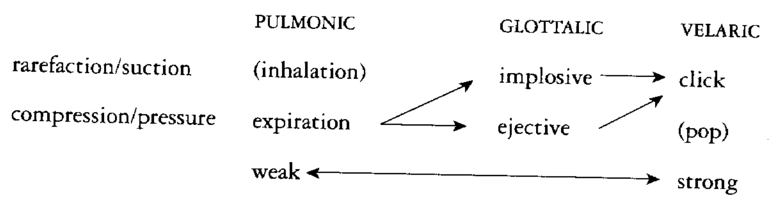
classification of the half-nasals as strengthened with respect to the velopharyngeal gesture is derived from the basic calculus that the activation of two antagonistic subgestures in one single segment involves more phonetic action than the operation of only one term. It may be due to this gestural complexity that half-nasalization is not as frequent as one might expect from its being one of the four possible reactions of the speech production mechanism to resolve the so-called stop-voicing dilemma (cf. Keating & Linker 1982). If there is a short moment of nasalization during the formation of a stop, the transglottal airflow indispensable for voicing can be maintained without additional acrobatics like reinforced lowering of the larynx, and the opposition between the series of voiced stops and the series of nasals is still left undamaged. But cases involving an across the board prenasalization of oral or nasal consonants are unknown to us. This is not to claim that prenasalized consonants never develop from the latter types. However, when they do, it is a contextually conditioned development, e.g. nasals may become prenasalized stops preceding an oral vowel or oral stops may be prenasalized following a nasal vowel. (Herbert 1986: 44). In view of this it is interesting that 13 out of the 19 languages with a series of prenasalized obstruents sampled in the UPSID lack a parallel series of plain voiced stops. So there could be a 'functional' relationship between voicing and prenasalization of stops. Interestingly, five of the remaining six languages pertain to African phyla, whereas the type of obstruent systems lacking the contrast between prenasalized and plain voiced stops is scattered widely with respect to genetic and areal affinity. In addition to these typological correlations, we observe that there is only a very small number of languages with voiceless prenasalized stops, e.g. Rundi (Mioni 1971). The other types of half-nasals are of very limited occurrence: In Ful and in some northeastern Bantu languages of Kenya (Möhlig 1974) the nasalization is extended over the whole duration of the half-nasal obstruent. According to descriptions in Ladefoged & Traill (1984), some of the nasalized clicks in Khoisan languages fall into this category, too. Postnasalized, i.e. nasally released stops, occur in a couple of Austronesian and Australian languages, e.g. Aranda (Hagège & Haudricourt 1978).

4.4.1.2. As is well known from instrumental phonetic investigations (e.g. Clumeck 1976), the inertia of the velopharyngeal gesture is considerable, i.e. the nasality of a nasal tends to spread over whole prosodic units of speech, and this inertia increases with tempo and casualness. So we can infer that the precise timing of velopharyngeal gestures in the production of half-nasals contributes to their subsequent simplification. There are several reconstructed instances of a change from half-nasals to plain voiceless stops or to nasals (Guthrie 1967-70 for the Bantu-stock; Haudricourt 1964 for the Austronesian phylum), but in some languages half-nasals develop into other strengthened categories of stops, viz. voiceless aspirates or ejectives (see Herbert 1986: 40ff).

4.4.1.3. Prenasalization as an intermediate step in the development from nasals to voiced stops is less than scarcely attested, though not impossible. In most language histories, nasals prove to be a stable category compared to other classes of sounds (cf. Maddieson 1984: chapter 4), in spite of the constant erosion that affects them in certain contexts, particularly in the postvocalic environment; but this erosion affects their gesture of articulation rather than their velopharyngeal gesture. The relative inertia of the velopharyngeal gesture provides for the survival of nasals in sound systems, denasalization being restricted to more special environments than nasalization. It follows from our gesture-based approach to segmental strength that nasals are not 'weaker' than other stop consonants, but more sonorant, as expressed by their representation in terms of the geometrical model (see 2.3.2.). The subgestures of lowering and raising of the soft palate are equivalent with respect to a scaling of their relative strength, and there is no evidence from synchrony or diachrony that would support a hierarchical ranking in this respect. On the other hand, there is evidence for classifying 'half-nasals' as stops with a strengthened velopharyngeal gesture. The tendency of this category to develop into plain voiceless stops reflects the phonetic constraints on the production of voiced stops and is often implicated in radical sound shifts affecting the whole system of obstruents, as in the case reported for Rotuman (Eastern Oceanic, north-west of the Fiji Islands) by Haudricourt (1964: 106), where the series of half nasals has undergone devoicing and the original voiceless plosives have shifted to fricatives (actually *p > f > h; *t > θ > f; *k > ʔ).

4.4.2. Unlike the velopharyngeal gesture, the initiatory gesture is not 'bipolar' in the sense envisaged in the preceding paragraph. It 'generates the airflow that powers speech production' (Liberman & Blumstein 1988:3), so its opposite would be silence. This suggests a representation along a strength scale parallel to the vector of its execution, as given in (28):

(28)



'*Initiation* is a bellows-like or piston-like movement of an organ (an *initiator*) that changes the volume of the vocal tract adjacent to it, thus compressing or dilating the air contained there and consequently *initiating* an actual or potential flow of air'. (Catford 1977: 15).

4.4.2.1. In the unmarked case, pulmonic initiation is expiratory, inhalation being merely an occasional surface phenomenon characteristic of certain speech acts, and even then specific to certain idiolects.

4.4.2.2. Glottalic initiation [29] can be either implosive or ejective. In the latter case, '(...) the glottis is tightly closed, and the larynx is jerked upwards by action of the extrinsic laryngeal muscles (...)' (Catford 1977: 68). If the supralaryngeal exit is barred by velopharyngeal constriction and obstruent articulation, the intraoral pressure exceeds that of normal pulmonic initiation (ibidem, 69), and the formant transitions are more significant than those of plain obstruents (Ladefoged 1964: 5ff). Thus the phonetic properties of ejectives justify our decision to classify them as strengthened with respect to the initiation gesture. The higher intraoral pressure produced by the rise of the larynx causes the articulatory gesture to be reinforced by tension of the respective musculature. Instrumental investigations of the articulation of ejectives have shown that the duration of the closure phase as well as the overall duration of ejective plosives exceeds that of plain, and even more so that of aspirated plosives significantly (for Korean, Han 1985, for Eastern Armenian, Chačatrjan & Ajrapetjan 1971, see also Hogan 1976). Ejectives are often characterized as 'strong' or 'strengthened' by reference to this reinforcement of the articulatory gesture, but the primary strengthening is that of initiation, the articulatory tensing being only epiphenomenal. In the production of implosives, the direction of the airstream must be inverted with respect to the nonimplosive environment, so their higher rank on the strength scale for initiation is justified as well.

4.4.2.3. Oral initiation ('velaric suction') [30] is clearly the most marked of all possible ways of creating pressure differences inside the vocal tract, and its systematic implementation is confined to a small number of genetically and areally related languages. According to Ladefoged & Traill (1984: 11), all clicks, including those with complex accompaniments like voicing, aspiration, glottalization, nasalization etc., should be analyzed as units, so that it would be more appropriate to speak of combined pulmonic and oral, or glottalic and oral initiation. Another way of expressing the peculiarity of 'extrapulmonic consonants' (Jakobson 1968) is to say that in the case of ejectives and implosives the gesture of initiation coincides with the gesture of phonation, whereas in the case of clicks it coincides with the gesture of articulation. We account for these coincidences by introducing the concept of *gestural conflation*, from which only the velopharyngeal gesture is suspended. [31] We have already mentioned conflation of initiation with phonation and articulation, respectively. The third logically possible instance of gestural conflation would be coincidence of phonation and articulation: this is the case

[29] One should prefer the term 'laryngeal' instead of the more widely used 'glottalic', because the labour of compression or rarefaction is performed by the musculature of the larynx, especially in the production of implosives.

[30] In the case of clicks, it would be more precise to speak of lingual initiation, since the rarefaction is accomplished by the musculature of the tongue.

[31] One could philosophize about whether the concept of gestual conflation applies to nasally released plosives, as in Aranda (/b^m, d^n/ etc.), but also in casual German [hat^{n}ʃo:n] *hatten schon*. In any case, these are also instances of gestural condensation.

of the so-called laryngeals (cf. 4.4.3.). The possible types of gestural conflation can be expressed through the following equations:

(29)	Initiation	=	Phonation	(ejectives, implosives)
	Initiation	=	Articulation	(clicks)
	Phonation	=	Articulation	(laryngeals)

The fact that 'extrapulmonic consonants' are not all frequent in the languages of the world [32] indicates a general tendency to keep the gestures of speech production separate with regard to their respective function. Laryngeals are of course not infrequent, [33] but prone to loss.

4.4.2.4. Our concept of gestural conflation leads us to the statement that the scaling in (28) is not intended to express an implication by which a language having clicks must also have ejective or implosive consonants. Nama, one of the Khoisan languages, has a set of 20 click phonemes, and all the non-clicks are pulmonically initiated (Beach 1938). There is no relation whatsoever between the scales of gestural strength and the presence or absence of a category of segments in the sound system of a given language. Otherwise, it would be impossible to set up a strength scale for the articulatory gesture as in 4.4.3. below, since the presence of stops would then imply the presence of all other categories of consonants, whereas the exact opposite proves to be the case. Likewise, there is no implicative relation between the two types of laryngeal initiation: 45 of the languages sampled in UPSID have ejectives but no implosives, 21 have implosives but no ejectives, and only 12 languages contain both segment categories (see also Fordyce 1980).

4.4.2.5. As we mentioned above, lowering of the larynx is one of the four possible techniques to resolve the stop-voicing dilemma. From this potential accommodative function we can arrive at the diachronic hypothesis already suggested by Greenberg (1970: 23) '(...) that at least one source of injectives might be a sound shift from voiced plain to voiced implosive stops.' Diachronic evidence supporting this claim comes from Sindhi (Chatterji 1931) and from Eastern Armenian (Pisowicz 1976), where a series of implosives has developed out of the former plain voiced stops. Other cases are less well attested, but the fact remains that a considerable number of languages in many different regions of the globe lack a series of plain voiced stops paralleling their implosives (cf. Greenberg 1970), a situation similar to that of the half-nasals (see 4.4.1.).

4.4.2.6. There is no immediate diachronic evidence for the further development of implosives. Certain inferences can be drawn from their patterning

[32] 78 (24,6%) of the languages sampled in UPSID contain nonpulmonically initiated consonants.
[33] 146 (46%) of the languages sampled in UPSID have /ʔ/, 202 (63,7%) /h/.

with respect to place of articulation, but a stop system like that of the Chadic language Kanakuru does not tell us directly whether a former */ɠ/ has become /ʔ/, which would then 'fill the hole in the pattern'. An alleged prehistoric */ɠ/ could just as well have collapsed with plain /g/ or, most probably, never have existed at all (see (30).

(30) Subsystem of plosives of Kanakuru (after Newman 1974):

p	t	k	?
b	d	g	
ɓ	ɗ		

4.4.2.7. A well known context-sensitive development with obvious phonetic causality is the change from implosive to pulmonic initiation in postnasal environments. However, this is exactly the position where ejectives appear to be favoured. Herbert (1986: 240f.) cites a statement by Doke (1926), according to which postnasal voiceless aspirates (and nonvelar voiceless fricatives) become ejective in Zulu by a synchronic rule, and there are parallel processes in other languages. The genesis of ejectives in this environment, as the genesis of ejectives on the whole, remains generally unexplained. It seems to be clear that the gesture of phonation must play a role in these processes, since it is the primary determinant of the approximation of the vocal cords. A tentative hypothesis for an account of postnasal ejectivization could be the following: delayed velopharyngeal constriction (due to the inertia of the respective gesture) prevents the build-up of intra-oral pressure sufficient for the plosion of the plosive, so the initiatory gesture is strengthened as a compensatory process. Catford (1974: 25) has tried to provide a phonetic explanation for the context-free development of ejectives from plain voiced stops, as attested in Eastern Armenian (Pisowicz 1976). However, there is no conceivable reason for the larynx to move upwards during the formation of the oral closure of a stop. On the contrary, we have just claimed that it should move downward in order to facilitate voicing. So the only interpretation we can offer for this process is that in such cases the gesture of phonation is reinforced as a reaction to the lack of transglottal airflow during stop articulation, which amounts to gestural conflation at the same time. We will clarify this idea, after having dealt with the gestures of phonation and articulation, in 4.5. below.

4.4.2.8. The further development of ejectives can be studied in some North-East-Caucasian languages, where they have become plain voiced plosives, e.g. in Chechen (Dešeriev 1967) and Ingush (Dolakova 1967).

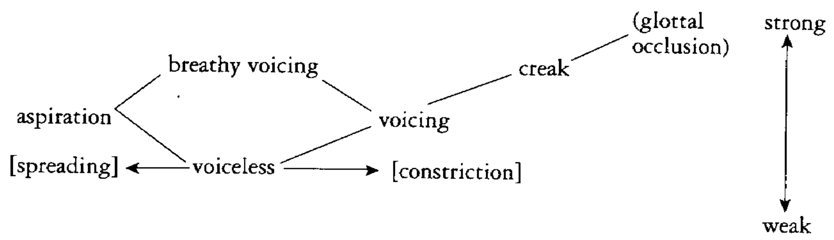
4.4.2.9. Virtually nothing can be said about the emergence and further development of clicks. The Khoisan languages seem to have had them at times, and several neighbouring non-Khoisan languages have acquired their clicks through adoption, not by mutation (Westphal 1971). Some east African languages are considered to be related to the Khoisan phylum partly because of the presence of clicks in their phoneme inventories (Greenberg 1966: 72f.; Tucker & Bryan 1977). Synchronically, click consonants prove to be highly resistant to phonological processes induced by their phonetic environment (Herbert 1986: 242).

4.4.3. The gesture of phonation corresponding to the L-node of the feature tree bears a certain resemblance to the velopharyngeal gesture in that it can be analyzed as consisting of two subgestures, viz. spreading vs. constriction of the vocal cords, encoded as [spread glottis] vs. [constricted glottis] in the feature specification of the tree. But due to the anatomical complexity of the inner larynx, the possible configurations of the subgestures are a bit more elaborate than just bipolar. The four logically possible combinations of the laryngeal features generate the following properties of sounds:

(31)	[- constricted glottis]	[- spread glottis]	:	voicelessness
	[- constricted glottis]	[+spread glottis]	:	aspiration
	[+constricted glottis]	[- spread glottis]	:	voicing
	[+constricted glottis]	[+spread glottis]	:	breathy voicing

'By *phonation* we mean any relevant activity in the larynx which is neither initiatory nor articulatory in function.' (Catford 1977: 16). Since the glottal stop and the variants of [h] are products of the gestural conflation of articulation and phonation, we need not consider them in this paragraph and so are left with the five categories of voiceless, voiced, aspirated, breathy, and creaky voiced sounds. Thus we can design the following representation for the gesture of phonation:

(32)



The relationship of representations in terms of features (31) and in terms of (sub)gestures (32) is established on the basis of the threshold phenomenon by which the continuum of spreading and constriction of the glottis is split up into different perceptual categories. On the importance of the concept of threshold in the mapping of articulation and perception, see Stevens & Keyser (1989: 84ff).

4.4.3.1. Since creak is produced with a closed glottis, we represent it as the strongest type of phonation due to glottal constriction. [34] On the status of the glottal stop with respect to phonation, see 4.4.3.

4.4.3.2. The existence of the category of voiced aspirates teaches us that the subgestures of spreading and constriction of the vocal cords can appear as condensed in a single segment, parallel to the complex gesture in the case of the half-nasals (cf. 4.4.1.).

4.4.3.3. The strengthened character of aspiration with respect to phonation seems to be intuitively obvious, so we need not cite examples from the vast instrumental phonetic evidence in support of the left part of our representation. [35] However, if we recall the strength scale proposed by Lass (1984) and discussed in 4.2.1., there seems to be a widespread inclination to posit aspiration as a weakened intermediate step in the spirantization of plosives. This view of the facts provides an optimal opportunity to demonstrate the superiority of a differentiated account of segmental strength over holistic approaches.

4.4.3.4. In terms of cardinal gestures, spirantization is the natural result of antagonism between strengthened phonation and articulation. Consider the development of the Proto-Indo-European series of breathy voiced plosives in the various daughter-languages: [36]

(33)	$*D^h$	>	T^h	in Greek and Proto-Italic
	*Dh	>	D/Đ	in Germanic
	*Dh	>	D	in Anatolian, Iranian, Balto-Slavic, Celtic, Arm
				no change in Indo-Aryan

Except in Indo-Aryan, the complex gesture of breathy voicing (as a condensation of the antagonistic subgestures of aspiration and voicing) has been weakened to only one of the subgestures. Most of the daughter-languages lost aspiration, whereas Greek and Proto-Italic lost voicing and in their further development aspiration as well. In the Hellenistic period, the series of voiceless aspirates (and the series of plain voiced plosives) of the Attic Koiné was weakened to spirants, and the Proto-Italic voiceless aspirates became ultimately *f*, *h*, *w* in Latin. However, as we will argue in this section, the

[34] Creaky voiced sounds are often transcribed with a superscript glottal stop, which indicates their strengthened glottal constriction/phonation tension.

[35] There is general agreement among phoneticians that aspiration is primarily a matter of phonation, not of initiation. Notice that, if this were not so, our model would wrongly predict the impossibility of total assimilations like Bartholomae's Law.

[36] For the sake of brevity, we use the cover symbols D^h for breathy voiced, T^h for voiceless aspirated, D for plain voiced stops, and Đ for voiced fricatives. For details, see any handbook on Indo-European comparative phonology.

spirantization of aspirates is not a deaspiration in the phonetic sense of the term but rather a weakening of the articulatory gesture, giving way to the strengthened phonation of the airstream which can thus be maintained. So the general process of spirantization indicates that what we have called the stop-voicing-dilemma in the preceding paragraphs should rather be termed 'stop-phonation-dilemma', including aspiration as a phonation-type.

4.4.3.5. There is phonetic as well as phonological evidence that in the process of spirantization the gesture of aspiration is not weakened at all. A confirmation of this assumption is provided by languages like English, where plosives remain unaspirated when following a tautosyllabic fricative (here, actually, a sibilant, due to the language-specific constraints on initial consonant clusters). Our claim is that in such a language the initial fricatives are actually aspirated, but since the aspiration can occur simultaneous with the articulation, it remains phonetically opaque due to its being masked by acoustically predominant fricative noise. [37] This implies only that in languages like Burmese, where there is a contrast between aspirated and unaspirated fricatives, the latter must be specified as [-spread glottis] in the phonological representation; but here there is no possibility to get away without such a specification.

4.4.3.6. What holds for fricatives must be valid also for voiceless approximants according to our definition in 2.3.1. In Ancient Greek, word-initial *r-* (from **sr-* and **wr-*) was aspirated, because the preceding obstruent lost its articulation but left its phonation gesture (*s-* >*h-* by phonetic law); [38] *w-* could have gone through a stage of devoicing (subsequently [φ] > [h] by the same law). This also happened to *l-* (from **sl-*), but in that case the aspiration must have been lost relatively soon. [39] Similar phenomena were present in Middle Indic, where the /s/ left its timing unit when Sanskrit clusters of the type *-sT-* became aspirated geminates *-TT*^{h}*-*).

4.4.3.7. As a consequence of the stop-phonation dilemma, voiceless aspirated and plain voiced plosives share the propensity to undergo weakening in one of the following ways:

(a) By 'dephonation', voiced plosives are devoiced, as in Germanic and Armenian, and aspirates are deaspirated, as in certain dialects of Bengali and Punjabi (see below).

(b) By 'dearticulation', the respective plosives undergo spirantization, as in Germanic, Spanish, Post-Classical Greek.

[37] Instrumental measurements by Yoshioka & Löfqvist (1981) support our view of the present phenomenon; see also Kingston (1988) and references therein.

[38] For a general account of this process see Méndez-Dosuna (1987).

[39] There are a few inscriptions with AH(se Lejeune (1972: Paragr. 140, where all instances of aspirated liquids and nasals are discussed meticulously).

Half-nasalization and glottalization, which have been treated in 4.4.1. and 4.4.2., respectively, are not weakening processes and are therefore less natural responses to the phonetic apory of stop phonation. As a by-product of our typology, we can claim that weakening processes are preferred over strengthening processes in the resolution of conflicts between interfering gestures or subgestures (cf. Dressler 1984).

4.4.3.8. Changes in the phonation-type of a segment category are often context sensitive. This is due to the unequal distribution of the subgestures within a syllable slope: the nucleus favors voicing, aspiration being characteristic of syllable margins, especially the onset. This means that the syllable type $C^{h}V$ results from a polarization of the phonation gesture across the *CV*-sequence. However, it is typical for the process of deaspiration mentioned under (a) above that the phonatory gesture of the consonant is shifted to the following vowel, giving rise to a contour tone for the latter. Therefore we can account for such processes of tonogenesis in terms of our concept of gestural condensation. To give an example that also reflects our strength hierarchy for phonation types, we refer to Thal-Lamti, a Dardic language of Northern Pakistan, where formerly voiced aspirates (inherited from Proto-Indo-Aryan) have lost the subgesture of aspiration, which caused a rising tone for the adjacent vowels, and the voiceless aspirates remained unchanged. The subsystem of plosives has thus been simplified, but the relevant oppositions have been maintained.

(34)

	D^{h}				(V́D)	
T^{h}		D	>	T^{h}		D
	T				T	

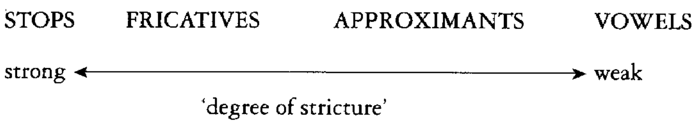
In other Dardic languages, both voiced an voiceless aspirates have undergone such changes (Ėdel'man 1965). Similar phenomena are attested for various modern Indo-Aryan and many East Asian languages (Chatterji 1964; Hagège & Haudricourt 1978). In terms of the geometrical model, these processes can be described as a spreading-without-delinking of the L-node of the consonant to adjacent vowels, but the changes in the specification of the node are better understood as a shift in gestural condensation from consonants to vowels, giving rise to a contour segment.

4.4.3.9. The role of aspiration in processes of tonogenesis confirms its status as a manner of phonation, and the apories brought about by its treatment as an articulatory feature are automatically avoided by a multigestural account of segmental phonology.

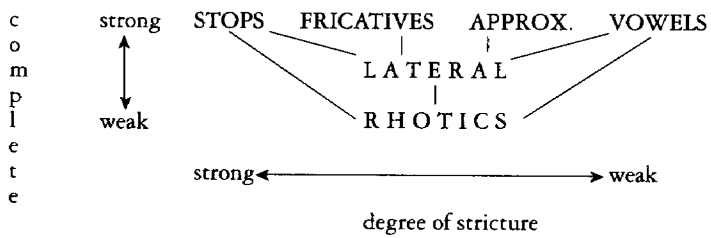
4.4.4. '*Articulation* is a movement or posture of an organ (an *articulator*) that interrupts or modifies the air-flow in such a way as to give rise to a specific type of sound. (Catford 1977: 15). It is difficult to represent the complexity of the articulatory gesture on a two-dimensional sheet of paper, for we have to account for the following three parameters:

(a) Degree of stricture (e.g. stops vs. fricatives)
(b) Completeness of stricture (e.g. stops vs. laterals)
(c) Gestural condensation (affricates and diphthongs).

Complete closure of the vocal tract at some 'place of articulation' is surely the strongest degree of articulatory stricture. It is graded down along the parameter of approximation of the active and passive articulators, according to the scale given in (35):

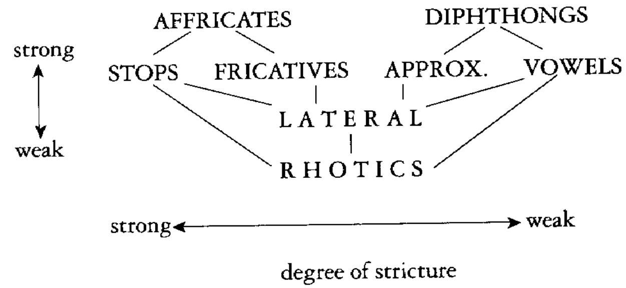
(35)


This arrangement is quite uncontroversial (cf. the approaches discussed in 4.2.1.), but at the same time unsatisfying, since it does not account for the special phonetic character of the various types of sounds subsumed under the heading 'approximant'. The laterals differ from the 'semi-vowel' type of approximants in that there is a stop-like contact of the articulators some place in the oral cavity, but this contact is *locally incomplete*, so no explosion or implosion can occur. Trills, taps, and flaps, on the other hand, show locally complete contact of the articulators, but the duration of the closure is too short to be called a 'phase', hence this volatile sort of constriction must be termed *temporally incomplete*. Since the "active articulator" is somewhat "passive" in the production of rhotics, we posit this category as relatively weaker than the laterals. The degree of locally or temporally incomplete stricture can vary from 'fricative' (voiceless and voiced lateral /ɬ/ and /ɮ/ as in Zulu; voiced fricative /ř/ as in Czech) to 'approximant', so the combination of parameters of degree with completeness of articulatory stricture is best represented as in (36):

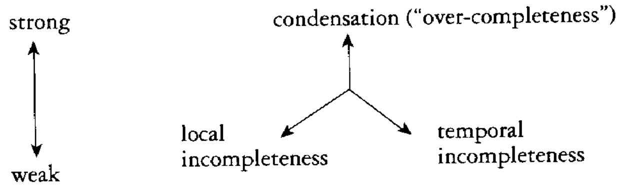
(36)


4.4.4.1. To this two-dimensional spectrum, the parameter of gestural condensation must be added to account for the contour segments. In the first place, these are affricates and diphthongs. Furthermore, the coarticulated segments like labialized, velarized, or palatalized consonants, as well as the

'multiply articulated' stops (e.g. labiovelars) are considered by us to be most adequately represented by the descriptive means of gestural condensation, but their strength value depends on that of the primary articulation, so we need not include them in the following scheme (37):

(37)


In order to clarify the three-dimensional nature of this representation a projection of the parameter of completeness and condensation along the axis of 'degree of stricture' is given in (38):

(38)


4.4.4.2. Our three-dimensional representation of the articulatory gesture reflects the following empirical observations:

(a) Most of the world's languages make use of all three parameters of articulatory modification: Only 13 (4,1%) of the 317 UPSID-languages lack the category liquid altogether, whereas 197 (62,1%) make use of the bifurcation of the parameter of completeness of stricture (cf. Maddieson 1980; 1984, 72ff.) [40] 220 ((69,4%) of the said languages have at least one affricate in their inventory of underlying segments, but on the other hand the number of languages with underlying diphthongs is surprisingly low: 26 (8,2%).

(b) There is a particular affinity of liquids (especially the rhotics) to both extremes of the stop-vowel-continuum: Liquids may arise directly from stops (e.g. through flapping) and may directly undergo vocalization.

(c) Rhotics are generally weaker than laterals. This asymmetry accounts for the preferred internal sequencing of tautosyllabic clusters of liquids (*lr-* as in Armenian, *-rl* as in English; no language seems to tolerate the reverse order of those elements).

[40] 75 languages have only one liquid, there being a slight preference for the rhotic type.

(d) When affricates are weakened, they generally lose the stronger of their subgestures, i.e. they become fricatives rather than stops. Similarly, diphthongs are weakened to vowels (by monophthongization), not to approximants; but here, of course, prosodic factors are strongly determinant.

(e) Lateral affricates are possible, but of limited occurrence, since the condensation of complete and incomplete stricture-types is more far fetched than that of gestures differing only in degree of stricture. Still, 15 (4,7%) of the above mentioned languages have lateral affricates. [41]

4.4.4.3. The treatment of coarticulated segments as strengthened with respect to articulation is already justified per definitionem. However, it is important to keep the notion 'coarticulated' (underlying segments) apart from the meaning of 'coarticulation' as an assimilatory phonological process and to remember what has been claimed in 4.3. above concerning the status of gestures in a theory of segmental phonology. Assimilation processes like the palatalization of a bilabial stop before a front vowel are weakening processes, since the distinctive labial colouring of the plosive release is injured by the palatal offglide, and the movements of the articulation are coordinated in a certain sense. But here we are dealing with motoric programs corresponding to underlying representations, stating that in languages like Russian or Lithuanian the pronunciation of, say, the phoneme /p^j/ involves a strengthening of the articulatory gesture, since the palatal offglide has to appear in all environments, without being triggered by the phonetic environment. [42]

4.4.4.4. The genesis of coarticulated sounds through loss of the conditioning environment is well attested from a variety of languages (see Bhat 1978 for palatalization). Their propensity to become weakened may be illustrated by the history of the Proto-Indo-European labialized velar plosives. In all the daughter-languages they underwent weakening sooner or later in various ways, except in Latin.

4.4.4.5. Since most of the context-free sound changes affecting the articulatory gesture cannot be separated from the impact of phonation, the overwhelming majority of instances of 'autonomous' changes of articulatory strength are bound to conditioning environments such as those expressed in Vennemann's 'Preference Laws' (see Vennemann 1988). We can refer to most of the examples collected in this book with some modifications (although we basically disagree with the scale of 'consonantal strength' adopted therein).

[41] 11 of them pertain to Northern Amerindian phyla.

[42] Straka (1964;1965) has been misunderstood in this very respect when he pointed out that palatalization involves an increase of articulatory energy. It would be absurd to claim that the anticipation of a gesture must always simplify the gestural configuration of the affected segment. Since in our model there is no basic ontological difference between processes and gestures (both are 'events', not 'units'), such problems of classification are in principle irrelevant.

For instance, the 'Head Law' rightly predicts that in the absence of a syllable head '... there will be changes filling the onset position; and there are indeed. Northern Speakers of German insert glottal stops at the beginning of naked syllables, especially word-initial and stressed ones.' (ibidem, 14). Since these glottal stops do not constitute a separate phoneme, their treatment as segments in geometrical representation would be awkward, because the creation of an I-node ex nihilo is much more costly than would be the association of any node to an already existing I-node. An analysis positing underlying I-nodes for all syllable onsets that must be 'filled' with a minimal, i.e. a laryngeal specification in the absence of any other specification would be even worse, because it would attribute to the glottal stop a quasi-phonemic status it does not have. As a solution to this problem we propose to conceive of the glottal stop of Northern German as an instance of strengthened phonation, e.g. the maximization of the subgesture of glottal constriction. All in all there are three different ways glottal stops can appear in a language:

(a) as an instrument of strengthened initiation in the production of ejectives;

(b) as a nonphonemic (often emphatic) accompaniment of 'naked' vowels, as in Northern German and French ('coup de glotte'), hence a strengthening of phonation;

(c) as a separate phoneme, as in Semitic languages and many others, an instance of gestural conflation of articulation and phonation.

If the glottal stop of Northern German were to count as a real plosive, we would have to explain why in this language the strongest type of obstruent is inserted to fill the onset position whereas in other languages the weakest sort of consonants, i.e. the approximants, serve as auxiliary syllable heads. In our opinion, both cases are minimal adjustments of the execution of cardinal gestures: some languages choose strengthening of articulation (glide formation), others strengthening of phonation (glottal occlusion).

4.4.4.6. The relative weakness of laryngeals with respect to other consonants is a consequence of the gestural conflation involved in their production. The phonation gestures of adjacent segments tend to interfere with the homorganic (i.e. glottal) articulation of laryngeals, and the articulatory gestures of the adjacent segments tend to overlap the laryngeals because of the lack of supralaryngeal gestures of the latter (a spreading-without-delinking process type in terms of the geometrical model). The consequence of this situation is diachronic instability. In the Indo-European languages, the three laryngeal phonemes of Proto-Indo-European have generally disappeared through manifold processes of vocalization (e.g. *HC > VC in Greek), deletion (e.g. *HV > V in most of the IE languages), or coalescence (*TH > T^h in Indo-Aryan), leaving but one direct trace in Hittite. [43] On the other

[43] There are many indirect reflexes (lengthening, colouring etc.).

hand, Semitic languages have retained Proto-Semitic laryngeals fairly well (except Akkadian, where all laryngeals merged to /ʔ/). Such phenomena as 'areal features' and 'basis of articulation' are of course beyond any explanatory scope of phonological theories. Although the search for an understanding of why certain changes occur is logically connected with an explanation of their local non-occurrence, we must begin our scrutiny with the what actually does occur.

4.4.4.7. Since articulation is the most salient 'instrument' in our 'quartet' of cardinal gestures, it is here that the factor of quantity becomes crucial as a phonological value. Basically, it is quite unproblematic to introduce length as a general dimension in which all gestures can be strengthened (cf. Hock's assessment cited in 4.2.2.). In fact, all processes of assimilation are reducible to a temporal aspect of gestural execution. However, only with respect to articulation does lengthening count as prosodic. We will not pursue this issue any further here, but will confine ourselves to the statement that the present account of segmental strength is in principle open for a unification with any theory of prosodic strength.

4.5. According to the definition of gestures given in 4.3., the independence of these motoric actions is only relative with respect to one another.

4.5.1. The interdependencies between the cardinal gestures presented in the preceding paragraphs are considerable. We have already discussed at some length the instances of gestural conflation and the antagonism between phonation and articulation, so what remains to be treated in this concluding section are the relations of convergence that hold between the cardinal gestures.

4.5.2. As suggested by the hierarchical representation of the class nodes (cf. 1.6.), initiation is the basic prerequisite for all the other gestures to apply. Pulmonic initiation provides the air stream indispensable for phonation, nasal resonance generation and aerodynamic circumstances of articulation. Its intensity is directly propagated by the respective correlates of the latter, i.e. the more energy invested in initiation, the stronger the phonation and turbulence that can be achieved. By virtue of conflation, glottalic initiation determines phonation in that ejectives can be only voiceless and implosives can be only voiced, both always unaspirated. But there is a clear tendency for strengthened initiation to be combined with strengthened articulation. All implosives are per definitionem stops, and of the 302 ejective phonemes contained in the UPSID only 21 (7%) are fricatives, whereas 94 (31,1%) are affricates and 187 (61,9%) are plosives. Furthermore, it is interesting to observe that (the total numbers of voiceless affricates and plosives in the UPSID being 477 and 1,719, respectively) the propensity of the

affricates to be ejective is higher than that of the plosives, as shown in table (39):

(39)		*voiceless plosives*	*voiceless affricates*
	non ejective	1,532 (89.1%)	383 (80.3%)
	ejective	187 (10.9%)	94 (19.7%)

These results must be taken as cross-linguistic evidence supporting our decision to place the category of affricates at the top of the strength scale for articulatory gestures (see (37)). The correlation of aspiration with respect to the categories of affricates and plosives is less spectacular, but still points in the same direction: 104 of the 477 voiceless affricate phonemes contained in the UPSID are aspirated, but only 321 of the 1,719 voiceless plosives have the gesture of phonation strengthened in that way. Compare the table given in (40):

(40)		*voiceless plosives*	*voiceless affricates*
	unaspirated	1,398 (8.3%)	373 (78.2%)
	aspirated	321 (18.7%)	104 (21.8%)

However, this statistical description is less significant because of the intrinsic aspiration of the fricative subgesture of affricates that could enhance the aspiration of the whole segment, whereas the stop-phonation dilemma disfavours aspiration of plosives.

4.5.3. If we compare these four types of speech sounds represented by the cover symbols T, T^s, T^h, T^{sh}, some questions concerning the relative weight of the cardinal gestures arise. For example, one might be led to assume that aspirated plosives and unaspirated affricates are of equal segmental strength, since both are strengthened with respect to a cardinal gesture, and if initiation is considered too, one would get a triad of T^h, T^s, T', all of equal segmental strength. A prenasalized stop ^{n}D would be one degree stronger, because of it being voiced in addition to the strengthening of its velopharyngeal gesture. However, this computational procedure is based on the premise that all cardinal gestures are compatible with respect to one another, and this we must seriously question. There is no universal metaparameter on which, say, the strengthening of phonation is equivalent to gestural condensation of articulation and so forth, just as there is no universal metaparameter on which the length of a physical object is compatible to its weight (although there are constraints imposed by other physical sources).

4.5.4. Our claim is that the phonetic incompatibility of strength scales of cardinal gestures is resolved at a language specific level, i.e. the 'anthropophonically constant parameters defining the possible range of underlying representations' are subject to an ordering in terms of abstract relations in a given language system. This ordering is conceived by us as the projection of universal strength scales onto the structure of the hierarchical representation of a segment in terms of the geometric model described in sections 1. -3. of the present paper. Due to the limitations imposed on graphic representations, we renounce any formalization of this fundamental mapping relation of phonetic means and phonological categories. We hope that future investigations of language specific phenomena will clarify the nature of the multidimensional approach to segmental strength sketched in this section.

5. We have tried in this paper to show how the hierarchical behaviour of phonological segments can be derived from the two concepts of sonority and segmental strength, which are basically independent qualities brought together in the course of phonological processing. It seems that the import of representations in terms of purely binary distinctive features which appear as the terminal nodes of the geometrical tree (as introduced in section 1.) can be questioned. In section 3. we have shown that 'major class features' can be totally dispensed with and that they can be replaced with configurational definitions. In this way, the paradox of the standard geometrical phonology, in which the 'major class features' were the only ones that would not spread, disappears. Furthermore, in section 4. we have demonstrated that processes referring to the quality of segmental strength operate on scales. On the basis of these findings we suggest that terminal distinctive features are merely idealizations of the more basic qualities of speech sounds that could be directly operationalized in terms of class nodes and cardinal gestures. The idealizations in terms of distinctive features are useful, but mainly for classificatory, taxonomic purposes.

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