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Source: *Phonology*, Vol. 6, No. 2, The Atoms of Phonological Representation (1989), pp. 253-284
Published by: Cambridge University Press
Stable URL: http://www.jstor.org/stable/4419999
Accessed: 13/02/2009 18:35

Phonology 6 (1989) 253–284
Printed in Great Britain

*Atoms of segmental structure: components, gestures and dependency**

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1 Introduction

In this article I discuss some aspects of a model of segmental structure, in particular the representation of vowels. The central claim is that vowels can be represented in terms of three unary primitives, organised in a binary structure involving both DOMINANCE and DEPENDENCY relations.

My goal is to explore the consequences of this claim. Certain aspects of the proposal differ in matters of principle from the theory of segmental structure advanced in Chomsky & Halle (1968; henceforth *SPE*), and subsequent work in this tradition up to and including the 'geometrical model' as developed in Steriade (1982), Clements (1985), Sagey (1986), McCarthy (1988) and Halle (1988), even though it is argued in some of these works that certain features are unary, that they are organised hierarchically and that certain features enter into dependency relations. Unfortunately, it will be impossible to discuss all differences in detail here. For the motivation of a number of the aspects of the framework I adopt it will therefore be necessary to refer to other literature. It is by no means the case that in this literature all conceptual or empirical differences between the (predominant versions of the) *SPE*-approach (in the broad sense) and what is advocated here and in related work are fully explored; indeed, some of the major grounds for comparison are not addressed at all. This is, however, unavoidable in dealing with models that are different at a fundamental level, rather than in details of 'execution'.

The main purpose of this paper is to provide a self-contained exposition of my version of the dependency approach to segmental structure, rather than to repeat all the argumentation in favour of the basic concepts, much of which is already available.

In §2 I will provide one type of motivation in favour of the central idea that the phonological primitives are unary. In general terms, this motivation will be of the following kind. I will argue that we should try to express what is constant (or recurrent) in phonology *directly* in terms of the basic vocabulary, especially when the alternative is to enrich the basic vocabulary with supplementary machinery, which, although descriptively adequate, takes a somewhat arbitrary form. By 'basic vocabulary' I mean here the primitives of segmental structure, including the smallest building blocks, the hierarchy and the dependency relations, and when referring to 'supplementary machinery' the various sorts of rules that specify default feature values and unmarked or predictable relations among values of different features (jointly referred to as redundancy rules).

In §3 I offer a theoretical discussion of the notions dependency and binarity, while §4 contains the proposal for the representation of vowel structure. In §5 I provide empirical motivation for the aspect of the proposal which differs from the theory posited in van der Hulst (1989), i.e. the concept of dominance.

The ideas which are central to the model discussed here originate from work on vowel structure reported in van der Hulst & Smith (1985, 1986, 1987, 1988), Ewen & van der Hulst (1985, 1987, 1988), van der Hulst *et al.* (1986) and van der Hulst (1988, 1989). Related proposals can be found in Rennison (1983, 1986, 1987a, b, 1988), Schane (1984, 1987), Goldsmith (1985, 1987) and Pulleyblank (1986, 1989). The use of unary primes and the dependency relation (or its complement, government) is, however, also characteristic of DEPENDENCY PHONOLOGY (henceforth DP; Anderson & Jones 1974; Anderson & Ewen 1987) and GOVERNMENT-BASED PHONOLOGY (henceforth GBP; Kaye *et al.* 1985, 1988). The latter model shares many fundamental properties with DP, but is more constrained and more precisely defined in a number of ways. I presuppose here virtually no knowledge of the principles of DP and GBP, nor of my own previous 'synthesis' of these approaches. For a discussion of these approaches, and a comparison with related *SPE*-work (in particular RADICAL UNDERSPECIFICATION THEORY; Archangeli 1988) see den Dikken & van der Hulst (1989).

2 General motivation for the present approach: restricting the theory

Four ideas are central to the proposal that I shall defend here. Firstly, all phonological primes are UNARY (they will be referred to here as ELEMENTS, as in GBP, or COMPONENTS, as in DP). Secondly, I follow DP in assuming that components group in GESTURES (comparable to the class nodes of Clements 1985), one of which is the LOCATIONAL GESTURE. In my proposal this gesture contains three components, referred to as |i|, |u| and |a| (components are enclosed in verticals). Thirdly, I claim that all phonological structure is BINARY: it is never the case that more than two units combine to form a constituent. Finally, it is postulated that whenever two units combine, one is the HEAD (or GOVERNOR) and the other the NON-HEAD (or DEPENDENT). Subsegmentally, these 'units' are components (or elements) and gestures. I will first discuss the unary–binary issue and then turn to the three other points, which all presuppose the notion of grouping.

The first, and central, motivation for a unary approach is the following. Any phonological prime divides the set of segments in two. In a binary feature theory both resulting classes have the same formal status, and both are 'natural', i.e. addressable (as either '[−F]' or '[+F]'). In a unary system, only one of the two sets is formally characterised by a common property [F]. Its complement class contains segments which do not necessarily share a formal property. Hence this class is not accessible to phonological generalisations. 'Lacking F' is not, then, a phonological prime; it cannot spread, delete, be inserted or be used to identify a class of segments. Compared to a binary system, a unary system (with the same number of features) reduces enormously the number of possible natural classes, phonological systems and processes. Purely on grounds of restrictiveness, a unary system is to be preferred over a binary system (cf. Kaye 1988), but the exploration of such a system can be further justified by the reasonable suspicion that a binary approach is overly rich. Indeed, Sanders (1972) provides some of the earliest arguments for assuming that this is the case.

In chapter 9 of *SPE*, Chomsky & Halle address this issue, with respect to whether the two values of binary features have the same status. They note that the appearance of one value is more likely in certain environments than the other, and to express this introduce 'markedness theory'. A second, related, motivation for unary features is the familiar point that unary primes express as directly as possible the notion of 'marked value' in the phonological structure, whereas a binary system requires supplementary rule machinery (such as *SPE* rules spelling out 'm' and 'u' values or the more recent 'default' rules of Radical Underspecification Theory; cf. Archangeli 1988). A unary system thus renders Radical Underspecification Theory superfluous, while at the same time maintaining its central thesis in the strongest possible form. For example, given that we adopt a unary prime advanced tongue root (ATR), there is no possibility of analysing a particular harmony system in terms of [−ATR]-spreading, even as the 'marked' option. It is precisely in this sense that Radical Underspecification Theory is non-falsifiable, whereas a unary approach is not (cf. Kaye 1988). For the same reason, approaches that allow for both binary features and unary features (cf. Goldsmith 1985, 1987; Steriade 1987; Mester & Itô 1989) are weaker theories.

The question of whether unary primes correspond in a one-to-one fashion to binary *SPE*-type features is logically independent from the issue just discussed. In the model proposed here, they do not. The choice of the particular primes assumed here, as well as their mode of combination, is partly guided by the desire to eliminate a second type of supplementary rules which would be necessary in an *SPE*-type approach. I have in mind here rules which rule out feature combinations such as [+high, +low]. In our system there are no combinations of primes which are *universally* ill-formed.

Characteristic of all variants of DP and GBP is the TRIDIRECTIONAL system (the term is due to Rennison 1983), which has also been adopted outside this framework (cf. the references above and, for discussion of earlier proposals, Anderson & Ewen 1987 and Wood 1982). In this article, I will consider the tridirectional system as it relates to vowels. Proposals for consonants are available (e.g. Anderson & Ewen 1987; Smith 1989; van der Hulst ms), but will not be dealt with here. I will also not discuss the overall organisation of the segment (involving manner of articulation, phonation types, initiation, tonal qualities, etc.).

A final point concerning the difference between binary features and what I propose involves neither the methodology of theory construction (restrictiveness) nor the definition of the phonological primes. The phonological primes proposed here have an internal structure which serves as the basis for phonetic interpretation. This claim is made explicitly in Kaye *et al.* (1985), and is also incorporated in van der Hulst (1988, 1989). I will discuss it in detail in §4.

I turn now to the issue of grouping. The idea that segments do not consist of an unstructured set of primes is quite common, both in DP and in work following the lead of Clements (1985). This is not to say that there is a consensus with respect to the precise way in which primes are grouped (for a discussion of this see den Dikken & van der Hulst 1989). In itself, however, grouping does not necessarily entail the use of the notions governor (head) and dependent (non-head). So even though headship has always been an essential part of *all* phonological structure (including segmental structure) in DP and GBP, it is only within certain more recent versions of the 'geometrical' line of work that dependencies between features and feature groups have been introduced; here, however, there is no claim that *all* such groupings are endocentric.

A further characteristic of the model proposed here is that enriching segmental representations by adding grouping (or constituent structure) involving the head–dependent relation leads to the elimination of a *third* category of supplementary rules needed in the *SPE*-system, rules which state unmarked relations between features. Consider for example the rule expressing the (unmarked) relation between backness and roundness. Such a relation can be expressed in the basic vocabulary by making it part of the inherent universal segmental structure. Thus the additional rule in (1a) is replaced by the structure in (1b):

(1) a. [αback] $\rightarrow$ [αround] b. [back]
|
[round]

Though (1b) does not express my own proposal (which pushes this point further), it does illustrate that there is an interaction between additional rules and 'structure'.

I have argued in this section that unary primes are to be preferred over binary features because they lead to a more constrained theory. By adopting unary primes we incorporate into the basic vocabulary what must otherwise be expressed in additional default rules. By choosing *particular* unary primes and by assuming some sort of grouping we can furthermore eliminate various other types of rules which are necessary as a supplement to an *SPE*-type binary feature system, whether they express logical incompatibilities or relations between formally unrelated features. This is a positive result if we realise that all these additional rules express statements which are formally arbitrary. Any default rule introducing the value 'α' for some feature [F] could also introduce '$-\alpha$' (in fact this is exploited in Radical Underspecification Theory by the introduction of 'complement rules', the inverse of default rules; cf. Archangeli 1988). The incompatibility of [+high] and [+low] might be 'reasonable', but unfortunately the theory allows much less 'reasonable' incompatibility statements (universal or language-specific) to be formulated for any subset of features. Finally, relations such as that between [back] and [round] could just as easily be formulated for any other subset of the features. The claim that this specific relation is phonetically explicable frustrates the basic task of constructing a phonological theory which accounts for it. To the extent that a different system of phonological primes can do without such arbitrary statements we have a powerful argument in favour of such a system. The argument is similar to that in favour of the unarity of the primes: the theory simply defines a smaller hypothesis space.

3 The head–dependency relation

At first sight, the use of unary components seems logically unrelated to the use of the dependency relation. Schane and Pulleyblank use unary primes ('particles' in Schane's approach) which are quite similar to those of DP and GBP, but they do not use the dependency relation. Goldsmith (1985: 254), using a tridirectional system, makes the cautious statement that 'it is by no means obvious that such a notion should not be built into the autosegmental representations'. Conversely, Steriade (1981) and Archangeli (1985) make use of features or feature groups which are directly linked to other features or feature groups, while Mester (1986, 1989) explicitly refers to such linkings between individidual features as 'dependency relations'; all within a binary feature system. McCarthy (1988) and Selkirk (1989) likewise explore the concept of dependency within a system of binary features.

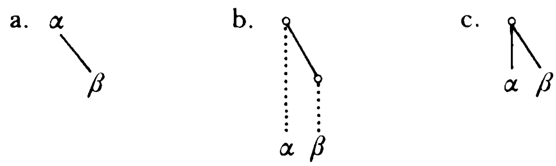
I will discuss the head–dependent relation in general terms (cf. Anderson & Ewen 1987: §3.1). Consider a simple constituent:

(2)
$$\begin{array}{c} \gamma \\ \diagup \quad \diagdown \\ \alpha \qquad \beta \end{array}$$

It is fairly generally acepted, with respect to both morphosyntactic and phonological structure, that 'γ' is not arbitrary, but rather a unit of the same type as 'α' (or 'β'). This has led to the idea that we can seriously constrain the notion of 'possible constituent' by requiring that every constituent be of the same *type* as one of its members, usually referred to as the HEAD of the constituent. Since only one daughter can be the head, headedness is a *relation between sister constituents* rather than an inherent property of the head itself, although it is possible that inherent properties of the head can determine its status in the head–dependency relation (for example, the weight of syllables in stress systems). We will say that the head GOVERNS its sister or, equivalently, that the sister is DEPENDENT on the head.

The requirement of headedness tells us nothing about the number of dependents that can be governed by the head, but we can further narrow down the class of possible constituents by postulating that every constituent has at most one non-head, i.e. all constituents are maximally binary. Another way of stating this requirement would be to say that the only way of building structure is through ADJUNCTION (to a head; see Kager 1988 for an application of this idea to foot construction).

To indicate the head, we could take any of the representations in (3) (various other formalisms have also been proposed):

(3)


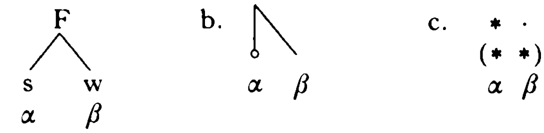
In all diagrams, precedence is represented on the horizontal axis, headship on the vertical axis. In DP, the notation in (4) is used for segmental structure of (non-complex/non-contour) segments:

(4)


In the case of the subsegmental structure of non-complex/non-contour segments, linear order is not relevant, and the notation in (4) is meant to express this. It might be the case, however, that whether or not two elements forming a constituent are linearised follows from the nature of the elements involved, in conjunction with general (possibly universal) linearisation principles. From this it would follow that in the case of complex or contour segments linear order is not a phonological property. If this is empirically correct, as I will assume, we do not need a contrast such as that between any of the representations (3) and that in (4). I claim that (4) (as well as (3a, b)) is inappropriate as a representation of a constituent structure, since it does not properly express the 'IS A' relation holding between a constituent and its daughter(s), and there is no way of referring to the properties of the whole constituent. The representation in (4) is especially confusing since it invites the use of the terms 'dominate' and 'depend' as complementaries. Thus Selkirk (1989), for example, says that a node α is dependent on a node β iff β immediately dominates α. In my view, the relation between α and β only involves domination in so far as the node dominating both α and β is 'of the same type' as α.

Segment-externally, the dependency–government relation is most familiar as the '*s–w*' relation of metrical phonology. Thus, syllables constitute feet, and in every foot there is one head syllable. Many graphic representations of foot structure have been used in the literature. (5a) is the earliest form in metrical phonology (Liberman & Prince 1977), while (5b) is the standard form in DP (and is also employed in Hammond 1984). (5c) is proposed in Halle & Vergnaud (1987):

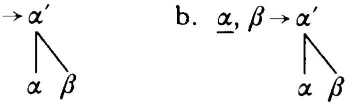
(5) a. b. c.



With respect to syllable structure, the notion 'head' has been frequently used, sometimes by explicitly extending the metrical formalism into this domain (Kiparsky 1981) or by assuming that headship is relevant at all levels of phonological structure, as in DP and GBP.

When dealing with constituents whose daughters are ordered in terms of precedence (in the extrasegmental realm), it may be possible that the head always occupies the same linear position with respect to the constituent edges. In that case we can derive headship from the linear position (cf. (6a)), and, *vice versa*, if constituents are known (and binary) we can leave the ordering information unspecified once we have identified the governor (cf. (6b)). A discussion of this point with respect to metrical structure can be found in Halle & Vergnaud (1987: 11ff):

(6) a. $\alpha > \beta \rightarrow \alpha'$ b. $\underline{\alpha}, \beta \rightarrow \alpha'$



In intrasegmental structure, linear ordering plays no role and therefore the government relation *must* be specified, unless it can be derived from certain inherent properties of α and/or β.

The basic claim made here is that headship and the principle of binarity (or simply adjunction) constrain *all* phonological constituent structure, whether segment-external or segment-internal. This claim is also made within GBP and, to a lesser extent, within DP. DP also allows, at least intrasegmentally, 'mutual dependency', which holds if both elements entering into a constituent are 'equally prominent'. Mester (1986, 1989) allows features which can enter into a dependency relation in one language to be unrelated in another. It seems to me that this is a wrong move to make. If we wish to constrain the notion of constituent structure in terms of obligatory headship, we cannot at the same time allow constituents which are in conflict with precisely this constraint.

In the next two sections, I will discuss the internal syntax of vowels. A central aspect of the proposal will be that the use of binarity, hierarchical organisation and the head–dependent relation can help us to develop a constrained theory of phonological primes. In particular, I will show that these requirements on constituent structure allow us to limit the number of primes. The argument is a simple one. When segments are conceived of as unordered sets, every phonologically relevant parameter requires a separate prime. However, when we add structure to the segment, different phonologically relevant phonetic parameters can be represented by the same prime in different structural positions, where structural positions can be defined in terms of dominance and dependency. Reductionism of this kind is vital in our quest for phonological atoms. There is more at stake here than a pure reduction in the number of primes, as I will show that this move enables us to directly express generalisations which would otherwise require unrelated (and formally arbitrary) statements.

4 Vowel structure

4.1 The proposal

In this section I will explain the mechanics of the theory as it applies to vocalic segments. I will briefly mention some empirical motivations, which will be further explored in §5. For the sake of continuity I indicate in this section how this proposal differs from its close relatives, including my own earlier proposal.

In van der Hulst (1988, 1989) I propose a system of vowels which differs from other unary systems, while sharing fundamental insights with some of them. The proposal is a development of DP and GBP. For a discussion of its relation with DP, GBP and some other approaches, see van der Hulst (1988) and for a broader discussion (also involving binary systems incorporating underspecification), den Dikken & van der Hulst (1989).

A characteristic aspect of all these proposals is a rejection of the *SPE*-feature system for vowels in favour of a system of three components (DP) or elements (GBP): |i|, |u| and |a|. A simple three-vowel system consisting of /i/, /u/ and /a/-type vowels is represented as:

(7) /i/ |i| /u/ |u|
  /a/ |a|

Additional vowels are represented by combinations of the three components. For example, mid front vowels can be represented as combinations of |i| and |a|. Since we assume that all constituent structure is headed, one element must be the head. Hence, given that we combine the two components |i| and |a|, there are two possible structures:

(8)	a. [e]	[æ]		b. [e]	[æ]
	i	a	GOVERNOR		
	a	i	DEPENDENT	i a	a i

The representations in (8a) are those of DP (I ignore here the possibility of mutual dependency), and are also used in van der Hulst (1988, 1989). As noted in §2, I will here employ (8b).

Saying that the vowel [e] is a combination of the components |i| and |a| is only meaningful if we assign a phonetic interpretation to the components and provide an algorithm for computing the interpretation of the segment resulting from combining the two components. This algorithm has to make it clear why combining |i| and |a| produces a low front vowel [æ] if |a| is the head and a mid front vowel otherwise. Intuitively it seems clear what we want to say: the head determines the *type* of vowel we get. If |a| is the head we get a low vowel, i.e. a vowel which can pattern with /a/; |i| indicates that it is a front low vowel. If |i| is the head we get a non-low front vowel, i.e. a vowel that can pattern with /i/; the presence of |a| implies that the vowel is somewhat open compared to /i/. In DP little more than this is made explicit, and this raises the question of why |i| occurring alone defines a vowel which is not merely front (or palatal), but also high. A similar question can be raised for the component |u|. On its own, this component defines a vowel which is round, back (or velar) and high, but in combination it represents roundness alone. How, then, does the interpretation calculus work?

In van der Hulst (1988, 1989), I propose that the status of each component as either governor or dependent is reflected by a distinct, but related, phonetic interpretation. This implies that each component universally combines two properties, corresponding to what would be separate phonological features in feature systems which do not make use of the dependency relation. The interpretations are those in (9):

(9) a. *Interpretation of* |u|

Governor:	Velar constriction
	|
Dependent:	Rounding

b. *Interpretation of* |i|

Governor:	Palatal constriction
	|
Dependent:	Advanced tongue root

c. *Interpretation of* |a|

Governor:	Pharyngeal constriction
	|
Dependent:	Openness

The dependent interpretations represent COLOURS and the governing interpretations LOCATIONS (the terminology is borrowed from the theory of Natural Phonology, where the distinction between phonetic features and phonological primes resembling the ones employed here is also made, albeit informally: cf. Donegan 1978; Anderson & Ewen 1987: 207ff).

The phonetic properties which are paired here are far from arbitrary (cf. van der Hulst 1988, 1989). The linking of the two properties of |u| is also implicitly assumed in DP. Especially noteworthy is the combination of palatality and ATR. In DP (and also in GBP) a separate component ATR forms part of the system, but it is either not well integrated (as in DP) or it has a number of properties which make it different from the other components (see den Dikken & van der Hulst 1989 for further discussion).

Returning to what I formulated as a major goal – the elimination of arbitrary rules which patch up defects in the feature system – let us note that if we simply had six binary features, we would have to add supplementary markedness rules to the system of the following kind:

(10) a. [+palatal] → [+ATR]
b. [+velar] → [+round]
c. [+pharyngeal] → [+open]

Such rules are formally arbitrary since, for example, nothing dictates why the values to the left of the arrows are not '–'. In order to capture the relations expressed in (10) within the present system, a single statement suffices, formulated in van der Hulst (1989) as:

(11) *Universal Redundancy Rule*

$$\begin{array}{ccc} \mathrm{f} & \rightarrow & \mathrm{f} \\ & & | \\ & & \mathrm{f} \end{array}$$

This redundancy rule states that it is natural for a component to occur both as governor and dependent in the representation of a vowel. In my revised proposal, I will derive the effect of this rule from an intrinsic property of the system. In the system outlined so far, we can derive eight possible combinations for any two features, assuming that governors may not combine, so that for |i| and |a| we get:

(12)
$$\begin{array}{cccccccc} \mathrm{i} & \mathrm{i} & \mathrm{i} & \mathrm{i} & \mathrm{a} & \mathrm{a} & \mathrm{a} & \mathrm{a} \\ | & & | & | & | & | & & | \\ \mathrm{i} & & \mathrm{a,i} & \mathrm{a} & \mathrm{i} & \mathrm{a,i} & & \mathrm{a} \end{array}$$

This system differs in two ways from DP and GBP. Firstly, as noted above, there is no need for an independent element or component |ATR|, since ATR is identified with |i| in dependent position. Secondly, DP and GBP also use a fifth component or element, which plays an essential role in the characterisation of central and back unrounded vowels. In DP the fifth element is |ə|, the centrality component; in GBP it is the 'cold vowel'. It is perfectly possible, however, to characterise central and back unrounded vowels without the use of an extra element, if we allow (11) to be suppressed in individual systems. Consider the following representations:

(13) a. /ɯ/ /u/ b. /i/ /ɨ/

u	u	i	i
	|	|	
	u	i	

(13a) represents the distinction between a back unrounded and a back rounded vowel, in accordance with the interpretations of the components. The representations in (13b) involve a distinction between a high advanced front vowel and its non-advanced counterpart. Systems involving central or back unrounded vowels thus require oppositions such as those in (13).

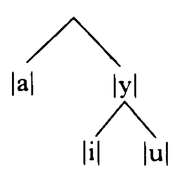
In the next section, I will introduce a calculus which will allow us to generate a slightly different set of permissible vowel structures from that in (12). I will develop a somewhat different view on the dual interpretation of |u| and also propose a fuller phonetic interpretation, involving the feature [tongue body constriction] (or [high]). The major modification I propose is the addition of a universal hierarchical organisation to the feature structures.

4.2 Dominance

In a number of the publications mentioned in §2, it is suggested that some sort of hierarchical structure (apart from the dependency relation) should be imposed on the three vowel components. I will briefly review some of the relevant considerations before I discuss the idea in detail. In §5 I present empirical motivation.

Firstly, Ewen & van der Hulst (1988) argue that certain systems can most adequately be characterised by assuming a two-way ('tongue body constriction–pharyngeal constriction') split in the vowel space rather than a three-way ('palatal–velar–pharyngeal') split. They claim that in such systems the choice between |i| and |u| *as governors* is neutralised. The 'archi-element', which is opposed to |a| in their proposal, is represented as |y|. The precise formal properties of the resulting system are not discussed, but the following type of structure is assumed:

(14)



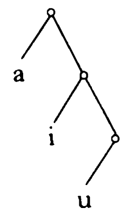
Ewen & van der Hulst do not propose a dual interpretation for |y|, which is glossed as 'tongue body constriction' (or 'lingual', following Lass 1976).

Secondly, in van der Hulst (1988, 1989) some further motivations for a structure along the lines of (14) are discussed. It is argued that the presence of a node which 'dominates' |i| and |u| explains the fact that in some harmony systems the spreading of |i| seems to entail the spreading of

|u|. This type of 'parasitic harmony' occurs in Kirghiz, for example. I will discuss this case in §5.

Thirdly, van der Hulst & Smith (1987) suggest on similar grounds that the three components are hierarchically organised in the following fashion (|ATR| was considered to be a separate component):

(15)



The argument advanced by van der Hulst & Smith (1987) involves other cases of parasitic harmony, one of which is also discussed in §5.

Apart from empirical considerations, there is also a purely formal reason for subjoining |i| and |u| to a node of some kind, *viz.* the claim that all phonological structure is binary. This claim forces us to reduce the three-way distinction between |i|, |u| and |a| to two two-way splits, automatically leading us to a structure like (14). Of course, the 'binarity principle' does not in itself tell us that we should combine |i| and |u|, rather than, for example, |i| and |a|. The specific grouping is determined on empirical grounds, such as the fact that |u| can be parasitic on |i|.

These empirical and theoretical considerations indicate the necessity of some hierarchical organisation. Following Humbert (1989), I will argue that (15) is indeed the appropriate way of looking at the locational components. Not only will (15) serve as a basis for accommodating the phenomena mentioned above, but we can also develop a more precise phonetic interpretation calculus in terms of this organisation. For the sake of comparison, I will briefly discuss the interpretation calculus of GBP.

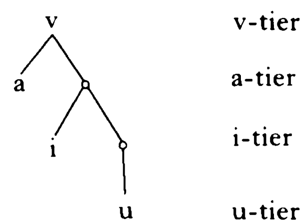
In systems using three components, a vowel /u/ is characterised exhaustively in terms of the element or component |u|. If the interpretation of |u| is just velar constriction ('backness') and roundness, we fail to express the fact that /u/ is also 'high'. Similar points can be made for other simple vowels like /i/. With respect to /a/ the situation is somewhat different: what is /a/, apart from pharyngeal ('low') and open? Ignoring this for the moment, let us agree at this point that the phonetic interpretation of the components has to be slightly richer than what we have provided in (9). In essence, this is the reason that in GBP elements are interpreted in terms of a richer (binary) feature specification (Kaye *et al.* 1985):

(16) $$|\mathrm{i}| = \begin{bmatrix} -\text{round} \\ -\textsc{back} \\ +\text{high} \\ -\text{low} \\ -\text{atr} \end{bmatrix} \qquad |\mathrm{u}| = \begin{bmatrix} +\textsc{round} \\ +\text{back} \\ +\text{high} \\ -\text{low} \\ -\text{atr} \end{bmatrix} \qquad |\mathrm{a}| = \begin{bmatrix} -\text{round} \\ +\text{back} \\ -\textsc{high} \\ -\text{low} \\ -\text{atr} \end{bmatrix}$$

It is important to realise that the binary features are not accessible to the phonology; they merely serve to provide a phonetic interpretation. In each of the vowels in (16) one feature is capitalised. This is the 'hot feature' in GBP. When two elements are combined, as in (17), the resulting segment is interpreted as having the hot feature value of the non-head (the 'operator') and the other feature specifications of the head:

(17)
$$\underset{\substack{|u|\\\text{(operator)}}}{\begin{bmatrix}+\textsc{round}\\+\text{back}\\+\text{high}\\-\text{low}\\-\text{atr}\end{bmatrix}} \cdot \underset{\substack{|a|\\\text{(head)}}}{\begin{bmatrix}-\text{round}\\+\text{back}\\-\textsc{high}\\+\text{low}\\-\text{atr}\end{bmatrix}} = \underset{[\text{ɔ}]}{\begin{bmatrix}+\text{round}\\+\text{back}\\-\text{high}\\+\text{low}\\-\text{atr}\end{bmatrix}}$$

Let us now look at the interpretation calculus that is associated with the hierarchical system of components. I place each component on a separate autosegmental tier, as in (18):

(18)


The graph in (18) resembles the GBP representations, but it must be borne in mind that in GBP no hierarchy as such is assumed. Rennison (1988), however, argues in favour of a hierarchical interpretation of the GBP representations.

The tiers represent phonetic parameters; for every tier there is a designated component, representing the phonologically accessible value of that parameter. I shall refer to the topmost tier as the 'v-tier'. This tier has no component, because it does not define a phonetic parameter. The content of this tier is determined by another gesture, the categorial gesture (see den Dikken & van der Hulst 1989 for a more detailed discussion of this gesture). The tiers (or components) in (18) have the following phonetic interpretation:

(19) |i| (-tier) $\begin{bmatrix}\text{pal}\\\textsc{atr}\end{bmatrix}$ |u| (-tier) [ROUND] |a| (-tier) $\begin{bmatrix}\text{phar}\\\textsc{open}\end{bmatrix}$

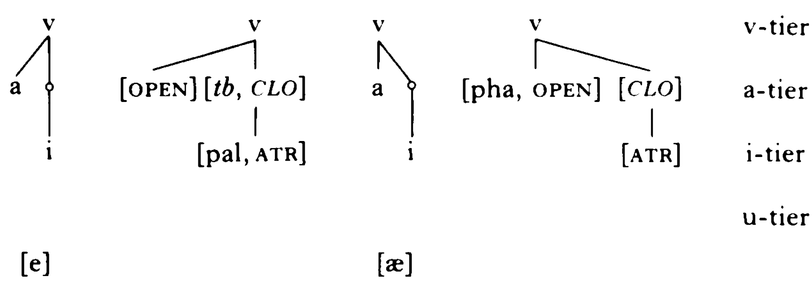
Observe that a dual interpretation is no longer assumed for |u| (as suggested in Humbert 1989). Where duality still exists, I will maintain the idea that a dependent component only attributes the 'colour' corresponding to a tier to the resulting segment, but contrary to my earlier proposal, I will assume that *both* features contribute to the interpretation if a component is the head.

To associate the v-tier, components have to pass through higher tiers, where they activate the unmarked value of those tiers. It is precisely this aspect of the interpretation calculus which gives us the richer phonetic interpretation involving the feature [high]. Thus, we arrive at a distinction between what I will call INTRINSIC features (marked values) and EXTRINSIC features (unmarked values; henceforth represented in italics):

(20)	Intrinsic	Extrinsic
a.	*Features on the |a|-tier*	
	[pharyngeal constriction] (pha)	[*tongue body constriction*] (*tb*)
	[OPEN]	[*CLOSED*] (*CLO*)
b.	*Features on the |i|-tier*	
	[palatal constriction] (pal)	[*velar constriction*] (*vel*)
	[ATR]	[*RTR*]
c.	*Features on the |u|-tier*	
	[ROUND] (RD)	(none)

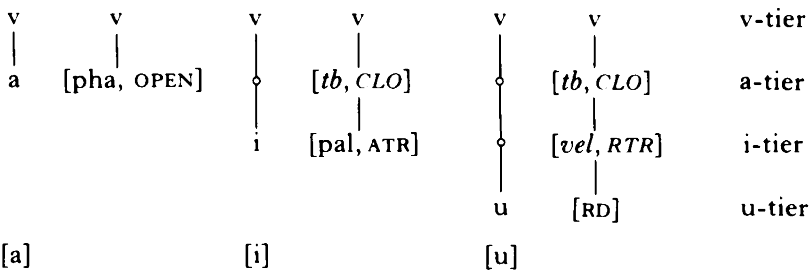
Clearly, since no component can pass through the |u|-tier, there can be no extrinsic feature for this tier. I will consider examples with |u| below. To exemplify this compositional mode of building up the interpretation, let us first consider combining |a| and |i|:

(21)

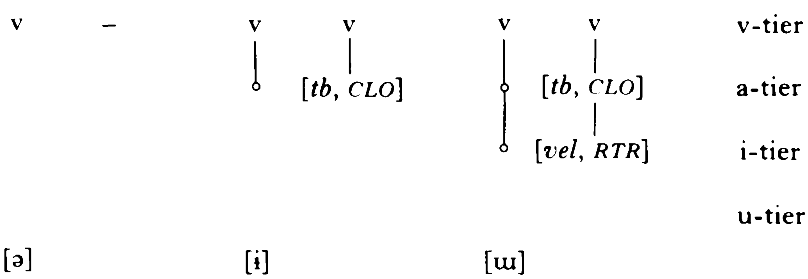


As will be observed in (21), two opposite features ([OPEN] and [*CLOSED*]) can be part of the interpretation of a single vowel. This, however, can only involve 'colours', and never 'location', because dependents do not project their locational properties. From a 'semantic point of view' this means that the relation between intrinsic and extrinsic locational features (corresponding to a tier) is that of complementarity, whereas the relation between two opposing colour features is that of antonymy (cf. Lyons 1968: 460ff). In the case of opposing colour features, the features coming from the head are more prominent than those from the dependent. The exact nature of this relationship is a matter of the overall vowel system, and may also be language-specific (i.e. the phonetic target position of a low mid vowel need not be exactly the same in all languages having this phonological category of sounds). A second point of interest regarding the representations in (21) is that any vowel which has |a| combined with one of the two other components automatically has the feature [*tongue body constriction*, *CLOSED*]. Hence no such product is phonetically as low as /a/. In §5 I will return to the importance of this point.

The three 'pure' vowels acquire the following representation and interpretation:

(22)


In van der Hulst (1988, 1989) I make crucial use of the possibility of a component 'governing itself'. Thus distinctions such as those in (13) can be made. In the present system such distinctions are made by allowing (23) as well as (22). In (23), which shows the representations for the 'empty vowel', the high close non-fronted non-advanced vowel and the back unrounded vowel, respectively, components occur at higher tiers *without* occurring on their own tier. This has consequences for their interpretation, which then consists solely of extrinsic features:

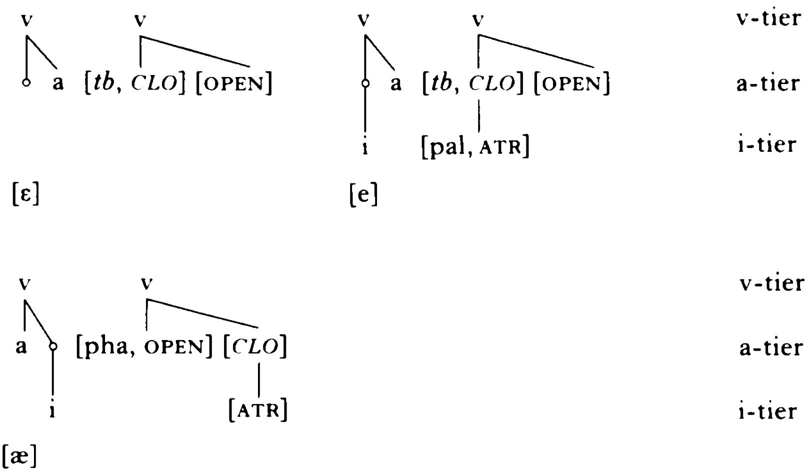
(23)


In a language lacking the contrasts between (22) and (23), the simpler representations in (23) are sufficient. We could then assume that unless a contrast is destroyed, components present on some higher tier are assigned to their own tier as well, which would be the reflection in this system of the Universal Redundancy Rule in (11). In the case of the empty vowel no such filling out is possible, which suggests that this 'vowel', when not contrastive, is filled out on a language-particular basis as [i], [u], [a] or even [e], where markedness considerations may play a role. I will not pursue this point here (for related discussion, see Anderson & Durand 1989; van der Hulst ms).

A further point to be made regarding the 'incomplete' representations in (23) is that such components have to be prevented from 'spreading'. The segments involved fail to induce spreading of those phonetic properties which do not correspond to a phonological component. Hence there can be no spreading of [*tb*] or [*vel*], etc. In the structure in (15), then we can say that non-terminal nodes cannot spread (Helga Humbert, personal communication). Observe that the nodes resemble the 'cold vowel' ([v]) of GBP, which also represents the 'opposite' properties of the elements (although |u| here has no opposite). Just like [v], '∘'s have no lines of their own. Notice that the existence of '∘' in this system is a necessary consequence of the hierarchy. Furthermore, in GBP the fact that spreading [v] has no effect is a matter of stipulation.

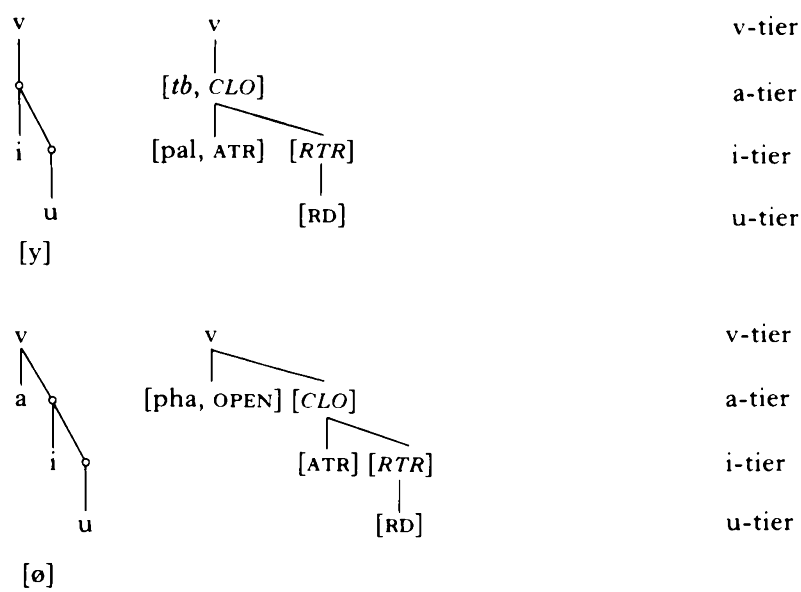
Given (23), we can represent three types of e-vowels:

(24)



The following examples involve the component |u|:

(25)



In this system, then, the claim is that front rounded vowels have some element of 'RTR-ness' in their interpretation. This is a claim which has been made before, but is not uncontroversial from an articulatory point of view (see Wood 1982 for discussion).

Given the system outlined above, we can characterise vowel systems of particular languages in terms of a number of parameter settings. I will not fully explore this point here, but limit myself to suggesting what such a parameter set could look like:

(26) *Parameters for vowel structures*

I. *Are there any head–dependent relations?*
- Yes → A. Is government bidirectional on the |a|-tier?
  - Yes → Two series of mid vowels
  - No → 1. Does |a| govern |i|/|u|?
    - Yes → [ɛ]/[ɔ]-type vowels
    - No → [e]/[o]-type vowels
- B. Is government bidirectional on the |i|-tier?
  - Yes → Two types of rounded vowels (?)
  - No → 1. Does |i| govern |u|?
    - Yes → rounded front vowels

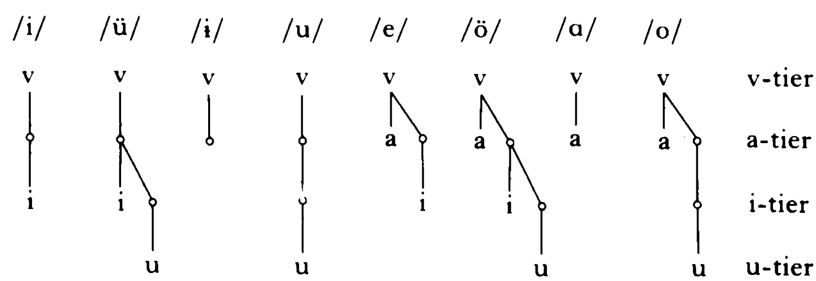
II. *Are there incomplete representations?*
- Yes → A. |i| incomplete → central vowels
- B. |u| incomplete → unrounded back vowels
- C. |a| incomplete → empty vowel

Let me say something about parameters IA and IB. If government on the |a|-tier is directional (IA: *no*) two options are specified. It is conceivable that in such a case |a| is the unmarked governor (IA1: *yes*), in which case we arrive at a 'two-height' vowel system in the sense that the 'mid' vowels and the low vowel form a natural class in terms of height. An example of such a system is Turkish:

(27) *Turkish*: IA1: *yes* → two-height system

IB1: *yes* → rounded front vowels

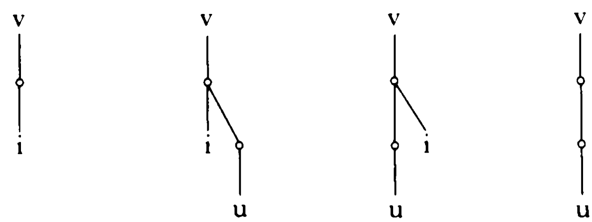
IIA: *yes* → central vowels



With respect to parameter IB, the question arises as to whether we need the possibility of bidirectional government on the |i|-tier. In both DP and GBP, the equivalent of this possibility is excluded (in ways which need not concern us here), for the good reason that we do not seem to need it. The only example that comes to mind is the representation of the two types of front rounded vowels in Swedish (cf. Lass 1984: 88):

(28) /i/ /ü/ /ʉ/ /u/

'outrounded' 'inrounded'



Ignoring this contrast, it is tempting to say that |u| simply can never govern, for example because it lacks an intrinsic locational feature. This would exclude a whole range of vowel structures. In the next section, however, I will suggest that by assuming a parametric choice between |i| governing |u| and *vice versa* we can make interesting claims about the difference between palatal and ATR harmony systems. This would entail that at least parameter IB1 must be assumed, leaving open the possibility of disallowing both directions of government within a single system.

4.3 Conclusion

I have outlined a system of representation for vowels using three basic elements |i|, |u| and |a|, which enter into a hierarchical layering of headed constituents. The structural richness of the system as compared to the *SPE* approach (excluding geometrical versions) is compensated not only by the low number of primes, but also and primarily by the fact that each component expresses the relatedness of several phonetic properties: |i| relates palatality, ATR-ness, height and closure, |u| roundness, velarity, height and closure, while |a| relates just pharyngeality and openness. These relations, which are expressed directly in the basic vocabulary of the system, would require a whole range of supplementary statements if the phonetic features here subsumed under a single component were independent phonological primes. And, of course, as argued above, if such phonetic features and supplementary rules were part of the system, many other supplementary rules, expressing totally absurd relations, would be available.

In the next section my goal is to demonstrate the application of the system and its empirical motivation with a number of examples. I will also add some more general considerations motivating the use of unary components, the hierarchy and the head–dependent relation. As I emphasised in §1, it will not be possible to motivate fully all aspects of the proposal in an article of this size, nor to explore at any length all the differences and similarities between the present proposal and the various versions of the geometrical approach which also incorporate head–dependency relations.

5 Empirical motivation: parasitic harmony

The motivation to be provided here involves vowel harmony. In the system proposed only three types of vowel harmony can exist: those involving |i|-spreading, |u|-spreading and |a|-spreading. In van der Hulst (1988) I claim that so-called palatal harmony systems and ATR harmony systems both involve the spreading of a *dependent* |i|, a claim modified in van der Hulst (1989), where I say that an ATR system results if |i| is consistently dependent (implying that |u| must be a governor), whereas a palatal system arises if a governing |i| spreads. |u|-spreading accounts for labial or rounding harmony. Finally, the nature of |a|-spreading may not at first sight be clear. In van der Hulst (1988, 1989), however, I show that |a|-spreading is involved in harmony systems which have been referred to as 'diagonal' or [−ATR] systems, both of which are unavailable in the unary system. *Prima facie*, the fact that only three types of vowel harmony exist provides evidence for the unary nature of vowel components. If we have five binary vowel features (say [high], [low], [back], [round], [ATR]), we would expect ten types of harmony systems. Other evidence involves the behaviour of non-alternating (usually neutral) vowels, which, in |i|-systems, are transparent if front or advanced and opaque if back or non-advanced. Similar asymmetries hold in |u| and |a|-systems. The crucial point (made in van der Hulst & Smith 1986) is that such asymmetries cannot be explained within a symmetrical binary feature system.

I do not claim that this view on both the number of possible harmony types and the behaviour of non-alternating vowels is without problems, which must, of course, be addressed if we are to take the claims seriously (see van der Hulst 1989: §§4–5 for an extensive discussion and some solutions of most of the obvious problems, such as the alleged [−ATR]-spreading in Nez Perce or Yoruba, [+back] spreading in Hungarian, transparent /i/ in Khalkha rounding harmony, etc.).

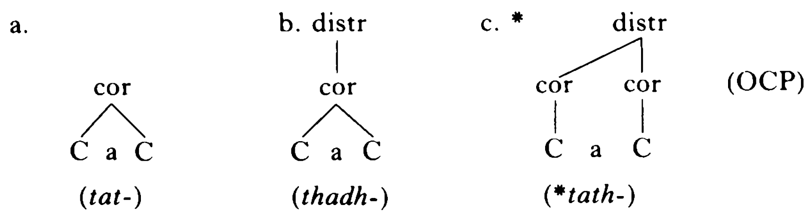
In this section, however, I wish to concentrate specifically on motivating the hierarchy assigned to the locational gesture and some of the government parameters.

5.1 Dominance and dependency

Mester (1986, 1989) develops a theory which captures a large number of phonological 'agreement phenomena' (cooccurrence restrictions and harmony processes) in terms of the Obligatory Contour Principle (OCP) and 'feature dependency' (see den Dikken & van der Hulst 1989, from which some of the discussion in this section is taken). By way of illustration, let us first look at one of his examples of tier dependency involving consonants. Consider the African language of Alur (North-east Congo), in which we find the following restriction on possible root shapes (from Tucker 1969: 126):

> the alveolar plosives *t* and *d* and interdental plosives (written *th* and *dh*) are mutually exclusive in CVC roots, i.e. words such as *dhetho* and *thedho* are possible, as are words such as *tado* and *tato*, but roots of the type *dh-t*, *th-d*, *t-dh*, *t-th*, etc. are not. This situation exists in Luo and Shilluk as well.

Thus agreement for the feature [coronal] implies agreement with respect to what Mester calls the 'secondary articulator'. This can readily be explained within the framework of his dependent tier ordering if it is assumed that the feature that distinguishes interdentals and alveolars, [distributed], is dependent on the primary place feature [coronal]. Mester also assumes that the OCP will rule out two adjacent units on the coronal tier, ignoring featural information which is dependent on [coronal]. On these assumptions, it follows that when two segments have identical and adjacent representations on the coronal tier there can be only one autosegment on this tier, which must be linked to the two segmental slots in question. As a consequence, there can also be maximally one autosegment on the [distributed] tier, which will then automatically be associated with both segments. Consider the examples in (29) (irrelevant details omitted):

(29) 

Thus the identity for [distributed] of two successive coronal consonants is explained, given that [distributed] is dependent on [coronal]. Such feature dependency is in fact part of Sagey's (1986, 1989) feature tree, in which [distributed] is 'under' the Coronal node. If this relation is to be seen as dependency in our sense, it will be necessary to assume that there is some node which dominates both [coronal] (which would be |i| in our system), being the head, and another dependent component (for example |i|, representing the 'extra mark' of distributed consonants). I have no proposals to make here regarding consonantal structure. Elsewhere, I will show that the dependency required here does indeed form part of the analysis of consonants in terms of the three components (cf. Smith 1989; van der Hulst ms). Here I am interested in reanalysing a number of

Mester's examples involving vowel structure in terms of the present model.

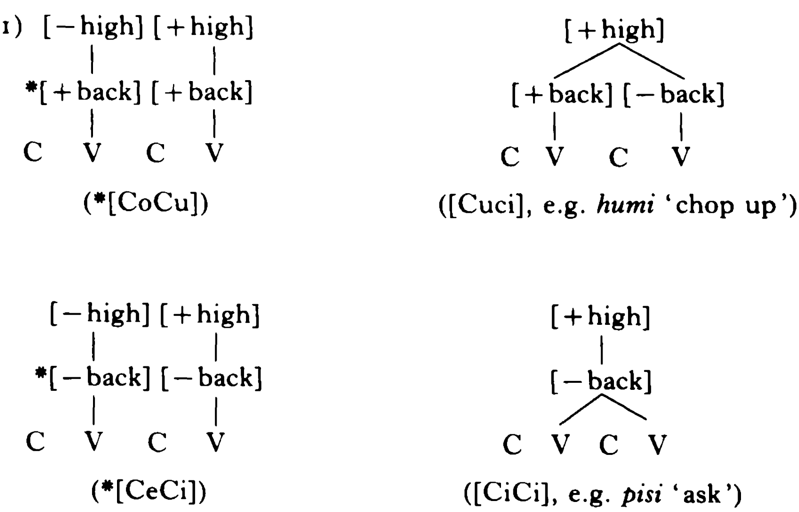
In the literature on what has come to be known as 'parasitic vowel harmony' (cf. Steriade 1981 for this term), a range of phenomena can be distinguished that lend themselves to an account in terms of a Mester-type dependent tier ordering.

In the Japanese language Ainu we can distinguish between two classes of roots. In one class the vowel found in the suffix is identical to the root vowel, as in (30a), while in the other class the suffix vowel is a high vowel opposite in backness to a (non-low) root vowel. This latter class is exemplified in (30b) (the examples and basic generalisation come from Itô 1984):

(30)	a.	mak-a	'to open'	tas-a	'to cross'
		ker-e	'to touch'	per-e	'to tear'
		pis-i	'to ask'	nik-i	'to fold'
		pop-o	'to boil'	tom-o	'to concentrate'
		tus-u	'to shake'	yup-u	'to tighten'
	b.	hum-i	'to chop up'	mus-i	'to choke'
		pok-i	'to lower'	hop-i	'to leave behind'
		pir-u	'to wipe'	kir-u	'to alter'
		ket-u	'to rub'	rek-u	'to ring'

Thus we see that in Ainu it is possible for two successive vowels to have the same value for backness *only* if they have the same height as well. In other words, two successive vowels of like backness must be equally high (and hence identical). We do not find sequences such as *[oCu] or *[eCi]. On the other hand, vowels of the same height can differ in backness (cf. (30b)). This is accounted for by Mester as an OCP effect, given that in Ainu the height tier is dependent upon the backness tier, as in (31):

(31)



Thus the OCP can account for the vowel cooccurrence restrictions found in Ainu, provided that the feature specifying vowel height is taken to be dependent upon the feature for backness. Similar cooccurrence restrictions in Ngbaka, a Congo-Kordofanian language, however, suggest that the ordering of the height and backness tiers should be reversed.

In Ngbaka, which has a standard five-vowel system with ATR-distinctions among the mid vowels, the following restrictions on vowel sequences hold in disyllabic words (Wescott 1965):

> If a disyllabic word contains /i/, it does not also contain /u/; if /e/, it does not also contain /ɔ/, /ɛ/, or /o/; if /u/, it does not also contain /i/; if /o/, it does not also contain /e/, /ɛ/, or /ɔ/; and if /ɔ/, it does not also contain /ɛ/, /e/, or /o/.

In a Ngbaka disyllabic word vowels of the same height must agree in backness, as in (32a, b), i.e. two different mid or high vowels are disallowed (32c). As soon as the two vowels differ in height, they can freely cooccur regardless of their backness, as is shown in (32d):

(32)	a.	bɛnɛ	'to cement a piece'	b.	liki	'to heat'
		bɔnɔ	'brains'		tulu	'mushroom'
		ʔele	'to forget'			
		zoko	'beautiful'			
	c.	*beno	*liku	d.	pɛpu	'wind'
		*benɔ	*luki		ninɛ	'amusement, entertainment'
		*bɛno			sɛti	'chance, luck'
		*bɛnɔ			gbie	'field'
		*benɛ			seti	'asleep'
		*bɔno			kɔpu	'cup'

In Mester's account, these cooccurrence restrictions follow from the OCP, given the dependent ordering of the height and back tiers displayed in (33):

(33)		[−back]		[+back]		[−back]		[+back]			[−back]	
		*[+high]		[+high]		[−high]		[+high]			[+high]	
	C	V	C	V	C	V	C	V	C	V	C	V
		(*[CiCu])				([CeCu]: [pɛpu])				([CiCi]: [liki])		

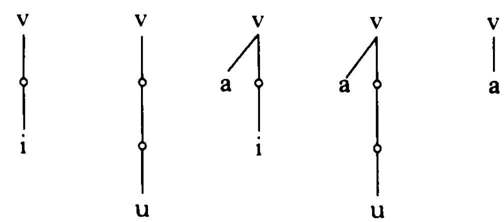
A major disadvantage of Mester's approach is that *both* values have to be underlying, which runs counter to the claims of Radical Underspecification Theory (cf. Archangeli 1988), and thus also to the idea of 'unarism'. Another drawback is that the hierarchical arrangement of features is language-specific.

I will now analyse these two cases in terms of the model proposed here. It will become clear that we have to make a distinction between parasitic harmony due to dominance and parasitic harmony due to dependency. Consider again the relevant restrictions:

(34) a. Identity in backness/roundness implies identity in height (Ainu)
b. Identity in height implies identity in backness/roundness (Ngbaka)

Ainu has a standard five-vowel system; Ngbaka has seven vowels, with the two mid series distinguished in terms of ATR. For the moment, I leave out the ATR distinction, which does not affect the point to be made. In the present model a three-height five-vowel system has the following representation (parameter IA1 for government on the |a|-tier is set to *no*):

(35) /i/ /u/ /e/ /o/ /a/



Given the representation in (35), we can state the cooccurrence restrictions in (34) in the following terms. In the case of Ngbaka (cf. (34b)) complete agreement is obligatory among vowels which are the same on their |a|-tier. This gives us three IDENTITY CLASSES: high vowels (lacking |a|), mid vowels (having dependent |a|) and the low vowel (having non-dependent |a|). Note that |i| and |u| count as the same when passing through the |a|-tier, since both activate the same extrinsic features on that tier. Hence sequences like /i+u/ or /e+o/ are ill-formed. The relevant notion here is therefore DOMINANCE. Agreement with respect to the |i| and |u|-tiers is conditioned by agreement on the dominant ('higher') |a|-tier.

For Ainu (cf. (34a)) a different type of condition is required. Here the constraint involves DEPENDENCY: like heads agree with respect to dependent information. This also defines three identity classes: non-low front vowels (being |i|-headed), non-low back vowels (being |u|-headed) and low vowels (being |a|-headed). Sequences such as /e+i/ and /o+u/, then, are ill-formed.

I will now discuss two other instances of parasitic harmony, present within a single language, which substantiate the distinction made here between parasitic harmony due to dominance and parasitic harmony due to dependency.

Many Turkic languages have both palatal and labial harmony. Usually, these languages have a two-height eight-vowel system, as given in (27) for Turkish. In Turkish, labial harmony is only applicable if the suffix vowel is high, a restriction which is common in the Turkic languages. Other Turkic languages have a different, limited labial harmony, in that low suffix vowels only fail to harmonise with *high* stem vowels. In yet other cases harmony is limited to spans of vowels of the same height. Given that the components are hierarchically arranged, such limitations can be stated in terms of dominance (as in Ainu). If the harmonic span must consist of vowels of the same height, the condition is that they may not differ with respect to the dominating |a|-tier. Since the Turkic languages also have palatal harmony, the condition might actually be that the span has to agree with respect to both the |a|-tier and the |i|-tier in order for labial harmony to take place. It is entirely natural for harmony to be limited to circumstances under which the segments involved are already very similar. Van der Hulst & Smith (1987: 87) formulate this as the 'Parasitic Principle':

(36) Two segments A and B can be colinked on tier T iff their shared specifications on all higher tiers are adjacent

Given a principle of this sort, and the 'peripherality' of |u|, it is to be expected that labial harmony is conditioned by agreement with respect to the less peripheral |i| and |a|-tiers. A second expectation is that we will also encounter cases in which palatal or ATR harmony is conditioned by agreement with respect to the |a|-tier, a point to which I will return later.

If high stem vowels cannot impose harmony on low suffix vowels, the condition is that the trigger has to contain a DOMINATING COMPONENT (a formalisation of what has been characterised in terms of 'sonority': cf. Steriade 1981). This applies in Turkish. Note that the appearance of low rounded vowels is generally restricted in such cases, in that low rounded vowels only occur after low rounded vowels (which can freely appear in the initial syllable of the word). I claim that such a condition finds a natural expression in the model presented here.

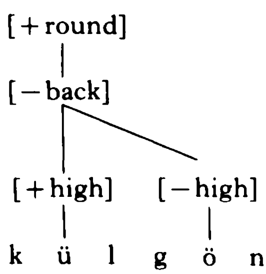
Consider now the fact that in a language like Kirghiz, rounding harmony will always take place if |i|-spreading takes place, while it does not always occur if the stem vowel is back; in particular there is no harmony if the stem vowel is high (and back) while the suffix vowel is low (and, of course, also back). Johnson (1980: 90) gives the following examples:

(37)				
bildi	bilgen	bilüü	'know'	
berdi	bergen	berüü	'give'	
küldü	külgön	külüü	'laugh'	
kördü	körgön	körüü	'see'	
kɨldɨ	kɨlgɑn	kɨluu	'do, perform'	
ɑldɨ	ɑlgɑn	ɑlguu	'taken'	
tuttu	tutkɑn	tutuu	'hold'	(*tutkon)
boldu	bolgon	boluu	'be, become'	

The same phenomenon of labial harmony being dependent on palatal harmony is attested in a variety of other Turkic languages (see Korn 1969).

Mester (1986), essentially following Steriade, argues that the harmonic transmission of [+round], parasitic on backness harmony, can be made sense of if it is assumed that the tier occupied by [round] is dependent on [back], and that backness harmony in Kirghiz spreads only [−back], since [−back] is the only value for this feature present in the underlying representation in Kirghiz. As an illustration, consider (38):

(38)



Observe that Mester's hierarchical arrangement is very similar to what is proposed here. This type of |u|-spreading can be explained by saying that in Kirghiz |i|-spreading takes place on the |a|-tier, the result being that |i| and |u| spread together. The joint spreading of |i| and |u| provides a classical argument for their forming a constituent, as in the current proposal. In addition, phenomena of this type provide a different, though related, type of motivation for the hierarchy. Here the relevant notion is not dominance, but rather dependency. |u| is dependent on |i|, and as such it is 'dragged along' when |i| spreads.

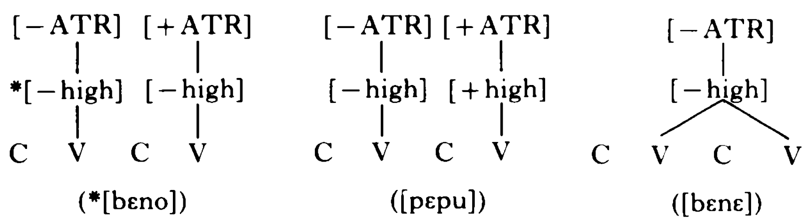
It is important to notice that within a binary approach, the situation might equally well have been that labial harmony was parasitic on the spread of [+back], or that the spreading of [αback] was dependent on the spreading of [βround]. Similarly, there is no particular reason for 'height' to condition labial spreading. The geometrical binary model makes no universal claims concerning which value spreads, nor what the dominance and dependency relations among features are. Of course, this model could be restricted so that stronger claims *are* made, ending up with a proposal similar to ours in this respect, but only by means of ancillary mechanisms of the type discussed above.

However, we must still explain why certain languages have agreement phenomena (statable in these terms), while others do not. Ideally we would merely have to define the representations (by setting the parameters in (26)). At present, however, it is not clear to me how to avoid language-particular statements. Thus I do not know why Kirghiz has parasitic |u|-spreading, while Turkish does not. In this sense, then, the analyses presented here are interim results.

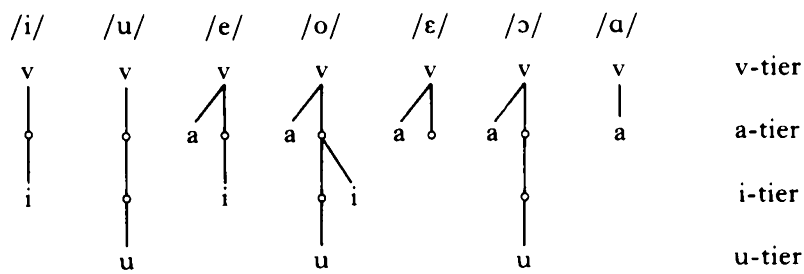
The model under consideration allows for the expression of various other parasitic effects, due to either dominance or dependency. I will limit myself here to mentioning some further areas for exploration.

In the next section, I will discuss ATR harmony systems in which the low vowel /a/ does not participate. This could be interpreted by saying that |i|-speading is parasitic on the presence of a component passing through the |a|-tier, in order to derive the non-low vowels as an identity class. Such an analysis would be in the spirit of Cole & Trigo (1989), but I am not sure that this is the correct way of looking at this phenomenon, since we now are expanding our theory by allowing reference to partial agreement on some tier (cf. (40)). An alternative approach is offered in the next section.

If 'ATR' harmony is even more restricted and only applies among mid vowels, a different situation obtains. In Ngbaka, as can be seen in (32), it is not just the feature [back] for which two successive vowels of identical height must agree: they must also be identical with respect to the feature [ATR]. Thus, in Mester's theory, the tier occupied by [ATR] must also be assumed to be dependent on the height tier in Ngbaka. Consider (39):

(39)


From the representations in (39) it follows straightforwardly that disharmony in ATR-ness is allowed just in case there is also disharmony in height. There is no problem in defining the required identity classes in our model, since the relevant relation is already part of the system:

(40)


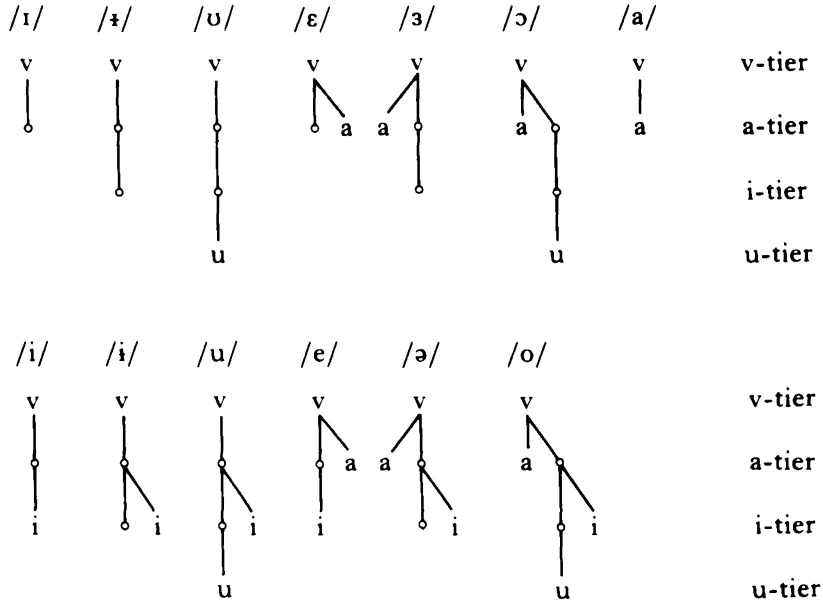
Mid vowels form an identity class, showing agreement on the |a|-tier. ATR harmony (|i|-spreading) is conditioned by this agreement.

5.2 Parameter setting and vowel system typology

The parasitic behaviour of |u| in Kirghiz is made possible by the fact that it is governed by |i|. Now consider what we predict if |u| is the governor on the |i|-tier. First of all, if |i| spreads in such a system, this would give us ATR harmony rather than palatal harmony, because |i| as a dependent is interpreted as [ATR] (this does not mean that all instances of spreading involve *dependent* |i|; cf. below). Secondly, we would not expect to find parasitic labial harmony in such a system. If this is correct (and it is, as far as I know), then we have a genuine example here of a case where the setting of a single parameter derives two seemingly unrelated facts, *viz.* the difference between palatal and ATR harmony and the absence *vs.* presence of parasitic labial harmony.

Consider a system with ATR harmony, that of Kpokolo, discussed in Kaye *et al.* (1985). This language has a rather complex vowel system, consisting of 13 vowels:

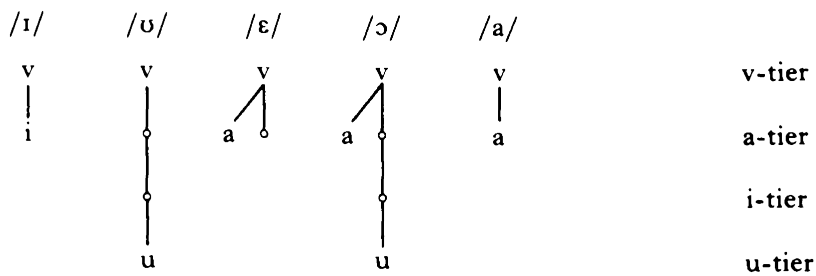
(41)

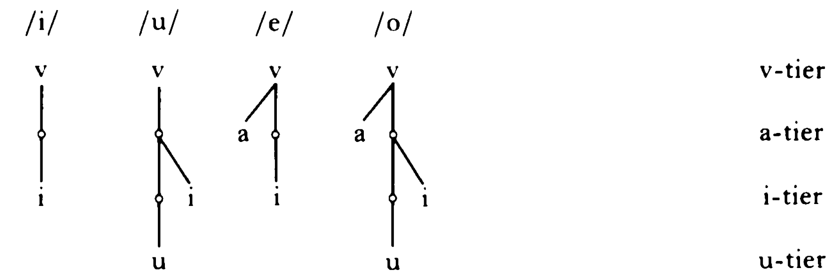


The ATR-congener of /ɜ/ and /a/ is the same, *viz.* /ə/. Given the workings of the system this is necessarily the case, because /a/ is provided with the extrinsic feature [*CLOSED*] when |i| is added to it. We thus motivate another aspect of the hierarchy.

I will now show how the setting of the government parameter on the |a|-tier can explain a further split in the two types of |i|-spreading system. In many ATR-systems the ATR congener of the low vowel is absent altogether. This, I propose, results from prohibiting |a| from governing |i|. To illustrate this I will take a simpler system, i.e. one with five non-advanced and four advanced vowels, such as that of Turkana:

(42)





I suggest that in cases of this type such spreading of |i| to /a/ is disallowed, leading to a situation in which the low vowel will block the spreading of |i|. Alternatively, we must allow some form of 'repair' in those cases where the ATR congener of /a/ merges with some other vowel. In Turkana for example the ATR counterpart of /a/ is /o/ (in suffixes), showing that |u| has been added to govern |i| (cf. Dimmendaal 1983; van der Hulst & Smith 1986).

Just as the parametric choice with respect to government on the |a|-tier decides between two types of ATR-system, so we also derive two types of palatal systems, allowing us to distinguish between Hungarian and Finnish in terms of the choice for government on the |a|-tier. In Finnish, /a/ has a harmonic counterpart /æ/, whereas this is not the case in Hungarian, where /a/'s palatal congener is a mid vowel. Goldsmith (1985) tentatively suggests a vowel-height parameter to account for this difference. Within the present system this parameter turns out to be IA1 in (26). Let us say that in Hungarian the value is *no* (|a| cannot govern), whereas in Finnish it is *yes*:

(43)

Finnish				*Hungarian*			
/i/	/y/		/u/	/i/	/y/		/u/
/e/	/ö/		/o/	/e/	/ö/		/o/
/æ/		/a/				/a/	

Prohibiting |a| from governing |i| in Hungarian guarantees that spreading |i| to /a/ leads to a vowel in which |i| governs |a|, in other words a mid vowel, on the assumption that there is a repair rule which switches headship. Actually, the situation might be different in Hungarian for short vowels, where the harmonic counterpart of /a/ is a low vowel which behaves differently from the harmonic counterpart of the long /a/. Such matters are more fully discussed in van der Hulst (1989).

5.3 Other empirical motivation

A fruitful topic involving vowel system typology not explored here would be to investigate the predictions this model makes regarding the shape variation of systems across languages and in language development. For example, we might analyse very simple systems (which Trubetzkoy 1939 terms 'linear systems') as having just the |a|-tier:

(44) /a/	/ə/	/ɨ/	
v	v	v	v-tier
a	a ∘	∘	a-tier

More complex systems would involve the presence of the |i|-tier, and finally the |u|-tier. (This way of representing complexity is reminiscent of what is called 'line conflation' in GBP.) Complexity might further be measured along another axis, *viz.* the distinctive presence of government and empty vowels as in (23).

In the area of acquisition (i.e. child phonology), the hierarchy provides a basis for solving the classical puzzle that coronal consonants and palatal vowels (both to be represented in terms of a governing |i|) seem to be unmarked compared to other segments in their major class, whereas children learning the phonology begin by taking labial and pharyngeal (*papa/mama*) as the first representatives of these classes. I suggest that this choice is determined by the fact that children uttering such words have simply acquired *syllables*, i.e. consonant and vowel sequences and no differentiation within these classes yet. As representatives of consonant and vowel the two extremes of the hierarchy are chosen: |u| (giving the labial consonant) and |a| (giving the pharyngeal vowel). Thus we provide a basis in the theory for insights expressed in Jakobson (1968): labial and pharyngeal are extremes, whereas coronal is intermediate, giving it its unmarked status.

Obviously, both areas (typology and development) have to be explored in much greater detail. However, such exploration might be most fruitfully conducted within the terms of our proposed system of representation.

6 Conclusions

In this paper I have proposed a representational system for vowels in which three unary components enter into a binary structure involving both dominance and dependency relations. I have proposed a way of deriving a phonetic interpretation for vowel structures. In this sense, we might characterise the approach as 'interpreted phonology'. Using a number of examples of vowel harmony systems, I have provided empirical motivation for the proposal and, finally, I have suggested some other areas where support seems forthcoming.

NOTES

* In developing the proposals made here I was fortunate to enter into discussions with a number of colleagues and students: Nick Clements, Tom Cook, Marcel

den Dikken, Colin Ewen, Paula Fikkert, Morris Halle, Teun Hoekstra, Helga Humbert, Jonathan Kaye, Petra Kottman, Claartje Levelt, John van Lit, John McCarthy, Iggy Roca, Lisa Selkirk, Norval Smith, Keith Snider and Moira Yip. Oral versions of this paper were presented at the University of Amherst and at MIT (November 1988) and at the Workshop on Government and Dependency Phonology in Leiden (December 1988). The presentation here benefited from the comments of two anonymous reviewers.

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