Vowel geometry

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1 Introduction

A basic assumption in current phonology is that features are not an unstructured set like (1a), but are arranged hierarchically into a constituent structure tree such as (1b), proposed in Sagey (1986: 61):

(1) a.

\[
\begin{array}{c}
\text{nasal} \\
\text{high} \\
\text{cont} \\
\text{distr} \\
\text{round} \\
\text{low} \\
\text{voice} \\
\text{ant} \\
\text{back} \\
\text{son}
\end{array}
\]

b.

\[
\begin{array}{c}
\text{Laryngeal} \\
\text{Supralaryngeal} \\
\text{constr} \\
\text{spread} \\
\text{stiff} \\
\text{slack} \\
\text{guttis} \\
\text{guttis} \ v.c. \ v.c. \\
\text{Soft} \\
\text{place} \\
\text{nasal} \\
\text{Labial} \\
\text{Dorsal} \\
\text{Coronal} \\
\text{round} \\
\text{high} \\
\text{low} \\
\text{back} \\
\text{ant} \\
\text{distr}
\end{array}
\]

Other groupings of features have been proposed (Clements 1985; Steriade 1987; inter alii).

A fundamental assumption of theories like (1b) is that rules operate on constituents, an assumption which is formalised by limiting rules to spreading or delinking a single node. This constraint limits the power of phonological rules, so that it remains possible to state a rule spreading
place of articulation features, since these features form a constituent, but it becomes impossible to state a rule simultaneously spreading [nasal] and [voice]. Since those two features, to the exclusion of all others, do not form a constituent in this model.

The aim of this paper is to focus on the place features of vowels, traditionally [round], [back], [high], [low] and [ATR], and to raise the question whether at some level these features form a phonological constituent, to the exclusion of other features. In so far as this question will be answered in the affirmative, a related issue to be investigated is the existence of intermediate nodes between that vowel feature node and its terminals. Following an overview of previous work on the grouping of place of articulation features, especially those assigned to vowels, the proposed organisation of vowel features into nodes is presented. It is first argued that the features governing vowel backness and rounding constitute a subconstituent under the Vowel Place node; it is then shown that features governing vowel height form a separate constituent under the Vowel Place node.

2 Background

2.1 Previous feature theories

The proposal that features for place of articulation should be gathered under a single node is set forth in Clements (1985), who does not assume any subgrouping under the Place node. The geometry assumed there seems to be as follows:

(2)

\[ \text{Place} \rightarrow \text{cor} \rightarrow \text{ant} \rightarrow \text{dist} \rightarrow \text{lab} \rightarrow \text{high} \rightarrow \text{back} \rightarrow \text{round} \]

A further elaboration of this model is set forth in Archangeli & Pulleyblank (1987), who follow the suggestion of Clements (1985) that place features might be distinguished for being primary vs. secondary features. The following organisation of place features is proposed:

(3)

\[ \text{Place} \rightarrow \text{Secondary place} \rightarrow \text{cor} \rightarrow \text{ant} \rightarrow \text{dist} \rightarrow \text{low} \rightarrow \text{high} \rightarrow \text{back} \rightarrow \text{round} \]

However, no arguments are given for this organisation of features.

Subsequent work by Sagey (1986) organises place features into sub-groups, as seen in (1) grouping is that the tree into constituents executes the particular organisation captured by Sagey's proposal, in a way that is:

To account for the fact that are usually transparent the dorsal place of articulation node unspecified for that feature can spread over no vowel harmony: dorsal consonants, since Dorsal node (Dorsal is common), and the into block such a harmony

Steriade (1987) proposes that:

tongue body position vowels and consonants node and the features separate Articulator, this, vowels and consonants Place. Supralaryngea in cases where these

The following organisation:

(4)

\[ \text{Dorsal} \rightarrow \text{high} \rightarrow \text{low} \rightarrow \text{back} \]

An advantage of this account of rules spread not blocked by consonants there is a process in K spreads the place feat causative *mT*. This

and uvulars (the latter 1964).
ures form a constituent, but eously spreading [nasal] and cision of all others, do not e place features of vowels, nd [ATR], and to raise the ures form a phonological s. In so far as this question issue to be investigated is the t vowel feature node and its us work on the grouping of use assigned to vowels, the nodes is presented. It is first ness and rounding constitute ode; it is then shown that erate constituent under the
groups, as seen in (1b). A motivating principle which underlies this grouping is that 'the terminal features are grouped at the next level in the tree into constituents according to which articulator in the vocal tract executes the particular feature' (1986: 15). The primary argument presented by Sagey for the structure in (1b) is that such a feature organisation captures generalisations regarding possible complex segments, in a way that (2) does not.

To account for the fact that consonants, including dorsal consonants, are usually transparent to vowel harmony, Sagey (1986: 147) claims that the dorsal place of articulation in consonants is represented with a Dorsal node unspecified for the features [back] and [high]. Thus any single vowel feature can spread over dorsal consonants. However, the model predicts that no vowel harmony rule could spread both [high] and [back] across dorsal consonants, since such a rule must be expressed as spreading of the Dorsal node (Dorsal is the lowest node which [high] and [back] have in common), and the intervening Dorsal node of velar consonants would block such a harmony process.

Steriade (1987) proposes a development of the model in Sagey (1986) which explains certain phenomena that might seem to motivate segregating vowel and consonant place features into disjoint tiers. Steriade proposes that:

tongue body position corresponds to different Articulator nodes in vowels and consonants; we would reserve for the vowels the Dorsal node and the features it dominates ([high], [low], [back]) and posit a separate Articulator, Velar, for velar/uvular consonants. Aside from this, vowels and consonants will share their class tiers; they will have Place, Supralaryngeal, Laryngeal and Root nodes on the same tiers even in cases where these nodes dominate disjoint sets of terminal features. (1987: 597)

The following organisation of place features is assumed:²

(4)

```
Place

Dorsal  Coronal  Labial  Velar

high  low  back  ant  distr  round  back  high
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An advantage of this model over that of Sagey (1986) is that it allows an account of rules spreading multiple vowel place features, rules which are not blocked by consonants, including dorsal consonants. For example, there is a process in Klamath (which has the vowels i, e, a and o) which spreads the place features of a vowel to certain prefixes such as the causative snV.² This rule applies across all consonants, including velars and uvulars (the latter transcribed as q, q' and q; data from Barker 1963, 1964).
Since multiple vowel place features spread, this process would have to be expressed as spreading of the Dorsal node from the root vowel to the target vowel under the geometry of Sasey (1986). But such spreading would be impossible, since there is an association line between the Place and Dorsal nodes of the intervening dorsal consonants which stands between target and trigger in sna-čk’a-Wa, sne-ge-jiga, sni-nklikt’a. If we adopt the model in (4), the rule can be expressed as spreading of the Dorsal node; since consonants, and particularly velar consonants, in this language do not have features under the Dorsal tier, they do not block the spreading of vowel features:

Under this model of feature organisation, the features [back], [high] and [low] may freely spread across any consonants, either singly or as a group.

The model advanced by Steriade predicts that the feature [round] may spread along with some other vowel features only if all vowel place features spread. Furthermore, such spreading can only apply across consonants having no Place node, typically laryngeal consonants. (Paradis & Prouet 1989 have argued that coronal consonants in Fula, Guere and Mau are unspecified for place features, hence may be skipped.) This prediction follows from the geometry in (4), and the fact that the only way within the model to assimilate both Dorsal features and the feature [round] is to spread the Place node, since the Place node is the lowest node in the feature hierarchy which dominates [round] and the remaining vowel place features. Regular consonants should not intervene, since spreading Place features from vowel to vowel would cross lines with the consonant, as in (7):

2.2 An alternative geometry

In this paper evidence be segregated from off geometry is proposed, rated by one node, dominated by a separate vowel place features at node. Thus, the geometry:

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(5) sna-batgal ‘gets someone up from bed’
sna-čk’a-Wa ‘makes cold’
sne-ge-jiga ‘makes tired’
sno-bo-stgi ‘causes something to turn black’
sni-jii-qiq’a ‘makes someone ticklish’
sni-nklikt’a ‘makes dusty’
sni-glikt’a ‘makes tight’

(7) Supralaryngeal

Place

Since laryngeal consonants intervene between the

(8) Supralaryngeal

Place

A crucial step in this are dominated by the L

dominated by the Dorsal
this process would have to from the root vowel to the 1986). But such spreading line between the Place consonants which stands *-ge-fga, sni-nklk‘a. If we reset as spreading of the velar consonants, in this tier, they do not block the features [back], [high] and either singly or as a group, at the feature [round] may be only if all vowel placing can only apply across alveolar consonants. (Paradigms in Fula, Guere and ce may be skipped.) This the fact that the only way features and the feature place node is the lowest node d] and the remaining vowel intervene, since spreading a lines with the consonant,

\[ Vowel\ geometry \]

Since laryngeal consonants are assumed to lack a Place node, they can intervene between the vowels involved in total assimilation:

\[ \overrightarrow{\text{Supralaryngeal}} \]

A crucial step in this argument is the assumption that the feature [round] is dominated by the Labial node, and that [high], [back] and [low] are dominated by the Dorsal node.

### 2.2 An alternative geometry

In this paper evidence is given against the assumption that [round] is to be segregated from other vowel features in this manner. An alternative geometry is proposed, where the features [back] and [round] are dominated by one node, and [high], [ATR] and possibly [low] are dominated by a separate node. Finally it is shown that the totality of vowel place features are dominated by a single node, the Vowel Place node. Thus, the geometry in (9) is proposed:

\[ \text{Place} \]

\[ \text{Dorsal} \]

\[ \text{Labial} \]

\[ \text{Coronal} \]

\[ \text{Vowel Place} \]

\[ \text{Height} \]

\[ \text{(low) ATR high} \]

\[ \text{Back-Round} \]

\[ \text{round back} \]
2.3 Round and labial

The model in (9) departs most radically from previous models in not placing [round] under the Labial node. It is therefore necessary to scrutinise the arguments for assigning [round] under Labial, and to consider whether that assignment makes other incorrect predictions. Finally, it is important to consider whether the grouping of [back] and [round] is grounded in plausible phonetic reasoning.

The theoretical driving force behind the geometry of Sagay (1986) is the assumption that feature geometry is motivated by articulator phonetics. In articulatorily driven geometry, each articulator has a corresponding node which dominates all and only the features executed by that articulator. On these grounds, tongue position features could not be a constituent with a lip protrusion feature, since lip protrusion and tongue backing are not executed by the same articulator. While we have no quarrel with the belief that aspects of phonological structure should be grounded in phonetic properties, there is no reason to give articulatory phonetics a privileged position over acoustic phonetics in explanations.

The grouping of [high], [low] and [ATR] on the one hand, vs. [back] and [round] on the other, has a very natural explanation in terms of acoustic properties—the primary acoustic correlate of the first group is an effect on F1, and the primary acoustic correlate of the second group is an effect on F2 (Ladefoged 1975: 173). In the case of [high], [low] and [ATR], acoustics and articulation make roughly the same prediction. But in the case of [back] and [round], acoustics and articulation make different predictions—the test of constituent spreading, which we shall apply below, shows us that the prediction of the acoustically driven model is correct. This underscores decisions about feature about vocal tract anator regarding phonological arguments.

In fact, the articulator the remaining vowel ft predicts non-existent t simulation of [high], [l]c. Suppose one were to fin vowel harmony exclu:

(10) eko → èkō
     iko → ikū
     uke → uki
     ikō → iku

In the geometry in (4),

(11) Place

Dorsal

Under the proposal may be a rule of total vowel node dominating both Vowel Place node, the spread. Since rules lik predicts the impossibil assignment of [round] assigned to.

Before proceeding tion, it is necessary to d claim made by the geo by the Labial node, ra vowel features (Dorsal to place [round] unde homology, the empiric node is that certain lang [round] on vowels at Campbell (1974), gives Tulu has a rule which labial consonant. In t which make labial cot argues that this proce spreading. The follow
allows any single feature to spread together as a height; this prediction will omit Tunica, Cheremis and back] and [round] spread, support the Back-Round vowel height may spread to rounding: this prediction in Kimantuumbi and Ewe sed, in support of the left 1 of where [low] should be gned to the Height node, d in this paper. However, compulsory, and until more in the feature hierarchy ow] must be viewed as correct. This underscores the point made by Clements (1985), that decisions about feature geometry are not to be based on a priori decisions about vocal tract anatomy, but should be grounded on generalisations regarding phonological processes, as well as acoustic and articulatory arguments.

In fact, the articulatorily driven model, which excludes [round] from the remaining vowel features (except at the level of the Place node), predicts non-existent types of multiple feature harmony, namely assimilation of [high], [low] and [back], without assimilation of [round]. Suppose one were to find alternations like those in (10), which is complete vowel harmony excluding [round]:

(10) eko → ekō
    iko → iku
    uko → uki
    ikō → iku

In the geometry in (4), such a process could be formalised as (11):

(11) Place

[Dorsal]

Under the proposal made here, any rule spreading [back] and [high] must be a rule of total vowel harmony, since the Vowel Place node is the lowest node dominating both [back] and [high]. Since [round] is also under the Vowel Place node, that feature would also spread if [back] and [high] spread. Since rules like (11) are unattested and since the model in (9) predicts the impossibility of such harmony, this constitutes an argument against assigning [round] to a node separate from the one which [back] is assigned to.

Before proceeding to arguments for the Back-Round constituent relation, it is necessary to dispense with one argument commonly given for the claim made by the geometries in (1b) and (4), that [round] is dominated by the Labial node, rather than whatever node dominates the remaining vowel features (Dorsal, in these models). Apart from the a priori decision to place [round] under Labial based on the articulation ~ constituency homology, the empirical argument for placing [round] under the Labial node is that certain languages exhibit some connection between the feature [round] on vowels and labial consonants. Sagey (1986: 137), citing Campbell (1974), gives a typical example from Tulu. According to Sagey, Tulu has a rule which rounds /i/ to [u] after either a round vowel or a labial consonant. In the SPE system of features, there are no features which make labial consonants and round vowels a natural class. Sagey argues that this process can be rendered as the natural process of Labial spreading. The following rule is offered (1986: 138):
Two redundancy rules are assumed: (i) a Labial node linked to a vowel is assigned the value [+round], and (ii) a Dorsal node on a vowel with a Labial node is interpreted as [+back]. This second convention is actually unnecessary since, as Bright (1972) states, the back unrounded vowel [i], not [ii], becomes [u], so the vowel is [+back] to begin with.

Sagey does not comment on the fact that since the Labial node is spread from the consonant to the vowel, and is later given the value [+round], then the consonant itself should also be rounded. In other words, applying the labial spreading rule followed by the redundancy rule for [round] to underlying /kappi/ 'blackness' would give the following structure:

Bright gives no evidence that the labial consonant becomes round, and, especially when the consonant is syllable-final and not immediately followed by a rounded vowel as in [avtu] from /avfi/ 'out', where consonant rounding would be especially salient, it is unlikely that such rounding is present. Additional machinery is necessary in this case, and others like it, to split the Labial node into two, so that only the Labial node of the vowel is filled in with the feature [+round].

There is no reason to reject the geometry in (9) based solely on the fact that the theory does not encode the relationship between [round] and Labial in constituent structure. There are analogous problems in the relation between vowel and consonant place features which still remain unexplained in the theories of Sagey (1986) and Steriade (1987). One such relation is the one between [coronal] and [−back]. Hume (1990) shows that there is a vowel-fronting rule in Maltese Arabic whereby /o/ becomes [i] when immediately followed by a coronal obstructant. Thus, the prefix vowel of imperfective verbs in the first binyan is a copy of the root vowel, but just in case the immediately following consonant is a coronal obstructant, the prefix has the vowel i:
node linked to a vowel is node on a vowel with a
and convention is actually
ck unrounded vowel [i],
begin with.
he Labial node is spread
en the value [+round],
other words, applying
ancy rule for [round] to
allowing structure:

(14) yo-l̪ot ‘he hits’
yo-ktor ‘he/it increases’
yi-skot ‘he is silent’
yi-dhol ‘he enters’

Similar effects are discussed in Hyman (1973), Pulleyblank (1989) and others.

By the reasoning that would force us to assign [round] under the Labial
ode on the strength of the fact that vowels can become [+round] in the
vironment of labial consonants, we would be equally compelled to
assign [−back] under the Coronal node, based on the evidence from
Maltese, inter alia, that vowels can become front in the environment of
coronal consonants.

This would be impossible under Steriaide’s geometry (4), since such a
move would imply that [back] and vowel height could never spread across
sonorants. Since the lowest node dominating [back] and [high] is the
Place node, rules of total vowel harmony such as are found in Klomath
would have to spread the Place node, but such spreading would be
incorrectly blocked by the Place nodes of intervening consonants.

The relationship between labial consonants and round vowels therefore
does not constitute an argument for grouping [high], [low] and [back]
under the Dorsal node, to the exclusion of [round], since the same
reasoning would also force [back] to be assigned to the Coronal node,
based on the coronal ← front interaction. Yet it is desirable to have a
functional explanation for why vowels do become round in the context of
labial consonants, and why vowels front near coronals. A model which
addresses the functional identity of consonantal and vocalic place features
is presented in Clements (1989, 1990) and Hume (1990). In that model,
place of articulation for both vowels and consonants is defined in terms of
a single set of features, [labial], [coronal], [dorsal] and [radial]. The
exclusively vocalic features [back], [round] and perhaps [ATR] are
eliminated. Place features are placed on different planes, depending on
whether they function as consonantal place features, in which case they are
immediately dominated by the highest Place node, the C-place node, or
function as vocalic features, in which case they are dominated by the lower
place node, the V-place node.
Under this model, Labial on the consonantal plane denotes labial closure as under previous models, but Labial on the vowel plane denotes lip protrusion, i.e. rounding. Similarly, Coronal on the consonantal plane is interpreted as raising of the tongue blade, but Coronal on the vocalic plane is interpreted as fronting of the tongue.

As far as the constituent structure of vowel features is concerned, the model proposed in (9) is fundamentally compatible with Clements’ proposal, (16). In particular, both models agree in assigning the features for vowel height under one constituent, and assigning the features for rounding and the front–back distinction under a different constituent. The differences between the models, while not trivial, do not materially affect the debate over the constituency of vowel features, but rather centre around the substance of the features themselves. The model in (16) employs two features for representing front v. back vowels, whereas the present model assumes a single binary feature. The model in (16) adopts a vocalic version of Radical (to describe pharyngealised vowels in the Lezgian languages Tsakhur and Udi), where such a feature is not assumed in the current theory; nothing in the nature of the proposal precludes including this feature.

2 Back-Round constituency

Given the previously noted problem that surface [+ round] vowels might in some languages be treated as underlyingly unspecified for rounding (the phonetic value of [round] being assigned on the basis of the backness of the vowel), rules motivating the constituency of [round] and [back] must come from languages where [round] cannot be predicted on the basis of other features. Furthermore, it is not sufficient merely to show that both [back] and [round] spread. Rather, one must show that there is a single spreading rule, not one rule spreading [back] and another spreading [round].

2.1 Eastern Cheremis

Eastern Cheremis (Mari), a Uralic language of the Soviet Union, has such a harmony rule. The vowels of Eastern Cheremis are those in (17):

The vowel harmony rule & Ingemann (1961) is that vowel harmony (kue ‘1
rot’), all involving the final stems which obey
Suffixes with the vowel suffix -na:

Finally, underived stem
Vowel harmony rule of Eastern Chermis is illustrated in (18). Sebeok & Ingemann (1961: 10) state that certain suffixes have a three-way alternation between final [e], [o], and [i], with o appearing after u or o, ə after ə or ə, and e after i, e, ə, and o. We therefore assume that the vowel underlying these alternations is e. Consonants and the vowel ə may stand between the triggering and harmonising vowels (Ingemann 1960; Minn 1960; Ristinen 1960; Sebeok & Ingemann 1961). This is illustrated below with the 3rd singular possessive suffix -əče:

(18) kir-əče 'his hand' surt-əče 'his house'
ergo-əče 'his boy' üp-əče 'his hair'
kobaštə-əče 'its fur' sür-əče 'its milk'
bozkent-əče 'beside it' surkəstə-əče 'to his house'
šužər-əče 'his sister' pörtsəstə-əče 'in his house'
boz-əče 'his wagon' kornə-əče 'his way'

Other affixes exhibit this alternation, for example the inessive case markers -əše and -ne, and the verbal noun suffix -me:

(19) čodra-štə 'forest' inessive
pörts-štə 'house' inessive
buğa-štə 'head' inessive
leš-ne 'near' pur-mo 'entering'
mundor-nə 'in the distance' aštə-mo 'made'
ošča-l no 'in front' šogə-mo 'standing'

Finally, underived stems are subject to harmony. The glossary of Sebeok & Ingemann (1961) lists only four lexical items which fail to undergo vowel harmony (hke ‘birch’, hze ‘how’, šue ‘sparse’ and uke ‘there is not’), all involving the sequence u...e, and over 200 underived mid-vowel final stems which obey the vowel harmony rule.

Suffixes with the vowel ə do not alternate, as shown by the 1st plural suffix -na:

(20) čodra-na ‘our forest’
pörts-na ‘our house’
buģ-na ‘our head’
ergə-na ‘our son’
I assume that the neutral vowel ə is merely specified as a skeletal position, so lacks place feature entirely. This assumption has independent justification in the language. Morpheme-final mid vowels reduce to ə when followed by another consonant, accounting for the alternation kobaše 'fur' ~ kobaš-ze 'its fur' or erga 'boy' (NOM) ~ erga-m 'boy' (ACC). This can be handled by deleting the place features of the vowel (or any node dominating place features), and by application of later default rules, the vowel is realised as ə. Rules of epenthesis insert the vowel ə to render syllabifiable certain consonant sequences. So, sequences of sibilants are broken up with epenthetic schwa, as shown by joltuš-əze 'his friend' (cf. aža-ž-at 'his father' (EMPHATIC)). Under the assumptions that vowel epenthesis merely inserts a prosodic element, and that ə lacks segmental features, we correctly predict that the epenthetic vowel of Cheremis is ə.

This leaves us with the matter of formalising a harmony rule which spreads a single node and assimilates [back] and [round], but not [high]. Under the hypothesis advanced here, that [back] and [round] are a constituent, the harmony rule will be formulated as in (21):

(21) Cheremis Back-Round Harmony

Vowel Place

Back-Round

[+round]

Height

[−low]

If we reject the hypothesis of Back-Round constituency in favour of models like that of Sager (1986) or Steriade (1987), there are two routes to take to account for these alternations. The first would be to reduce this phenomenon to spreading of one feature, and let default rules assign the appropriate value for the other feature. But since there is a contrast between ə, ə and ə, this is impossible. Spreading the feature [round] alone is insufficient, since there is no way of knowing on the basis of the value of [round] whether a vowel is front or back. We could suppose that the rule spreads [back], with the value of [round] being assigned on the basis of [back]. But [−back] vowels are not necessarily [+round] −i and e are not. Therefore, underspecification and default values are irrelevant to the analysis of Cheremis harmony.

Alternatively, we could assume two separate harmony rules, one assimilating [back] and the other assimilating [round], as in (22):

(22) a. Round Ho

Place

Dorsal

Labial

b. Back Har

Place

Dorsal

(23) šoge-m

šoge-na

šoge-ne-m

šoge-ze-ze

burgem-ze

There are good re condition, which is a would have to be sta The second piece which are exceptions few underrformed kuz, su and tke exceptions to a sinl stems are exceptions word is an exception the other. As the exi harmonise. If harm morpeme to be an e is only one rule to b

(24) šoga-de
tol-de
koč-še
ioga-da-mo
koč-ta-mo
(22) a. **Round Harmony**

\[
\begin{array}{c}
\text{Place} \\
\text{Dorsal} \\
\text{Labial} \\
\end{array}
\]

\[
\begin{array}{c}
[+\text{round}] \\
[-\text{high}, -\text{low}] \\
\end{array}
\]

b. **Back Harmony**

\[
\begin{array}{c}
\text{Place} \\
\text{Dorsal} \\
\end{array}
\]

\[
\begin{array}{c}
[-\text{high}, -\text{low}] \\
[+\text{back}] \\
\end{array}
\]

There are good reasons not to have two rules. First, as shown in (23), harmony only applies to word-final \( e \), and non-final \( e \) does not harmonise:

(23) \( \dot{\text{šo}}\text{ge}-\text{m} \) 'I stand'
\( \dot{\text{šo}}\text{ge}-\text{na} \) 'we stand'
\( \dot{\text{šo}}\text{ga}-\text{ne}-\text{m} \) 'I want to stand'
\( \dot{\text{šo}}\text{ga}-\text{ne}-\text{že} \) 'he wants to stand'
\( \text{bur}\text{g}\text{e}-\text{m} \) 'his clothing'

If harmony were decomposed into two rules, the absolute word-final condition, which is a rather unusual condition on a vowel harmony rule, would have to be stated twice.

The second piece of evidence comes from the vocalic pattern of words which are exceptions to vowel harmony. We have noted that there are a few underived forms which are exceptions to vowel harmony, *viz.* \( \text{k}u\text{e}, \text{k}u\text{ze}, \text{šu}e \) and \( \text{u}k\text{e} \). Under the single-rule approach, these words are exceptions to a single rule, whereas under the two-rule approach, these stems are exceptions to both rules — it is an unexplained accident that no word is an exception to one harmony rule without being an exception to the other. As the examples of (24) show, the suffix -\( \text{de} \) regularly fails to harmonise. If harmony is made into two rules, there is no reason for this morpheme to be an exception to both rules. If there is only one rule, there is only one rule to be an exception to.

(24) \( \dot{\text{šo}}\text{ga}-\text{de} \) 'without standing'
\( \text{tol}-\text{de} \) 'without coming'
\( \dot{\text{šo}}\text{ga}-\text{da}-\text{mo} \) 'without standing'
\( \dot{\text{šo}}\text{ga}-\text{to}-\text{mo} \) 'without eating'
The last two examples show that a suffix may follow -de, causing reduction of e to ə, and harmony propagates over that vowel to affect the verbal noun suffix -me (seen earlier in (19)). Thus one cannot dispose of the problem of -de by assigning that morpheme to a stratum after vowel harmony.

2.2 Tunica

A second argument for the constituency of [back] and [round] comes from Tunica (formerly spoken in Louisiana). Haas (1940, 1946) states that the vowels of Tunica are i, e, æ, o, ə, and u. The vowels e and æ are described as low vowels: e is ‘a low vowel, slightly closer than the a of Eng. mat but not so close as the e of Eng. met...’, and æ is ‘a rounded low back vowel but not quite so low as a in Eng. all’ (1940: 15). Based on this description, and the pattern of vowel harmony, we will treat e and æ as [+low] vowels. The vowels of Tunica are thus as follows:

\[
\begin{array}{cccc}
\text{high} & \text{low} & \text{back} & \text{round} \\
i & + & - & - \\
e & - & + & - \\
æ & - & + & - \\
a & - & + & + \\
o & - & - & + \\
u & + & - & + \\
\end{array}
\]

The low vowel a becomes e after a front non-round vowel, and becomes ə after a back round vowel: see Odden (1977) and Hammond (1984) for additional discussion of Tunica. Besides the Back-Round harmony rule, there are two additional processes which are relevant to the discussion. By the first rule, Truncation, the leftmost of two adjacent vowels deletes. The relevant vowel cluster may be brought into existence by applying a rule to delete intervocalic h which is preceded by at least two syllables:

\[
\begin{array}{c}
lətakətə \\
lətakətə-ənī → lətakətənī \\
nisara \\
nisara-ənī → nisarenī \\
saku \\
saku-hila-wihē → sākilawihē \\
∽ənī \\
∽ənī-hila-wihē → ∼ənīlēwihē \\
lūta \\
lūta-hila-wihē → lūtilawihē \\
(cf. lā-hila-tihē ‘when the sun was about to set’) \\
∽unīma \\
∽unīma-hat → ∼unīmat \\
(cf. mā-hat ‘you, on your part’) \\
\end{array}
\]

By a second process e before a glottal stop:

\[
\begin{array}{c}
\text{hāra} ‘to sing' \\
nāsī ‘to lead' \\
yā ‘to do' \\
hōpi ‘to emer’ \\
\end{array}
\]

The vowel harmony, vowels, and to vowels we see examples of Back suffixes -ənī and -hē becomes ə after any bac round vowel. The trigg

\[
\begin{array}{c}
mūlī \\
mūlī-ənī \\
tāšle \\
tāšle-ənī \\
lupitehē \\
lupitehē-ənī \\
mōliu \\
mōliu-ənī \\
mōlōhō \\
mōlōhō-ənī \\
∽uwi \\
∽uwi-hat \\
sahikū \\
sahikū-hat \\
\end{array}
\]

This process also applies across h. The vowel wh Preglottal Apocope if t that h postvocally.

Back-Round harmony

\[
\begin{array}{c}
∽kī \\
∽kī-ənī \\
pō-∽kī \\
mē-∽kī \\
nāsī-∽kī \\
mōtu-∽kī-ənī \\
\end{array}
\]

This process of har consonant intervenes t

\[
\begin{array}{c}
hupu-hk-∽kī \\
P\text{cu-hk-∽kī} \\
\end{array}
\]
By a second process of Preglottal Apocope, an unstressed vowel deletes before a glottal stop:

(27) hāra 'to sing'  hār-řaki 'she sang'
    nāši 'to lead'  nāš-řukki 'he sang'
    yā 'to do'  yā-řaki 'she did'
    hopi 'to emerge'  hopi-řukki 'he emerged'

The vowel harmony rule, illustrated in (28), applies to strictly adjacent vowels, and to vowels separated by the laryngeal glides ũ and ũ. In (28), we see examples of Back-Round harmony applying to the vowel r of the suffixes -enti and -(h)at (seen in (26)) after a vowel. Suffix-initial r becomes e after any back round vowel, and becomes a after any front non-round vowel. The triggering vowel to the left then deletes by Truncation:

(28) mili → mili-áni → mili-řáni 'it is red'
    tāšle → tāšle-áni → tāšle-řáni 'it is beautiful'
    lůpičše → lůpičše-áni → lůpičše-řáni 'she will not die'
    mōlu → mōlu-áni → mōlu-řáni 'it is full'
    mōlu-řáni → mōlu-řáni 'it is full, it is said'
    mōlo-řa → mōlo-řa 'it is not full'
    mōlo-řa-áni → mōlo-řa-řáni 'it is not full, it is said'
    Ūwi → Ūwi-řat → Ūwi-řat 'he, on his part'
    sahu → sahu 'one'
    sahu-řat → sahu-řat 'one, on one's part'

This process also applies across ũ and, at least in the negative suffix ũaha, across ũ. The vowel which conditions Back-Round harmony will delete by Preglottal Apocope if unstressed. Other suffixes beginning with ũ delete that ũ postvocically, so it is not possible to find additional examples of Back-Round harmony applying across ũ:

(29) ũaki → čū-ũaki 'she is'
    čū-ũaki → čū-ũaki 'she took'
    pō-ũaki → pō-ũaki 'she saw'
    mē-ũaki → mē-ũaki 'she searched'
    nāši-ũaki → nāš-ũaki 'she led'
    mōlu-ũaha-áni → mōlu-ũaha-řáni 'it is not full'

This process of harmony is blocked if a supralaryngeal articulated consonant intervenes between the target and trigger vowels:

(30) hipu-hk-ũaki 'she is dancing'
    čū-hk-ũaki 'she is taking'
We now turn to the matter of formalising this harmony rule. The feature [round] is contrastive for the two low back vowels o and a. Therefore, the simultaneous assimilation of [back] and [round] seen above cannot be reduced to assimilation of [back] plus default assignment of [+round] to back (low) vowels, since the back vowel a itself is [+round]. As these data also show, vowel height is not assimilated by this process, so the rule cannot be construed as spreading of the Place node. Only [back] and [round] are assimilated, and in the model proposed here, the rule is formulated as (31):

\[
\text{(31) Tunica Back-Round Harmony}
\]

\[
\begin{array}{c}
\text{Vowel Place} \\
\text{Back-Round} \\
\text{Height} \\
[+\text{low}]
\end{array}
\]

The condition that only laryngeals may stand between trigger and focus is unusual: in other harmonies where only laryngeal consonants may stand between the vowels, the harmony is complete assimilation. This condition on intervening elements is problematic for the following reason. It is widely assumed (see Steriade 1987, inter alia) that phonological rules do not contain an explicit list of elements allowed to stand between the elements of the rule (e.g. 'X \neq f \neq x'). Rather, such conditions are held to be the consequence of the representation of segments and a theory of adjacency conditions (e.g. 'the focus and determinant must be adjacent at level X'). The condition on intervening consonants could be handled by requiring the Place nodes of the trigger and focus to be adjacent. This condition would be satisfied only between strictly adjacent vowels, or by vowels separated just by laryngeals: regular consonants, having a Place node, would block the spread of vowel features. This kind of adjacency requirement would be at best highly marked, the unmarked choices being that the vowels involved in vowel-to-vowel assimilation must be in adjacent syllables, or else may be inde finitely separated.

Subj ect ing the rule to the requirement that the Place nodes of focus and determinant be adjacent is, in fact, unprecedented. Steriade (1987) proposes that adjacency conditions are stated prosodically, hence will involve X-slots, syllables, and the like. Archangeli & Pulleyblank (1987) propose that adjacency be determined either at the highest level of phonological representation (X-slots or syllable heads) or at the lowest level (the spreading node itself). Neither theory would countenance the requirement that the Place nodes of the involved vowels must be adjacent, since it is not the Place node which is spreading.

There is a plausible alternative account of apparent 'translaryngeal harmony' in Tunica, grounded in the assumption that low vowels and laryngeals form a harmony rule spread [pharyngeal] or [radi] applies to strictly ac syllables only the lary cannot affect a separ Thus the derivation:

\[
\text{(32) }
\]

\[
\begin{array}{c}
\text{Place} \\
\text{Vowel Place} \\
\text{Back-Round}
\end{array}
\]

Assigning [+low] to Brame (1972) shows Arabic form a natural consonants. Odden (1 vowel dissimilation ir by a laryngeal conson be explained by assign partially unifying lary (1989). Although Ht of h and f which wo [+ back] and [+ roun that such an effect, w event very hard to h hypothesis cannot be Whichever account should be only one ri vowel height. The onl rule is to postulate tw [round]. If there are t highly marked adjac apply to [+ low] cons

2.3 Wikchamni

The Wikchamni dialect spreading [round] anc dialect, the underlyin
this harmony rule. The back vowels e and a, as well as [round] seen above, have default assignment of vowel a itself is [−round], modulated by this process, so e Place node. Only [back] proposed here, the rule is laryngeals form a natural class defined by the feature [+low]. The harmony rule spreads [back] and [round] to [+low] (equivalently, [pharyngeal] or [radical]) segments, as is stated in (31). The rule only applies to strictly adjacent segments, and given that among the non-syllabic only the laryngeals h and ? are specified [+low], vowel harmony cannot affect a separated from the trigger vowel by any other consonant. Thus the derivation for i?η to i?ε proceeds as follows:

\[
\text{(32)}
\]

Assigning [+low] to the laryngeals has precedent in other languages—Braine (1972) shows how the laryngeals and pharyngeals of Maltese Arabic form a natural class in triggering a rule lowering i to a near [+low] consonants. Odden (1988) discusses a rule of vowel harmony and a rule of vowel dissimilation in Kena which apply to a provided it is not preceded by a laryngeal consonant, and shows that blockage of these two rules can be explained by assigning laryngeals the feature [+low]. Similar proposals partially unifying laryngeals and pharyngeals are presented in McCarthy (1989). Although Haas does not mention any special phonetic properties of h and ? which would directly lead us to conclude that they too are [+back] and [+round] between back round vowels, it is quite possible that such an effect, which is non-contrastive and would have been in any event very hard to hear, was simply not recorded. Unfortunately, this hypothesis cannot be verified phonetically.

Whichever account of the ‘translaryngeal’ condition is preferred, there should be only one rule, one which spreads [back] and [round], but not vowel height. The only alternative to spreading [back] and [round] by one rule is to postulate two rules, one spreading [back] and the other spreading [round]. If there are two rules, both rules would either be subject to the highly marked adjacency condition, or else both would coincidentally apply to [+low] consonants and vowels.

2.3 Wikchamni

The Wikchamni dialect of Yokuts (California) also has a harmony rule spreading [round] and [back], as pointed out in Archangeli (1985). In this dialect, the underlying vowels are i, i, u, o and a. The vowels which
Archangelic treats as front round vowels and writes as ī and ū are written as ē and ē in Gamble (1978). The choice of symbols made by Gamble and data from vowel formants suggest strongly that these should be interpreted as back unrounded vowels. I follow Gamble in writing them as ē and ē:

(33)  

<table>
<thead>
<tr>
<th></th>
<th>high</th>
<th>low</th>
<th>back</th>
<th>round</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ē</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>u</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>ū</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>a</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

In Wikchamni, vowels of the same height assimilate [back] and [round], as illustrated in (34):

(34) pin'ū - pin'ū 'stung'
     hūtū - hūtū 'knew'
     tūtū - tūtū 'made'
     tūnū - tūnū 'went'
     tōtū - tōtū 'might run'
     tōyōtū - tōyōtū 'might doctor'
     hūkūnū - hūkūnū 'might mix'

The same-height condition can be formalised either in terms of the feature [high], or else in terms of the total set of vowel height features. Nothing of substance depends on this choice.

Vowel harmony is formalised as (35) under the theory that [back] and [round] are a constituent. The identical vowel height condition can be explained by fusing height features, so that identical height sequences are represented with a branching structure:

(35) Wikchamni Back-Round Harmony

Vowel Place

Back-Round

Height

Since the rule is subject to an identical-height condition, it is quite unlikely that assimilation of [back] and [round] is accomplished by two separate rules which happen to share this condition.

As pointed out to me by a reviewer, this rule could also be construed as total vowel harmony, in so far as the height features of the involved vowels agree to begin with, and the [back] and [round] specifications of the vowels are assimilated by the rule, rendering the resulting vowel (segmentally) identical to the preceding vowel. The rule could therefore be formalised as place spreading:

(36) Wikchamni Place

Place

Vowel Place

Height

However, this is still only the tip of the iceberg. Under the Steriade/Sagey [round] and other vowel would have to be expressed harmony rule applies across the Place node of the Place nodes of consonants block the rule. So even Round spreading as some evidence for placing all Place nodes, one which is not overtly obvious.

2.4 Other examples

Other examples of Back-Back-Round harmony is that Masuki has a rule that includes, as illustrated with:

(37) pi-rīw 'arrow (of)

pu-moi 'egg (of)

pi-sī 'leg (of)

Clements (1989) cites a phonological constituent process in Maxakali 'voc inserting a glide between consonant (t, n, c, ē). The after деж, and as the approx y and ē after nasal:

(38) /p'ītīc/ → p

/p'ītīt/ → k

/p'īn/ → p

/pōhōc/ → p

/pōn/ → ū

/kakcoppit/ → k

/kōkfin/ → ū

/tatt/ → t

/tōntat/ → ū
(36) Wikchammi Place Spreading

Place

Vowel Place

Height

However, this is still only possible under the geometry proposed here. Under the Steriade/Sagey model, where the lowest node dominating both [round] and other vowel features is the Place node, total vowel harmony would have to be expressed as spreading of the Place node. Since this harmony rule applies across all consonants, the rule cannot be spreading of the Place node of the first vowel, on the grounds that the intervening Place nodes of consonants (for example t and ŋ in the form hutì-û) should block the rule. So even under the interpretation of Wikchammi Back-Round spreading as some kind of place spreading, we would still have evidence for placing all vowels features under a single node (the Vowel Place node), one which does not characterise consonants.

2.4 Other examples

Other examples of Back-Round harmony can be found, suggesting that Back-Round harmony is not particularly rare. Carson (1982: 51–52) notes that Macushi has a rule harmonising backness and roundness in certain affixes, as illustrated with the Class A prefix pi-:

(37) pi-riw ‘arrow (of someone)’
    pi-moi ‘egg (of someone)’
    pi-si ‘leg (of someone)’

Clements (1989) cites additional cases where [back] and [round] form a phonological constituent. Guzhinsky et al. (1970: 82–89) describe a process in Maksakali ‘vocalising’ coda consonants, part of which involves inserting a glide between the nuclear vowel and a vocalised coronal consonant (t, n, s, ŋ). The glide which is inserted is realised as y after i, w after a, and as the approximant ɣ after a and ŋ (or the nasal equivalents ĕ, ŋ and ｡ after nasal vowels):

(38) /piːtʃ/ → [pitiːj] ‘heavy’
    /kiːtʃ/ → [kiːtʃiː] ‘old’
    /pʲn/ → [pʲŋn] ‘noise made by jumping’
    /pɔhɔː/ → [pɔhɔː] ‘arrow’
    /ɕɔn/ → [ʃɔn] ‘to open’
    /kakɔpɔtʃ/ → [kakɔpɔtʃ] ‘boy’
    /koŋtʃ/ → [koŋtʃ] ‘meat’
    /tɔtʃ/ → [tɔtʃ] ‘to carry’
    /fiŋtʃ/ → [fiŋtʃ] ‘breast’
The inserted segment then is a [+high] segment agreeing in the features [back] and [round] with the preceding vowel.

In FipFip Bamileke (Hyman 1972), the features [back] and [round] spread from the stem vowel to the high vowel of the reduplicated syllable, without spreading the height of the stem vowel:

(39) si-sii 'spoil'
    si-suu 'vomit'
    si-suru 'miss'
    ku-ko 'take'\textsuperscript{13}

The prefix vowel is realised as [+high], presumably by application of default rules for vowel height.

In a Western Interior dialect of Ewe (Westermann 1930: 193-195; Clements 1974: 288), postcolitics with the vowel \(\_a\) assimilate backness and roundness, but not vowel height, from an immediately preceding vowel. Thus, \(\_a\) becomes the low back rounded vowel \(\_\_\) after \(\textit{u}, \textit{o}\) and \(\textit{a}\), and becomes the low front rounded vowel \(\_\_\) after \(\textit{i}\) and \(\textit{e}\) (examples of \(\_\_\) are not provided):

(40) ga-a → gaa 'the money'
    ko-a → koo 'the knot'
    te-a → tez 'the yam'
    to-a → too 'the mountain'
    bli-a → blie 'the corn'
    du-a → duo 'the town'

The same assimilation affects the habitual suffix -\(\_a\):

(41) me ta-a → me taa 'I usually draw'
    me do-a → me dzo 'I usually sleep'
    me de-a → me dez 'I usually go there'
    me do-a → me doz 'I usually plant'
    me di-a → me die 'I usually look for'
    me blu-a → me bluo 'I usually stir'
    me de-a → me dez 'I usually go there'

Westermann mentions that this harmony is optional in the plural (when the article is followed by \(\textit{wo}\)), so both \(\textit{así-a-wo}\) and \(\textit{así-e-wo}\) 'the groundnuts' are possible. If this harmony process were implemented by two separate rules, one spreading [round] and the other spreading [back], one would expect to find optional spreading of one feature without spreading of the other feature. If there is a single process of Back-Round harmony, we correctly predict that \(\_a\) assimilates both [back] and [round], or neither [back] and [round].

3 High-ATR and low

The second proposition to be supported is that [high] and [ATR] are a constituent. To show this, we will consider the height harmony rule of

Kimatuumbi, a Bantu lang.. (42). Data for Kimatuumbi

(42) high  low
    i    +    -
    u    +    -
    o    +    -
    e    -    -
    a    -    +

Breaking with traditional \(\text{u}\) familiar phonetic symbols have transcribed the high vowels as \(\text{i, u}\), and the mi.

Stem-medial vowels are from the [+high, +ATR] vowels assimilate the valu. low vowel. The height hi- out the lexicon, and cas b in (43), which contains alternates according to reciprocal suffix \(\text{an}\), whi

(43) ùt-a → tc
    yb-a → tc
    yoot-o-a → tc
    bik-a → b
    gonja → t
    chéng-a → t
    káat-a → t
    bülut-a → t
    lip-a → t
    yóngoy-a → t

Further examples initial \(\text{u}\). No produ. vowel harmony alts. The consonant \(\text{i}\) is ir.

(such as underlying
Kimatuumbi, a Bantu language of Tanzania, whose vowels are given in (42). Data for Kimatuumbi are from my own field notes:

\[
\begin{array}{ccccc}
& \text{high} & \text{low} & \text{ATR} & \text{back} \\
\i & + & - & + & - \\
\u & + & - & + & - \\
\o & + & - & - & - \\
\o & + & - & - & - \\
\a & - & + & - & + \\
\end{array}
\]

Breaking with traditional transcription for Bantu languages, I will use the familiar phonetic symbols. Other works on Kimatuumbi by this author have transcribed the high [+ATR] vowels as \(i, u\), the high \([-ATR]\) vowels as \(i, u\), and the mid \([-ATR]\) vowels as \(e, o\).

Stem-medial vowels are either (phonetically invariant) \(a\), or are selected from the [+high, +ATR] vowels \(i\) and \(u\). The stem-medial non-low vowels assimilate the value of [high] and [ATR] from the preceding non-low vowel. This height harmony rule is observed systematically throughout the lexicon, and can be directly motivated through alternations as seen in (43), which contains stems followed by the causative suffix \(iy\), which alternates according to the height of the preceding vowel, and the reciprocal suffix \(an\), which is invariant.

(43) \(\begin{array}{lll}
\text{ut-a} & \text{‘to pull’} & \text{ut-iy-a} & \text{‘to make pull’} \\
\text{yib-a} & \text{‘to steal’} & \text{yib-iy-a} & \text{‘to make steal’} \\
\text{yöyyout-a} & \text{‘to whisper’} & \text{yöyyout-iy-a} & \text{‘to make whisper’} \\
\text{bük-a} & \text{‘to put’} & \text{bük-iy-a} & \text{‘to make put’} \\
\text{gönja} & \text{‘to sleep’} & \text{gönj-iy-a} & \text{‘to make sleep’} \\
\text{chëng-a} & \text{‘to build’} & \text{chëng-iy-a} & \text{‘to make build’} \\
\text{kät-a} & \text{‘to cut’} & \text{kät-iy-a} & \text{‘to make cut’} \\
\text{bulut-a} & \text{‘to drag’} & \text{bulut-iy-a} & \text{‘to drag each other’} \\
\text{lip-a} & \text{‘to pay’} & \text{lip-iy-a} & \text{‘to pay each other’} \\
\text{yöongyo-a} & \text{‘to hurry someone’} & \text{yöongyo-iy-a} & \text{‘to hurry each other’} \\
\text{wikily-a} & \text{‘to cover’} & \text{wikily-iy-a} & \text{‘to cover each other’} \\
\text{gömb-a} & \text{‘to shoot’} & \text{gömb-iy-a} & \text{‘to shoot each other’} \\
\text{ék-a} & \text{‘to laugh’} & \text{ék-iy-a} & \text{‘to laugh at each other’} \\
\text{kät-a} & \text{‘to cut’} & \text{kät-iy-a} & \text{‘to cut each other’} \\
\end{array}\)

Further examples of height harmony can be seen in (44), involving non-initial \(U\). No productive suffixes in Kimatuumbi contain \(U\). However, vowel harmony alternations affecting \(U\) can still be directly illustrated. The consonant \(l\) is inserted between a stem which ends in a non-low vowel (such as underlying /tuku/) and a following non-low suffix such as the
applied -l (which undergoes Glide Formation before another vowel). Before a suffix beginning with a low vowel, l is not inserted, so Glide Formation applies. In the following example, we find pairs of verbs derived from a verb root, the first illustrating the stem without inserted l (therefore Glide Formation applies), and the second illustrating insertion of l, and hence application of height harmony:

(44) tipw-a 'to break off maize'
    tipul-y-a 'to break off maize for'
    gulw-a 'to wash dishes'
    gilul-y-a 'to wash dishes for'
    tikw-a 'to break'
    tikol-y-a 'to break for'
    yöongw-a 'to answer'
    yöongol-y-a 'to answer for'
    lsoncw-a 'to find a witch'
    lindal-y-a 'to find a witch for'
    tyamnw-s 'to sneeze'
    tyamul-y-a 'to sneeze on'

When final u ~ w appears as a vowel, its height is determined by the preceding vowel.

The fact that [high] and [ATR] spread together, without spreading [back] or [round], shows that [high] and [ATR] are a constituent under the Height node. This harmony will be formulated as in (45):

(45) Kimattumbi Height Harmony

\[
\begin{array}{c}
\text{Vowel Place} \\
\text{Height} \\
\end{array}
\]

\[
\begin{array}{c}
\text{[~low]} \\
\text{[~low]} \\
\end{array}
\]

One might consider treating this as two rules, [ATR] harmony and [high] harmony. There are good reasons not to do this. First, harmony has a peculiar condition on it seen in (46), namely that the vowel e does not cause u to assimilate, although all other vowels cause u to assimilate, and e will cause i to assimilate:

(46) chëkul-y-a 'laugh for'
    ntmul-y-a 'dance for'
    trkol-y-a 'break for' /ukulya/
    wšškana 'possible' /wššikana/

This peculiar condition, however, it is to be stated, should not be stated twice.

Second, various suffixes such as the perfective (-ite) fail to harmonize, and stems such as bššiy which are lexical exceptions to Height Harmony are exceptions to assimilation of both features, as shown in (47):

(47) akalaang-ite
    achëlëw-ite
    akon'ond-ite
    alšši-ite
    lššiya

Hyman (1989) and Val height harmony in the vowels in the non-initial syllable; the non-low vowel in [high] i vowel's after [a] surface as non-initial syllables as being affecting the applied spreading [ATR] feature [ATR]:

(48) eři-lim-ir-a
    eři-buk-ir-a
    eři-lim-ir-a
    eři-hum-ir-a
    eři-bšš-er-a
    eři-kar-ir-a
    eři-humat-ir-a
    eři-gumat-ir-a

Similar height harmony in the data of the [ATR] from the precede:

(49) iššu → išši
    asi → así
    ako → awo
    iye → iye
    bisa → bisa
    afše → afše

These data all provide a constituent, since they are back and round.

The position of the could be assigned in the theory of feature consist here, as spelled out in a node, giving (50a). It Height node, giving (5) so-called Vertical Move node, which then dom
before another vowel). is not inserted, so Glide we find pairs of verbs e stem without inserted / and illustrating insertion

<table>
<thead>
<tr>
<th>47</th>
<th>akilaang-itta</th>
<th>'he fried'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>achilelw-itte</td>
<td>'he was late'</td>
</tr>
<tr>
<td></td>
<td>akon'oond-itte</td>
<td>'he filtered'</td>
</tr>
<tr>
<td></td>
<td>aloot-itte</td>
<td>'he dreamed'</td>
</tr>
<tr>
<td></td>
<td>ëöčiya</td>
<td>'to request'</td>
</tr>
</tbody>
</table>

Hyman (1989) and Valinande (1984: 89–120) discuss a similar rule of height harmony in the Bantu language Kinande. Like Kimattaumbi, vowels in the non-initial syllable of the stem harmonise with the preceding non-low vowel in [high] and [ATR]. Unlike the case with Kimattaumbi, vowels after [a] surface as [+high, −ATR]. We will treat the vowels of non-initial syllables as being underlyingly [+high, −ATR]. Examples affecting the applied suffix -ir are given below. By a separate rule spreading [ATR] leftward, prefix vowels (eri-) agree with the stem in the feature [ATR]:

<table>
<thead>
<tr>
<th>48</th>
<th>eri-lim-ir-a</th>
<th>'to exterminate for'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>eri-huk-ir-a</td>
<td>'to cook for'</td>
</tr>
<tr>
<td></td>
<td>eri-lim-tr-a</td>
<td>'to cultivate for'</td>
</tr>
<tr>
<td></td>
<td>eri-hum-tr-a</td>
<td>'to beat for'</td>
</tr>
<tr>
<td></td>
<td>eri-hek-tr-a</td>
<td>'to carry for'</td>
</tr>
<tr>
<td></td>
<td>eri-bah-er-a</td>
<td>'to tie for'</td>
</tr>
<tr>
<td></td>
<td>eri-kar-tr-a</td>
<td>'to tie for'</td>
</tr>
<tr>
<td></td>
<td>eri-himut-tr-a</td>
<td>'to squeeze for'</td>
</tr>
<tr>
<td></td>
<td>eri-gumat-tr-a</td>
<td>'to stuff in mouth for'</td>
</tr>
</tbody>
</table>

Similar height harmony is found in a number of languages discussed in Clements (1974), including Ewe (see also Westermann 1930), Likpe and Sae. The data in (49) show that postdencies in Ewe assimilate [high] and [ATR] from the preceding vowel:

<table>
<thead>
<tr>
<th>49</th>
<th>avu' é → avu i</th>
<th>'it's a dog'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>asi é → Asi i</td>
<td>'it's water'</td>
</tr>
<tr>
<td></td>
<td>awo é → awo é</td>
<td>'it's you'</td>
</tr>
<tr>
<td></td>
<td>aye é → aye é</td>
<td>'it's a spider'</td>
</tr>
<tr>
<td></td>
<td>ašè é → ašè é</td>
<td>'it's a horse'</td>
</tr>
<tr>
<td></td>
<td>ñbling é → ñbling é</td>
<td>'it's a loud'</td>
</tr>
</tbody>
</table>

These data all provide evidence that the features [high] and [ATR] form a constituent, since these features can spread as a unit to the exclusion of [back] and [round].

The position of the feature [low] is more problematic. That feature could be assigned in three different places consistent with the overall theory of feature constituency and examples of height harmony given here, as spelled out in (50). It might directly descend from the Vowel Place node, giving (50a). It might be a sister of [high] and [ATR] under the Height node, giving (50b). Or, as in (50c), Vowel Place might dominate a so-called Vertical Movement node, which dominates [low] and the Height node, which then dominates [high] and [ATR]:

- [low]
- [high]
- [ATR]
- Vowel Place
- Vertical Movement
- Height
- [low]
As we have seen with the constituency of [back] and [round], invoking *a priori* arguments based on the articulators used to execute features is not uniformly reliable for deciding where in the feature hierarchy a feature resides. The best argument for selecting among these competing theories would be constituent spreading. What we specifically require is a rule which spreads [low] and some other feature. It is crucial that this rule not be a rule of total harmony (spreading of the Vowel Place node), since total vowel harmony would only establish that [low] is somewhere under the Vowel Place node. I have found no truly compelling evidence which answers this question; therefore, an answer to the question of the location [low] in feature geometry must await future research — note, though, that the organisation in (50a) predicts that we will never find such spreading. I present the one salient case below.

Hyman (1988) motivates a height harmony rule in the Cameroonian Grassfields Bantu language Esimbi which may support grouping the three height features together. The non-low prefix vowels /I/ and /U/ are realised as í, ú before underlying i, u, as e, o before e, o, a, and as e, o before e, o, a. By a later rule, all stem vowels become [+high, +ATR].

(51) /I-ka/ → e-ði 'place' /U-ba/ → ð-bi 'come'
/I-ko/ → e-zu 'snake' /U-ho/ → ð-hu 'knead'
/I-yes/ → e-yi 'hole' /U-re/ → ð-ri 'daub'
/I-ba/ → e-bi 'cane rat' /U-dzo/ → ð-dzi 'steal'
/I-nono/ → e-nunu 'bird' /U-tó/ → ð-to 'insult'
/I-gebi/ → e-gbi 'bushfowl' /U-sc/ → ð-si 'laugh'
/I-su/ → i-si 'fish' /U-zu/ → ð-zu 'kill'
/I-bi/ → i-bi 'goat' /U-ri/ → ð-ri 'eat'

If we interpret the nations straightforwad vowel height feature: following derivations

(52) a. Vowel Pl
   Height

b. Vowel Pl
   Height

However, as Hyman for by spreading the is redundantly [−h] harmony process, location of [low] in

4 Conclusions

In this paper it ha articulation in vowel into a constituent, t vowel harmony wh Furthermore, it has acoustic effect is ar subconstituent (Bu shown that [high] quence is an effect vowel place.

We have seen su may also be a part there are other inte clear evidence rega future research tut [high] and [ATR] continuum of vow
If we interpret the vowels $a$, $o$, and $e$ as [+low] vowels, these alternations straightforwardly support the inclusion of [low] in the set of vowel height features, and are thus consistent with (50b) or (50c). The following derivations illustrate this interpretation of height spreading:

(52) a. $i\quad t\quad l\quad a \rightarrow e\rightarrow t\rightarrow l$

\[
\begin{align*}
\text{Vowel Place} & \\
\text{Height} & \\
& [+\text{low}] \\
\end{align*}
\]

b. $i\quad g\quad b\quad e \rightarrow e\rightarrow g\rightarrow b$

\[
\begin{align*}
\text{Vowel Place} & \\
\text{Height} & \\
& [-\text{high}] \\
& [+\text{ATR}] \\
\end{align*}
\]

However, as Hyman points out, these alternations can also be accounted for by spreading the features [high] and [ATR], given that the vowel [a] is redundantly [−high, −ATR]. Under such an interpretation of the harmony process, we lack the evidence needed for determining the location of [low] in the feature hierarchy.

4 Conclusions

In this paper it has been demonstrated that the features for place of articulation in vowels must be grouped together in the feature hierarchy into a constituent, the Vowel Place node, to explain the existence of total vowel harmony which spreads vowel place features across consonants. Furthermore, it has been demonstrated that those features whose primary acoustic effect is an effect on F2, namely [back] and [round], form one subconstituent (Back-Round) under Vowel Place. Finally, it has been shown that [high] and [ATR], features whose primary acoustic consequence is an effect on F1, form a separate constituent (Height) under vowel place.

We have seen suggestive evidence from Esimbi that the feature [low] may also be a part of the Height constituent, though we have noted that there are other interpretations of the facts, which would leave us with no clear evidence regarding the status of [low]. It would not be surprising if future research turns up evidence that [low] belongs with the features [high] and [ATR] under the Height node, given that the phonetic continuum of vowel height is expressed phonologically with the three
features [high], [low] and [ATR]. If the organising principle behind vowel place features is the acoustically driven distinction between features affecting F1 and those affecting F2, we would predict precisely this outcome. However, as this paper has also shown, one cannot determine constituency relations between phonological features solely on the basis of a priori decisions regarding the kinds of phonetic principles which phonology is grounded in. Such decisions must be made on empirical grounds, using the evidence of phonological rules themselves.

Notes

* An earlier version of this paper was presented at the Winter LSA meeting in New Orleans, December 1988. I would like to thank Jill Beckman, Nick Clements, Laura Downing, Larry Hyman, Lisa Selkirk and Robert Vago for helpful comments on this paper.

[1] A reviewer reminds me of the nasal spreading rule of Terena, which spreads [nasal] up to the first obstruent; the obstruent becomes a voiced prenasalised consonant. This rule operates in nouns and verbs infected for 1st person singular, so /owoko/ becomes [owôgô] 'my house'. This would seem to be a case of voice and nasal spreading simultaneously; however, all nasalised consonants in Terena are voiced, so the secondary voicing of the nasalised obstruent can be explained on independent grounds.

[2] Clements (1985) does not provide a display or a verbal statement of the features which are dominated by the Place node. The display given here, which appears to conform to the spirit of Clement's proposal, is drawn from Sager (1986: 27).

[3] Steread (1987) does not provide a display listing all place features and their organisation, so I have constructed the following display on the basis of her examples. She does not state where the feature [ATR] is to be assigned, and she also does not state which features are assigned under the velar node.

[4] Numerous prefixes in Klamath have a vowel which harmonises completely with the following vowel. These prefixes can be treated as having a vowel nucleus unspecified for place features; their surface features then arise by spreading from the following vowel.

[5] A number of languages, such as Klamath, have rules of total vowel assimilation, which applies across all consonants. It would thus appear that the form *mo*:bi 'causes something to turn black' involves spreading of [round] along with other vocalic features, in contradiction to Sterea's prediction. Since the vowel system of Klamath is /i, e, a, o/, the value of the feature [round] can be predicted on the basis of the values of the features [back] and [low]. Counterexamples to this prediction would therefore have to come from languages where [round] can be shown not to be redundantly predictable on the basis of other vowel features.

[6] The existence of a Supralaryngeal node is controversial; see Iversen (1989). Nothing in Sterea's argument depends on the existence of such a node, and this rule could be rewritten to spread Place to whatever node is assumed to immediately dominate Place.

[7] In so far as [low] is one of the features used to express the notion of vowel height, one might expect [low] to be dominated by the Vowel Height node. However, I have found little empirical evidence in the form of constituent-spreading arguments to show that this expectation is borne out.

[8] It is far from clear, from the perspective of phonetic theory, what an articulator is in any meaningful way, how one distinguishes one articulator from another, or whether phoneticians and phonologists are speaking of the same thing when speaking of 'articulators'. In short, it is far from certain that the notion 'articulator' is a real construct of phonological theory.

[9] The theory proposes [round], which contrasts with Sterea's proposal of Sterea (1985) being totally convincing. For example, corona /par/ and *par* at contrast between a case of [back]. However, the former is not in the latter, e.g. by later crenthi.

[10] Obviously it is a major feature that the phonological alternation namely none of which is used in Pančuvidez and Džeti between pharyngeal:

(i) sa 'ip

sa-c-če 'impl

(ii) xib-qo '60

sa-qo-vice '20

xib-qo-vice '20

In the first case, pl. 'decades' suffix -če is its pharyngealisation consonant. No other variant of the principle governs is governed by a form of this kind. Simulations are not not we will leave this question.

[11] Frontal e does not re-vowel-initial: cf. to-

[12] This proposal is at laryngeal consonants. Laryngeal may, on a to, or may have a unencodable - laryngeal some vocalic process segments. One would in a single language - vocalic harmony, which

[13] The harmony is not stem vowel is non-hi non-roundness from complications do not

[14] The stem-medial non-vowel height features assigned the value [+ underlying values of [−high] spread remin
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