On Vowel Place Features

Keren Rice
University of Toronto

The representation of place of articulation of vowels has been a major topic in recent work in phonology (e.g. Clements 1991, Clements & Hume 1995, Halle 1995, Harris & Lindsay forthcoming, van der Hulst 1993, Hume 1992, Kaye, Lowenstamm, & Vergnaud 1985, Odden 1991, Sagey 1986, Selkirk 1992). In this paper I examine two issues concerning the representation of vowel place, what features are required to mark place and how they come to be specified. The arguments in this paper find their foundations in a larger research program, one that makes two basic assumptions, following work by Avery and Rice (Avery & Rice 1989, Rice & Avery 1991, 1993, 1995). The first is that features are arranged in markedness hierarchies which are reflected in feature geometry. Importantly, the addition of structure proceeds monotonically, in a step-by-step fashion, forcing the position that a less marked segment has relatively less structure compared to a more marked segment. The second is that markedness hierarchies can interact with each other in such a way as to limit the complexity of segments. For instance, Rice & Avery 1991 argue that laterals of places of articulation other than coronal are not found not because the feature marking laterality is a dependent of a coronal feature, but rather because the combination of marked sonority and marked place is disfavored.

This paper focuses on the representation of place of articulation in vowels. With respect to the assumptions above, I argue that back vowels are marked relative to non-back vowels, and that front vowels are marked relative to central vowels. In order to capture these contrasts, vowels use only two place features phonologically, Coronal and a feature that I call Peripheral. Further, I argue that vowels are restricted to these places of articulation phonologically as a consequence of limits on complexity; vowels are more limited than consonants in the places of articulation that they employ because of the increased sonority of vowels over consonants.

The first part of the paper is concerned with the phonological representation of place of articulation in vowels. Two claims about the representation of vowels are often found in the literature. First, a frequent assumption (outside of the underspecification literature; e.g. Archangeli 1988, Archangeli & Pulleyblank 1994) is that 'what-you-see-is-what-you-get' (Anderson & Ewen 1987, Clements 1991, van der Hulst 1993, Kaye, Lowenstamm, & Vergnaud 1985, Steriade 1995, to represent some different frameworks). In other words, the phonetic realization of a vowel determines its phonological representation and, vice versa, the phonetic representation is uniquely determinable from the phonological representation alone, all other things being constant. Second, most recent North American work assumes the need for three place features for vowels, one marking labiality, one velarity, and one palatality. Such an analysis is assumed by Chomsky & Halle 1968, using the binary features [back] (palatality, velarity) and [round] (labiality); it is carried over into work by Sagey 1986, who assumes that unary features Labial (labiality), Coronal (palatality), and Dorsal (velarity) are used to mark vowels, and, with different definitions of the features, in work by Clements 1991, Clements & Hume 1995.

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1 By this I mean that if a feature is contrastive, it is contrastive for the entire system. [ATR] may not be contrastive in a language, and as such is missing from phonological representations. However, if /i/ is found in a language, it is considered to be high and front no matter what contrasts it enters into.
and Hume 1992. Steriade 1995 states unequivocally that features of labiality, velarility, and palatality are necessary phonologically, and treats velarity and palatalness as equipollent. I will argue that only two place features are required for vowels phonologically, one marking palatalness (Coronal) and one non-centralness (Peripheral).

I begin with an examination of phonetically front vowels, arguing against the what-you-see-is-what-you-get hypothesis. Following closely work by Rose 1993 and Walker 1993 I argue that the palatalness feature, Coronal, is present distinctively on a phonetically front vowel only if that vowel contrasts with a central vowel at its height. If no central vowel is present, Coronal is not a phonological feature of front vowels. Thus the phonetic front vowel is phonologically simply a non-peripheral vowel unless contrasts force a finer-grained distinction amongst non-peripherals. Representations of a phonetic high front vowel in a system with a single non-peripheral vowel and in one with two non-peripheral vowels are given in (1). In particular, the presence of a central vowel of the same height forces the presence of Coronal on the front vowel (Rose 1993, Walker 1993).

(1) single non-peripheral vowel two non-peripheral vowels

\[
\begin{array}{c}
\text{V-Place} \\
\mid \\
\text{Coronal}
\end{array}
\] 

\[
\begin{array}{c}
\text{V-Place} \\
\mid \\
\text{V-Place}
\end{array}
\]

\(\hat{i}/ \quad \hat{i}/ \quad \hat{i}/\)

(The standard phonemicization of the vowels is included under each representation.) The representation of \(\hat{i}\) has two sources: it may or may not be marked by Coronal phonologically. Likewise, the representation of \(\hat{i}/\) is ambiguous: it may or may not have the feature Coronal, depending on what it contrasts with.

In the second part of the paper, I argue that the features Labial, marking labiality, and Dorsal, marking velarity, do not both play a role in phonology, but that these should be treated phonologically as a single feature which I call Peripheral. Vowels thus have the maximal feature structure in (2a), with two distinctive features for place of articulation, rather than that in (2b), with three distinctive features for place of articulation, the structure argued for by, for instance, Clements 1991 and Clements & Hume 1995.

(2) a. proposed geometry b. Clements 1991

\[
\begin{array}{c}
\text{Place} \\
\mid \\
\text{Coronal} \\
\mid \\
\text{Peripheral}
\end{array}
\] 

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

Several arguments can be found against the three-way place distinction for vowels. Empirically, a three-way place distinction is overly powerful, overgenerating both possible inventories and rule systems. A two-way distinction between palatalness and a cover feature that subsumes the velarity and labiality features generates exactly the contrasts found within languages and rule systems. Theoretically, a three-way featural distinction makes unexpected predictions about markedness of vowels.

With respect to representations then, I argue that the only distinctive features required to express vowel place contrasts are Coronal and Peripheral. Coronal is present only when forced by contrasting places of articulation within the non-peripheral vowels.

In the third part of the paper, I address an issue that arises from the discussion of phonological representations, namely the relationship between the phonological and the phonetic representations. While Coronal may be missing from the phonological representation (1), a non-peripheral vowel in a system with a single such vowel is generally phonetically front. Likewise, while the three-way place distinction is not necessary phonologically, it is certainly true that different peripheral vowels occur non-
distinctively. I argue that Coronal, Labial, and Dorsal do enter into vowel representations: if they do not play a phonological role, they may serve as phonetic implementation or enhancement features in the sense of Stevens, Keyser, & Kawasaki 1986 and Stevens & Keyser 1989, features that serve to enhance perceptual salience, and thus play an active role phonetically in terms of implementation.

The general conclusions are summarized below.

a. Specification is contrast driven. A phonological representation may be phonetically ambiguous: it can be realized in more than one way. Likewise, a phonetic representation may be phonologically ambiguous: it is not always possible to identify uniquely the representation of a sound just from that sound itself; but rather it is necessary to know what sounds it is opposed to in its inventory.

b. Enhancement rules provide phonetic features which are absent distinctively. A source of variation is that languages differ in whether enhancement occurs or not.

1. Background assumptions

I make several assumptions in this paper, which I lay out in this section.

1.1 Feature organization

I assume, after Clements 1985, Sagey 1986, McCarthy 1988, and others that features are hierarchically organized and that place features are unary. I further assume a set of unified place features for consonants and vowels; see Clements 1991, Clements & Hume 1995, and Hume 1991 for references within a feature geometry framework. Finally, I assume that aperture features are independent of place features. I focus only on place features. My examples are drawn almost entirely from high vowels, although the conclusions extend to non-high vowels. Finally, I ignore tongue root distinctions.

1.2 A theory of specification

I assume (and provide some evidence for), after Avery & Rice 1989, Dyck 1995, Rice & Avery 1991, 1995, Rice 1993a, b, Rose 1993, 1994, Walker 1993, Wu 1994, and others the theory of Modified Contrastive Specification. This theory holds that the specification of phonological features involves two major components. The first is contrast: features are required distinctively only as contrasts are introduced into a system. The second is a markedness hierarchy that specifies which feature is introduced in order to mark a contrast. For instance, if a language has only one vowel at a particular height, that vowel is unmarked for place. If it has two vowels at a height, the feature Peripheral is introduced first and the second vowel remains unmarked for place. It is only when a third vowel is introduced that the feature Coronal enters into the system. The phonological representations required in each of these systems are illustrated in (3).

\[
\begin{array}{llll}
\text{single place} & \text{two places} & \text{three places} \\
\text{Place} & \text{Place} & \text{Place} & \text{Place} & \text{Place} & \text{Place} \\
 & \text{Peripheral} & \text{Peripheral} & \text{Coronal}
\end{array}
\]

Representations thus encode markedness relations directly. A guiding principle for building representations is monotonicity: inventories are built up monotonically, with the addition of structure proceeding one step at a time. Thus phonologically more marked segments require the existence of less marked segments. See Rice & Avery 1995.
1.3 A theory of phonetic implementation

In addition to specification of features for purposes of contrast, features can be specified for phonetic reasons. I assume that the actual phonetic instantiation of a sound is determined by a theory of enhancement, following Stevens, Keyser, & Kawasaki 1986 and Stevens & Keyser 1989 and developed within Modified Contrastive Specification by Avery & Rice 1989, Dyck 1995, Rice & Avery 1995, Rice 1993a, 1993b, and Wu 1994. I spell out this model briefly here, and discuss it further in section 4.

Phonetic interpretation of a phonological representation involves two components. The first consists of the features that can be enhancement features. These are often called redundant or default features; see, for instance, Archangeli 1988). These are, basically, features that do not function in the phonology of a language but nevertheless are necessary to define the segment phonetically. Stevens, Keyser, & Kawasaki 1986 and Stevens & Keyser 1989 argue that enhancement features are features that are phonologically inert in a language, but serve a phonetic role: they function to enhance the salience of a sound, or to make it more acoustically distinctive. As discussed in the introduction, I argue that only Coronal and Peripheral play a role in the phonology of vowels. Suppose that a language has a two-way contrast in place of articulation, as in (3b). The non-peripheral vowel is often realized as phonetically front. In order to achieve this, Coronal can serve as an enhancement feature. Labial and Dorsal can serve as enhancement features for Peripheral vowels. Coronal for a phonologically unmarked place of articulation and Labial and Dorsal for a Peripheral place of articulation thus define the first aspect of phonetic implementation: these are universally the only features that can function as enhancement features for the representations in question.

The second aspect of phonetic implementation is language-particular: a potential enhancement feature may or may not be implemented. A major source of between-language variation comes in whether or not an enhancement feature is actually implemented; see Dyck 1995 on vowel height, Piggott 1992 and Rice 1993a on nasals and voiced stops, and Rice 1993b on coronals and velars. Whether a particular feature is used as an enhancement feature is based a language-particular facts; see section 4.

2. Non-peripheral vowels

I begin with an examination of non-peripheral, i.e. front or central, vowels. In this section I look specifically at the patterning of central vowels, drawing the generalization that central vowels pattern as if they were placeless based on their phonology (e.g. Clements 1991, Rose 1993, Walker 1993) and their acoustic properties (Steriade 1993).

2.1 Non-peripheral vowels 1: central vowels as placeless

2.1.1 Evidence from assimilation: central vowels are targets for assimilation

The first bit of evidence that central vowels are placeless comes through their ability to function as a target for assimilation processes. A common assumption is that target/non-target behavior of a particular segment correlates with the degree of specification: a representation that is unspecified for, say, a place feature, can be a target of spreading of place features, but one that is specified for a place feature does not serve as a target. Thus, structure-building but not structure-changing processes are possible; see Mascaro 1987, Inkelas & Cho 1993, Avery & Rice 1989, Piggott 1992, and others for discussion. Using the criterion that targets are phonologically missing the type of feature that targets them, central vowels can be seen to pattern as if they were placeless.
One often-cited example of this comes from what is known as the enunciative vowel in Tulu, a Dravidian language (Bright 1972). [i] and [u] are in complementary distribution, with [u] appearing when the preceding vowel is /u/, as shown in (4).²

(4) no assimilation  assimilation after a labial vowel
   naːdi ‘country’  uccu ‘snake’
   ari-n-i ‘rice (accusative)’  uru-n-u ‘country village (accusative)’

If the central vowel is placeless, the rule in Tulu is easily expressible, as in (5).

(5) \[ \begin{array}{c}
\text{V-Place} \\
\text{Peripheral}
\end{array} \] 

Korean provides similar evidence from assimilation: central vowels assimilate in place to the preceding vowel. Korean has the vowel inventory in (6).

(6) \[ \begin{array}{c}
i i u \\
c a o \\
æ a
\end{array} \]

The central vowels may assimilate to the preceding vowel, as in (7) (Sohn 1987).

(7) \[ \begin{array}{c}
/pe-ə/  \quad p[ce] ‘to cut’ \\
/kæ-ə/  \quad k[æe] ‘to fold’ \\
/ɪs-imyan/  \quad [ii]myan ‘to connect’ \\
/p’iam/  \quad p’[æ]m ‘cheek’
\end{array} \]

If the central vowel is placeless, this assimilatory patterning is easily expressed, as in (8).

(8) \[ \begin{array}{c}
\text{V-Place} \\
\text{Coronal}
\end{array} \] 

The place features of the preceding vowel spread to the central vowel. While the central vowels in a language like Korean assimilate in place to an adjacent vowel, this is not true of the non-central vowels: they do not show assimilatory such behavior. For instance, in an /i-u/ sequence in Korean, the vowels can combine to [ui], a high front round vowel; however, neither [u] nor [i] can result; see section 2.4.3. This difference in assimilatory patterning can be taken to indicate that the central vowel is lacking place features, taking them on from something in the environment, while the front vowel has a place feature; under assimilation an additive relationship is found.

2.1.2 Evidence from deletion: central vowels are subject to deletion

A second type of evidence for central vowels being unspecified for place comes through their frequent deletability; see Rose 1993. Central vowels may delete in the presence of non-central vowels. Chaha (Rose 1993) provides one example of this. The Chaha inventory is given in (9).

² Labial consonants also trigger rounding assimilation in Tulu; I abstract away from this.
The vowel schwa deletes in the environment of another vowel, as in (10).

(10) /yə-ef/       /yə-od/  
     y[ə]f         y[o]d  
     ‘let him cover with a lid’  ‘let him tell’

In a sequence of non-central vowels, no deletion is found; rather glide insertion applies, as in (11).

(11) mezo-axə  mezo[owa]x  
gəβəre-u     gəβər[ewu]  
     ‘your five cents’  ‘he is a farmer’

Thus both assimilation and deletion provide evidence for central vowels being regarded as placeless: these vowels are frequent targets of assimilation and are subject to deletion when adjacent to another vowel.

2.2 Non-peripheral vowels 2: front vowels as placeless

I now turn to the patterning of phonetically front vowels. Front vowels pattern in two different ways: in some languages they pattern as if they were placeless based on their phonology and in other languages, they pattern as if they were marked for place. In this section I examine evidence for phonetic front vowels patterning as if they were placeless.

2.2.1 Evidence from assimilation: front vowels are targets for assimilation

Just as assimilation evidence suggested that central vowels are placeless, such evidence also indicates that front vowels are placeless. Consider first Yawelmani. This language has the short vowel inventory in (12) (Archangeli 1984, Newman 1944).

(12) i       u  
     a         o

Yawelmani exhibits a high harmony process, as illustrated in (13). A suffix high vowel must agree in place with the stem vowel.

(13) xil-h[i]n  ‘tangles’  
dub-h[u]n  ‘leads by the hand’

Consider the rule that is required if the suffix vowel is underlyingly marked for place of articulation. I assume that it has the vowel /i/; evidence for this comes from the patterning of the suffix vowel after a stem with a non-high vowel: the suffix always surfaces as [hin], as in [xat-hin]. If Coronal is present on this vowel, then harmony involves the spreading of Peripheral accompanied by the loss of Coronal, presumably as a consequence of structure preservation. This is illustrated in (14).

(14) V-Place       V-Place  
     Peripheral     Coronal

Now suppose that Coronal is absent on the front vowel. The rule is more simply expressed, as in (15), without recourse to delinking.
While the target of assimilation is central in a language like Korean and front in a language like Yawelmani, these vowels are similar in phonological functioning; both can be targets of assimilation. This suggests that perhaps they should share a representation. Arapaho (Algonquian) provides further support for the claim that front vowels can be unspecified for place. (16) gives the vowel inventory (Picard 1977, Goddard 1974).

Rounding harmony is found whereby /ε/ is rounded when followed by /o/, with a possible laryngeal (h, w, glottal stop) intervening.

If /ɛ/ is unspecified for place, harmony is easily expressible; if it is specified Coronal, this feature must delink. Again, we see a parallel between the patterning of the central vowel in Korean and the front vowel in Arapaho, suggesting a similar representation.

Attic Greek provides similar evidence for front vowels being unspecified for place. Attic Greek had the short vowel inventory in (18) (de Haas 1988:97).

The following assimilation types are found in Attic, ignoring height (de Haas 1988:126).

The high front vowel appears only in second position in the forms presented by de Haas, and is realized as a glide; de Haas does not show the high back vowel combining.

2.2.2 Evidence from deletion: front vowels are subject to deletion

Just as patterning under deletion provided evidence for central vowels being unspecified for place, similar patterning yields evidence for front vowels being unspecified for place. In particular, front vowels may delete in the presence of non-front vowels. Rose 1993, based on Mackridge 1985, cites vowel deletion facts in Modern Greek as evidence for this. Modern Greek has the vowel inventory in (20).

In vowel sequences, /i/ deletes when adjacent to /e u o a/, /e/ adjacent to /i u o a/, /u/ adjacent to /o a/, and /o/ adjacent to /a/, where order is irrelevant. What matters is that a front vowel deletes when adjacent to a back vowel. Examples are given in (21).
(21)  to exo  t[o]xo  ‘I have it’
      to ixa  t[o]xa  ‘I had it’
      afitos pu erxete  afitos p[u]rxete  ‘the one who comes’
      su ixa pi  s[u]xa pi  ‘I’d told you’

2.3 Summary

Both phonetic front and central vowels may pattern phonologically as if they were missing a specified place of articulation. In particular, both can be targets for assimilation and both can delete when adjacent to another vowel.

2.4 Non-peripheral vowels 3: resolving the paradox

In the languages discussed in sections 2.1 and 2.2, we have seen a paradox: both central and front vowels can pattern as if they were phonologically unspecified for place. On closer examination, phonetic front vowels exhibit two types of patterning: they may pattern like central vowels, as if they were placeless, or they may pattern as if they were marked for place. In this section, I examine differences between languages where central vowels pattern as if they were placeless and those where front vowels pattern as if they were placeless. I argue, after Rose 1993 and Walker 1993, that there is a systematic difference between these language types. If we abandon the what-you-see-is-what-you-get assumption, that a particular phonetic realization is uniquely associated with a single phonological representation, then we see that there is a principled grounds for determining whether the front or central vowel patterns as if it were missing a place feature. Specifically, if there is a single non-peripheral vowel at a height, that vowel patterns as if it were unmarked for place. If there are both a front and a central vowel at a height, the central vowel patterns as if it were unmarked for place. In this section then I provide evidence for the following claims.

(22)  i. Front unround vowels are not triggers unless there is a central vowel at the same height.

         ii. Front unround vowels are targets unless there is a central vowel at the same height.

In representational terms, this hypothesis can be formalized as in (23). See Rose 1993 and Walker 1993 for more extensive development.

(23)  Coronal is present phonologically on a front unround vowel only if it has a central counterpart.

In other words, the primary distinction in vowel systems is between peripheral and non-peripheral vowels; given this distinction only the peripheral vowel has a marked feature. It is only when non-peripheral vowels must be distinguished that Coronal is brought into play in a phonological system. In the following discussion I examine a particular type of language, those with asymmetrical inventories, to provide evidence for this claim.

2.4.1 Evidence from triggers

2.4.1.1 Finnish

Finnish provides interesting evidence for the hypothesis in (23). Finnish has an asymmetric vowel inventory, as in (24) (Harms 1964, Steriade 1987).
While there are three front unrounded vowels, only the low vowel has a central counterpart. Following the hypothesis in (23), this means that the non-low front unrounded vowels are not marked for place while the low front vowel, which must be distinguished from the low central vowel, is marked for place. The vowels thus have the representations in (25).

\[(25) \quad \text{i, e} \quad \text{ü, ō} \quad \text{u, o} \quad \text{æ} \quad \text{a} \quad \text{V-Place} \quad \text{V-Place} \quad \text{V-Place} \quad \text{V-Place} \quad \text{V-Place} \quad \text{Coronal Periphera} \quad \text{Peripheral} \quad \text{Coronal} \]

Finnish exhibits vowel harmony: a stem contains all front vowels or all back vowels, with the exception /i/ and /æ/, which occur with both front and back vowels. The system is asymmetric in that /i/ and /æ/ fail to trigger harmony while /æ/ does. This is accounted for directly by the representations in (25). Since /i/ and /æ/ are unmarked for place, they have no feature to spread, and cannot be harmony triggers. The low vowel /æ/, on the other hand, is phonologically a front vowel, and participates in the harmony system. While Finnish has three phonetically front vowels, it has but a single phonological front vowel.

2.4.1.2 Hungarian

Hungarian has the vowel inventory in (26) (Farkas & Beddor 1987:91).

\[(26) \quad \text{i} \quad \text{ü} \quad \text{u} \quad \text{i:} \quad \text{ü:} \quad \text{u:} \quad \text{æ} \quad \text{a} \quad \text{ød} \quad \text{o} \quad \text{e:} \quad \text{ō:} \quad \text{o:} \quad \text{a:} \quad \text{Coronal} \quad \text{Peripheral} \quad \text{Peripheral} \quad \text{Coronal} \]

Fronting harmony is triggered by front round vowels and by the short low front /æ/. While this appears to be an odd class, these are exactly the vowels that must be marked Coronal. Coronal is present on front round vowels to distinguish them from back round vowels; it is present on /æ/ since it has a central counterpart, /a/; it is not present on the other front vowels because they do not have a paired non-peripheral counterpart.

2.4.1.3 Vietnamese

Vietnamese is another language with an unbalanced front-central vowel system. North Vietnamese has the vowel inventory shown in (27) (Thompson 1965).

\[(27) \quad \begin{array}{ccc} \text{high} & \text{front} & \text{central} & \text{back} \\ \text{i} & \text{ü} & \text{u} \\ \text{upper mid} & \text{ē} & \text{ō} & \text{ō} \\ \text{lower mid} & \text{e} & & \text{o} \\ \text{upper low} & \text{ā} & \text{â} & \text{a} \\ \text{low} & & & \text{a} \end{array} \]

Velar consonants show different allophones depending on the preceding vowel. After a back vowel, a velar is phonetically labio-dorsal; I ignore this. After other vowels, velars are realized as described in (28).
Stem-final consonants: [p t c k m n ñ ñ] on the surface
[c ñ] after i, è, ñ
[k ñ] after e, a, and all other (non-back) vowels

Palatals occur after a subset of front vowels. It initially seems mysterious how this class is determined. However, an examination of the front/central system shows that front vowels that trigger palatalization have central counterparts; those that do not trigger palatalization do not have such counterparts. The representations in (29) are expected.

\[
\begin{array}{ll}
i & \text{è å} \\
e & \text{a úó â} \\
\text{V-Place} & \text{V-Place} \\
\text{Coronal}
\end{array}
\]

The palatalized consonants can be viewed as derived from underlying velars that take on the place feature of the preceding vowel, as in (30).

\[
\begin{array}{ll}
\text{C-Place} & \text{C-Place} \\
\text{V-Place} & \text{Dorsal V-Place} \\
\text{Coronal}
\end{array}
\]

Nonpalatalized consonants (velars) occur after the other phonetic front vowels because these lack the feature Coronal phonologically.

2.4.1.4 Summary

Coronal can spread from a front vowel only if a central vowel of the same found is found. If no central vowel is present at a height, Coronal is not active on the front vowel.

2.4.2 Arguments from target asymmetries

Evidence from front vowels as assimilation triggers shows two types of patterning: front vowels are triggers if they have a central counterpart; if they have no central counterpart, they are not triggers. A similar set of facts holds of targets. The following generalization can be made, repeated form (21).

\[
\begin{array}{ll}
\text{Front vowels are targets for assimilation unless there is a central vowel at the same height, in which case that vowel is a target.}
\end{array}
\]

This follows from the representations provided in (1) and repeated in (32).

\[
\begin{array}{ll}
\text{Front vowel, no central vowel} & \text{Front vowel, central vowel in system} \\
\text{Place} & \text{Place} \\
\text{Coronal}
\end{array}
\]

I examine rounding harmony in languages with and without front/central contrasts, beginning with those without a contrast. In these languages, front vowels assimilate to the roundness and backness of an adjacent back round vowel. This was illustrated for Yawelmani (13) and Arapaho (17). The process is summarized in (33).
Now consider languages with rounding harmony that have a phonological front/central contrast. Here the central vowel assimilates completely to the back round vowel. This is true in Turkish. The Turkish vowel inventory is given in (34).

(34)  
\[
\begin{array}{l}
i \\
e \\
i \\
o \\
u \\
ö \\
a \\
o \\
\end{array}
\]

Following Rose 1993 and Walker 1993, I assume the vowel representations in (35).

(35)  
\[
\begin{array}{cccc}
\text{front unrounded} & \text{front rounded} & \text{central} & \text{back rounded} \\
\text{V-Place} & \text{V-Place} & \text{V-Place} & \text{V-Place} \\
\mid & / \ \backslash & \mid & \mid \\
\text{Coronal} & \text{Coronal Peripheral} & \text{Peripheral} & \text{Peripheral} \\
\end{array}
\]

Turkish rounding harmony is illustrated in (36), with the process shown in (37).

(36)  
\[
\begin{array}{lll}
\text{nominative sg.} & \text{genitive sg.} \\
ip & \text{ip-in} & \text{‘rope’} \\
k\text{ız} & \text{kız-in} & \text{‘girl’} \\
y\text{üz} & \text{yüzün} & \text{‘face’} \\
p\text{ul} & \text{pul-un} & \text{‘stamp’} \\
\end{array}
\]

(37)  
\[
\begin{array}{c}
\text{V-Place} \\
\mid & \mid \\
\text{Peripheral} \\
\end{array}
\]

The suffix vowel is unmarked for place, assimilating to features of the stem vowel.

While suffixes generally harmonize with the previous vowel in Turkish, one suffix is reported by Clements & Sezer (1982:231) to have an invariant high front vowel.

(38)  
\[
\begin{array}{ll}
\text{arab-istan-i} & \text{‘Arabia (accusative)’} \\
mool-istan-i & \text{‘Mongolia (accusative)’} \\
türk-istan-i & \text{‘Turkestan (accusative)’} \\
\end{array}
\]

This suffix is opaque to harmony. If it is Coronal, the failure to assimilate makes sense: the central vowel, with no place feature, takes on features of a preceding segment, while a vowel with a specified feature fails to assimilate. The same patterning is found with a suffix specified as Peripheral: it is invariant, never alternating with a front round vowel.

(39)  
\[
\begin{array}{l}
gid-edur-sun \ ‘\text{let him keep going’} \\
koš-adur-sun \ ‘\text{let him keep running’} \\
güll-edur-sun \ ‘\text{let him keep laughing’} \\
bak-adur-sun \ ‘\text{let him keep looking’} \\
\end{array}
\]

Again, only the placeless vowel serves as an assimilation target.
2.4.3 Arguments from deletion, diphthongization, and coalescence

Arguments from coalescence also bear on the representations of central and front vowels. In some languages, front vowels do not retain their frontness under deletion/coalescence of a front and back vowel; in some they retain their frontness through diphthongization; in others a new single segment which combines features of the front and back vowels, a monophthong, is created by coalescence. The difference between these classes is by now unsurprising: a single segment which combines features of the two vowels is possible only if a central vowel is found at the same height.

In Modern Greek (21) front vowels are subject to deletion in the environment of a peripheral vowel, with no trace of the front vowel. As illustrated in (20), there is no central vowel in the Greek inventory at the same height as the front vowels in question.

Sanskrit is another illustration of what can happen when coalescence between a phonetically front and a back vowel occur. Sanskrit has the inventory in (40).

\((40)\quad \text{i} \quad \text{u} \quad \text{a}\)

In high vowel sequences, diphthongs can be created, as in (41), from Schane 1987:283.

\((41)\quad \text{i} \quad \text{u} \quad \text{i} : \quad \text{yu} \quad \text{u} \quad \text{wi} \quad \text{u} : \)

In this type of system, all traces of a front vowel can be lost, as in Greek, or the frontness can be maintained through the creation of a diphthong, as in Sanskrit. The diagrams in (42) show the combination of a front unround vowel and a back round vowel.

\[(42)\quad \text{process} \quad \text{input} \quad \text{result} \]
\[\quad \text{deletion} \quad \text{Root} \quad \text{Root} \quad \text{Root} \]
\[\quad \mid \mid \mid \]
\[\quad \text{V-P} \quad \text{V-P} \quad \text{V-P} \]
\[\quad \mid \mid \mid \]
\[\quad \text{Peripheral} \quad \text{Peripheral} \quad \text{Peripheral} \]
\[\quad \text{diphthongization} \quad \text{Root} \quad \text{Root} \quad \text{Root} \]
\[\quad \mid \mid \mid \]
\[\quad \text{V-P} \quad \text{V-P} \quad / \quad \text{V-P} \quad \text{V-P} \quad \text{V-P} \]
\[\quad \mid \mid \mid \]
\[\quad \text{Peripheral} \quad \text{Peripheral} \quad \text{Peripheral} \]

I assume that in the creation of a diphthong, the two V-Place nodes are maintained, while in deletion one of the V-Place nodes deletes along with its Root node.

It is interesting that in this system type, no examples of /i-u/ being realized as [ii] are found. This is in contrast with systems with front and central vowels of the same height: in this case the front vowels retain their place feature under coalescence. This is illustrated in Korean in (43) (Sohn 1987; see (6) for the Korean inventory).

\[(43)\quad \text{kwemul} \quad \text{kömul} \quad \text{‘monster’} \]
\[\quad \text{wisæŋ} \quad \text{üsaŋ} \quad \text{‘hypocrisy’} \]
\[\quad \text{p’yocok} \quad \text{p’öcok} \quad \text{‘sharp’} \]
Under conditions of coalescence, features of both the front vowel and the back vowel are maintained, as illustrated in (44).

(44) | input | result |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Root</td>
<td>Root</td>
</tr>
<tr>
<td></td>
<td>Root</td>
</tr>
<tr>
<td>V-P</td>
<td>V-P</td>
</tr>
<tr>
<td></td>
<td>/ \</td>
</tr>
<tr>
<td>Coronal Peripheral</td>
<td>Coronal Peripheral</td>
</tr>
</tbody>
</table>

Both the Root and V-Place nodes are lost, with Coronal remaining, creating a front round vowel. While deletion and diphthongization processes could be found in this language type, this type is distinguished from the first one by allowing this third possibility of monophthongization as well.

Asmat (Flamengo Bay dialect, Papuan, Voorhove 1965) is another language that allows the creation of a front round vowel. In this case, the process is assimilatory, adding the feature from the round segment to the front vowel.

(45) i i u
    e a o

When a front a back vowel are adjacent, the front vowel is rounded, as in (46).

(46) tiw / tüw    ‘son’
    iwnim / üwnim ‘water’s edge’

To summarize, the following differences in patterning of a front vowel-back vowel sequence are found, depending on inventory.³

(47) no non-peripheral contrast: Deletion of front vowel or diphthongization.
     non-peripheral contrast: Coalescence of front vowel also possible.

---

³ Rotuman (Churchward 1940, de Haas 1988, McCarthy 1986) appears to be a counterexample. Rotuman has the vowel system i e a o u. Front round vowels are derived from a combination of a back vowel followed by a front vowel, as in (i).

i. complete phase incomplete phase
   hoti höt    ‘to embark’
   futi füt    ‘to pull’
   mose mös    ‘to sleep’

In other cases, the incomplete phase has a diphthong.

ii. tiko tık    ‘flesh’
    hosa hös    ‘flower’
    pure püler ‘to decide’

de Haas proposes that Rotuman has metathesis, changing CV (complete phase) to VC (incomplete phase). The vowels are restructured into one syllable, creating a diphthong. He argues that the created front round vowels should receive the same treatment. These vowels, dubbed tertiary vowels by Churchward, contrast with underlying vowels in being of medium length. They occur mainly in closed syllables; de Haas speculates that they are long vowels, shortened to medium in a closed syllable. Given this, the front round vowels have the phonological representation of diphthongs; the surface form is a product of the phonetics and not of the phonology.
While a language with a non-peripheral contrast can create a single segment from a front vowel-back vowel sequence, a segment maintaining features of both vowels, in the languages without such a contrast, either the front vowel deletes or, if features of both vowels are retained, this is accomplished through the creation of a diphthong rather than through the creation of a single segment.

2.5 Summary

In summary, I have argued, based on Rose 1993 and Walker 1993, that phonetically front vowels pattern in two ways: in some languages they are assimilation triggers and in others they cannot be, in some languages they serve as assimilation targets and in other languages they cannot; in some languages they leave no trace of their frontness in coalescence/deletion processes or they form a diphthong while in others their frontness is preserved. These facts are not random, but correlate with the presence/absence of a central vowel in the system. The facts are summarized in (48). The first column shows the focus of discussion, the second indicates a language without a front/central contrast at a particular height, and the third refers to a language with such a contrast.

<table>
<thead>
<tr>
<th>(48)</th>
<th>no front/central contrast</th>
<th>front/central contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>front vowel as trigger</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>front vowel as target for rounding harmony</td>
<td>result [u]</td>
<td>result [il], or not a target</td>
</tr>
<tr>
<td>deletion/diphthongization/coalescence in /i-u/ sequence</td>
<td>deletion or diphthongization</td>
<td>deletion, diphthongization, or creation of front rounded vowel [ü]</td>
</tr>
</tbody>
</table>

I have proposed that these facts are to be accounted for phonologically by allowing two types of representations for phonetic front vowels. If there is a central vowel, then the phonetic front vowel is also phonologically front; if there is no central vowel, then the phonetic front vowel is simply non-peripheral, or is unmarked for place of articulation. Globality is thus required in determining the representation of the front vowel: the representation of the front vowel cannot be determined by inspecting that vowel alone; it is necessary instead to examine the contrasts in the inventory. The material presented in this section strongly argues that the phonological patterning of a segment cannot be determined on the basis of the phonetics of that segment alone; rather non-local information about contrasts plays a critical role in predicting phonological patterning.

3. Peripheral vowels

In this section I turn to the second part of the representational question. So far I have been using the feature Peripheral without comment. The features Labial and Dorsal (or equivalent features) are generally assumed to be necessary in vowels in addition to Coronal. In this section I question this assumption, presenting arguments that these two features are not used phonologically for non-front, non-central vowels, but only Peripheral is. In particular, I argue for the structure in (49a) rather than those in (49b) or (49c) as the phonological representation of the vowels in question.

(49) a. V-Place
     b. V-Place
     c. V-Place
           / \           / \           / \           \ \        \ \        \ \   Peripheral Labial Dorsal Peripheral Labial Dorsal
3.1. Evidence from contrasts

3.1.1 Contrasts in vowel inventories

The first argument, an empirical one, comes from contrasts in vowel inventories. Consonants and vowels have been treated differently by phonologists. In consonants it has been assumed that if a language does not have a contrast between, say, an alveolar and a dental, the consonant is simply marked coronal (or unmarked for a place feature, an issue that I will not deal with here). It is only if the language contrasts an alveolar and a dental that it is necessary to mark these features. Thus, while the phonetics drives the presence of place features in a gross sense, in a more detailed sense, the actual realization of the place of articulation of the consonant is considered to be a phonetic detail rather than a phonological distinction. See Steriade 1995 for recent discussion of place in consonants along these lines.

Vowels have been handled differently. While in consonants it is assumed that a feature can be non-distinctive in one language and distinctive in another, in vowels it is assumed that the phonetic realization of the vowel largely determines its phonological representation. For instance, Clements 1991 presents the representations in (50).

\[
\begin{array}{ccccccc}
\text{labial} & i & \ddot{u} & i & u & \dddot{u} & u \\
\text{coronal} & + & + & - & + & - & + \\
\text{dorsal} & - & - & - & - & + & + \\
\end{array}
\]

He shows that contrasts between pairs of these vowels occurs in languages; for instance, in the Swedish dialect of Finland, the contrast /i/, /\ddot{u}/, /u/ occurs; in Nimboran (Austronesian), both /i/ and /\ddot{u}/ are found. Interestingly, however, Clements does not cite cases where the two central vowels contrast in a language, nor cases where the two back vowels contrast. Thus, his claim is basically that the phonological representation of a vowel is determinable from its phonetic realization.

Lass 1984b, working within a different framework, makes a claim that results in a similarly large possible phonemic vowel inventory. Lass argues for two principles. The first, the Phonemic Availability Principle, is based on the notion of contrast.

\[
\text{(51) Phonemic Availability Principle: Any pair of qualities that contrast phonemically in some language are primitive. (102)}
\]

This principle is designed to limit the number of possible ‘basic’ vowel types. Pairwise comparisons allow Lass to establish not only the well-accepted contrasts (e.g. i:u, i:u, but also some that he claims might be disputed; he mentions, for the high vowels, [i]:[u] and [u]:[u]). Lass combines the Phonemic Availability Principle with a second principle.

\[
\text{(52) Dialect Distinguishability Principle: Any pair of qualities capable of consistently signaling a dialect difference within one language, and therefore available as speaker choices, are primitive. (103)}
\]

The combination of these two principles leads Lass to propose a system with five degrees of backness: front, centralized front, central, centralized back, and back.

In this section, I examine vowel inventories, and argue that linguists have relied too much on phonetics and contrasts within individual languages without looking enough at cross-language patterns. In examining inventories cross-linguistically, I argue that several points stand out. First, no language has more than four distinctive places of articulation at any particular vowel height. Second, no language has contrasting central vowels at a particular height. And third, no language has contrasting back vowels at a
particular height. These observations lead to the conclusion that a two place system is adequate to capture the phonological places of articulation found in languages.

Consider the predictions of a theory with three features available for marking place in vowels. The maximum number of vowels in an inventory at any height is predicted to be six. However, in the surveys of inventories in the literature (e.g. Clements 1991, Crothers 1978, Hockett 1955, Ladefoged & Maddieson 1990, Lass 1984a, b, Maddieson 1984), the maximal number of occurring place contrasts at any height is four. Under the assumption that a feature system should not overgenerate possible feature combinations unless there are phonetic reasons for ruling out the combination (e.g. *[aspirated, glottalized]), the two-feature hypothesis is to be preferred. This assumption is summarized in (53).

(53) Assumption: A feature system should not overgenerate possible feature combinations unless there are phonetic reasons for ruling out the combination (e.g. *[aspirated, glottalized]).

I will compare the following two hypotheses.

(54) Hypothesis 1 (three places of articulation)
     Coronal, Labial, and Dorsal are required for vowels.
     Coronal and Dorsal cannot co-occur)

     Hypothesis 2 (two places of articulation)
     Coronal and Peripheral are required for vowels.

Under Hypothesis 1, while the cooccurrence of Coronal and Dorsal are ruled out, all other possible feature combinations are allowed.

I use IPA symbols, as in (55).

(55)

<table>
<thead>
<tr>
<th>front unround</th>
<th>front round</th>
<th>central unround</th>
<th>central round</th>
<th>back unround</th>
<th>back round</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>ii</td>
<td>i</td>
<td>u</td>
<td>w</td>
<td>u</td>
</tr>
</tbody>
</table>

When vowel inventories are surveyed, the following observation can be made.

(56) Observation: Languages have a maximum of four distinctive places of articulation at any given height, with only a single central and back vowel.

This is illustrated in (57), focusing on high vowels; similar patterns obtain at other heights. What is important is that no inventories are reported in which more than four high vowels exist in the system.4

---

4 I have moved some vowels in this chart. In particular, some sources claim that a language has a high back round and a high back unround vowel. In these cases, the vowel patterns phonologically as if it were central (e.g. discussion of Turkish in section 2.2.1), and I treat these vowels as central. The chart brings out dramatically the fact that no language has more than four distinct places of articulation for high vowels.
single place of articulation
Adygh

two places of articulation
Chipewyan, Ainu, Aleut
Jagaru, Nunggubuyu,
Japanese, Alawa, Nez Perce

three places of articulation
Amahuaca, Lappish
Tabassaran, Kyuri
Nemboi, Tsou, Wolcian
Nimboran

four places of articulation
Turkish, Korean
Swedish

In general, inventories illustrate the following patterns:

Within the front vowels, contrasts may exist between an unrounded and a rounded vowel in the language.
Within the central and back vowels, no single language makes a contrast between unrounded and rounded vowels.

No languages occur in which a distinctive central unround and central round vowel are found; likewise, back unround and back round vowels are not distinguished within a system, but only between systems.

Consider the combinatorial possibilities under the three-place model, following the assumption that Coronal and Dorsal cannot combine with one another.

Coronal Coronal/Labial no features Labial Dorsal Lab/Dors

This model predicts that round/unround contrasts are available within a language for front, central, and back vowels. It thus adequately predicts all the places of articulation that occur when all languages are taken into account by providing a distinct representation for each vowel with a distinct symbol, i.e. the IPA system. However, when the actual systems are taken into account, this model must be questioned: it predicts that one might find a single language with five or six possible places of articulation at a particular height. This, as the languages in (57) illustrate, is not the case: the maximal number of places of articulation at a particular height is four.

Compare the predictions of the three-feature model with those of the two-feature model. Under this model, the combinatorial possibilities of features are as shown in (60).

Coronal Coronal/Peripheral no features Peripheral

This model predicts that in any particular language it would be possible to have a front unround vowel, a front round vowel, a single central vowel, and a single back vowel, for a maximum of four possible places of articulation. As illustrated in (57), this is the case. Rather than treating the difference between, say, the back unround and the back round vowel as a matter for the phonology, as, for example, Clements 1991 does, under this model, the difference between these must fall to the phonetic component of the language: the claim is that no language has these vowels distinctively.
I draw the following conclusion. The Coronal/Peripheral model yields exactly the set of contrasts found distinctively in languages. No combinatorial restrictions are required as all possible combinations of places are realized. The parallel with consonants is clear: just as features for marking whether a consonant is dental or alveolar are invoked only in the presence of a contrast within a language, features to distinguish a central unround and central round vowel or a back unround and back round vowel should be brought into play only if these categories are distinguished within a language. I have argued that languages do not make such divisions within the central or the back vowels. Given this, features that distinguish such vowels should not be part of a phonological representation, but rather are learned phonetic properties of individual languages or dialects.

3.1.2 Contrasts in secondary articulations

Not only is the two-place model supported through an examination of possible vowel inventories, it also receives support when secondary articulations are examined. Consider the predictions made by the two different theories with respect to secondary articulations.

(61) Secondary articulations: predictions of the Labial/Coronal/Dorsal model
A single language can show distinct labialization, coronalization (palatalization), and velarization (ignoring possible combinations of these).

(62) Secondary articulations: predictions of the Coronal/Peripheral model
A single language can have distinct coronalization and labialization or velarization (or both combined), but cannot have both labialization and velarization distinctively (again, ignoring possible combinations).

When secondary articulations are examined, the following generalization can be made.

(63) No language has distinctive labialization and velarization both.

Some possible combinations of secondary articulations found in languages are given in (64). A comma means that the language illustrates independently both the secondary articulations named; a slash indicates that these are combined together in that language. For instance, labialization, velarization means that these are distinct secondary articulations, while labialization/velarization indicates that they are non-distinct.

(64) coronalization
labialization
velarization
labialization/velarization
coronalization, labialization
coronalization, velarization
coronalization, labialization/velarization
*labialization, velarization
*coronalization, labialization, velarization

Russian labials, dentals, velars; Irish velars
Chipewyan velars
Ponapean labials, Menominee
Nambakaengo labials, dentals, velars
Irish dentals
Irish labials, Nupe

(64) reveals that within a language, while a single consonant can be labialized and velarized simultaneously, a single place of articulation cannot occur in both a labialized and a velarized form. This is strikingly different from coronalization, which can appear independently. Under the three-place model, there is no reason to expect this asymmetry: Labial, Coronal, and Dorsal should all be able to function independently as secondary articulations, and three secondary articulations should be possible. Under the two-place
model, the facts are predicted: two phonological secondary articulations are possible, Coronal and Peripheral. The Peripheral secondary articulation is realizable in different ways (section 4). No further simple secondary articulations are predictable.

3.2 Summary

The survey of occurring places of articulation for vowels and secondary articulations provides evidence for the two-place model. While the three-place model offers an account of the phonetics of languages, it overgenerates existing language types. The two-place model shows a fit between predicted places in any single language and actual contrasts. What remains for the two-place model is to show how, for example, a vowel that is Peripheral can be realized as back unround in one language and as back round in another. This is parallel to the problem of consonants referred to earlier: how is it that some languages realize a consonant that is just Coronal as dental, and others as alveolar? In consonants, nondistinctive coronal subclasses are generally considered to be differentiated phonetically; I claim that vowels deserve the same treatment; see section 4.

3.3 Evidence from markedness considerations

An assumption that is often made in a phonological theory that incorporates underspecification is that more common sounds are structurally less complex, or involve fewer features, than less common sounds; see, for example, Dresher & van der Hulst 1993, Rice 1992, Rice & Avery 1993, Rice & Avery 1995, Rose 1993, and Walker 1993 for development. Under this assumption, theoretical problems exist for the three-place model of vowel place.

I assume the following complexity scale; see Dresher & van der Hulst 1993, Rice & Avery 1993, Walker 1993, and others for further discussion.

(65) \[ \begin{array}{ccc}
X & X & X \\
\downarrow & /\ & \\
Y & Y & Z
\end{array} \]

The first representation is the least complex; the second is more complex than the first, but less than the third, and the third is the most complex. As argued in the sources above, increasing structure correlates with increasing markedness, with the existence of the more complex structure implying the existence of the less complex one. The markedness predictions made by the three-place model are rather surprising under this assumption. Consider the representations of back round vowels and back unround vowels. Back round vowels involve two features, Labial and Dorsal, and are thus structurally more complex than back unround vowels, which involve only a single feature Dorsal. Back round vowels are also structurally more complex than central round vowels, which involve only a single feature Labial. Front round vowels and back round vowels are of equal complexity to back round vowels. The markedness scale predicted here is the following: front unround = back unround = central round > front round = back round (‘>‘ indicates less marked). This scale is not borne out by facts of phonological inventories: in examining inventories, we find rather that front round vowels imply the existence of back round vowels: inventories are not found with front round vowels to the exclusion of back round vowels, while many inventories of the reverse type are found. This is predicted by the two-place theory coupled with the markedness assumptions discussed above: front round vowels imply the existence of back rounded vowels since front round vowels are more complex than back vowels, having two features rather than one.

I have assumed a definition of markedness based on structural properties. Markedness can be looked at in a second way: segments can be considered to be more or less marked in terms of frequency. Thus, part of the basis for Kean’s 1975 claim that
coronals are the unmarked consonant follows from the fact that almost every language contains a coronal stop; see also Paradis & Prunet 1991 for markedness arguments based on frequency. When the frequencies of the vowels of different places of articulation are examined, the difference between the frequency of occurrence of the back rounded vowel and the others is striking; in Maddison’s 1984 survey, he reports 254 languages as having a high back round vowel. The other places of articulation are dramatically smaller in number: Maddison reports that 21 languages have high front round vowels, 6 have high central round vowels, and 20 have high back unround vowels. Thus predictions of the three-place model based on statistical markedness are not borne out since the back round vowels occur in significantly more languages than do the others.

In the two-place model, back round and back unround vowels share a phonological representation: it is not meaningful to speak of their different frequencies phonologically; rather these vowels differ in phonetic enhancement features. Since enhancement features serve to enhance the salience of the vowel, it is not surprising that phonetically the back round vowel is more complex than the back unround vowel. This theory also makes right predictions concerning back round and front round vowels: back round vowels require a single feature, Peripheral, while front round vowels require two features, Coronal and Peripheral. The difference in frequency is thus a consequence of complexity.

Given the three-place model, one could envisage a solution to this problem: in addition to feature geometry, an independent markedness scale could be used; such an approach is used for consonantal place by Clements 1990. Here we can appeal to simplicity: the model that I have proposed collapses markedness scales and featural organization, with both expressed through geometry (one could likewise imagine both being expressed through hierarchies, as has been proposed in work in Optimality Theory; see Prince & Smolensky 1993); the vowel representations proposed by the three-place model require the independent existence of feature geometry and a markedness scale.

3.4 Evidence from the back/round relationship

The next argument comes from the relationship between Labial and Dorsal. It has long been noted that these features are intimately related. Using the features proposed in Sound Pattern of English (Chomsky & Halle 1968), linguists noted that [back] and [round] are linked, with one often redundant from the other (e.g. Chomsky & Halle 1968, Schane 1973). Considerable attention was paid to the directionality of the relationship: is [back] predictable from [round] or vice versa? A non-hierarchical notational system forced this topic to be discussed as part of redundancy, markedness, and linking rules. With feature geometry, the insight that there is a close relationship between the two features was lost: [back] was encompassed by Dorsal and [round] by Labial. These features do not form a constituent in the Coronal/Labial/Back theory. However, in the Coronal/Peripheral theory, they are a constituent, in fact they are a single feature.

This argument can be viewed as one for constituency rather than for specification. One could imagine the geometry in (66) for vowels.

(66)  

Place  
/ \  
Peripheral Coronal  
/ \  
Dorsal Labial

Dorsal and Labial are dependents of Peripheral, so it is not surprising to find a special relationship between them. However, inventory predictions remain problematic, even if the relationship problem receives a solution. In addition, the markedness problems (section 3.3) are equivalent to those of the three-place model: markedness facts do not follow directly from the representation, but must be encoded in a separate way.
3.5 Evidence from phonological processes and natural classes

While evidence from inventories, markedness, and the relationship between Labial and Dorsal provides support for the two-place model, many phonological arguments have been given for the phonological features [back] and [round], or Dorsal and Labial within the three-place model, as separate features. The question that I address in this section is whether phonological evidence exists for Dorsal and Labial functioning independently of one another. This is, of course, not predicted by the two-place model, where phonologically only the single feature Peripheral is available. I will claim that reference to peripherality alone is sufficient to account for phonological processes.

Two kinds of languages might present problems to this hypothesis. First are languages in which Dorsal and Labial have been argued to be independent. And second are languages where back vowels and velar consonants appear to form a natural class. Since back vowels are not specially marked by Dorsal, as in Clements’ model, one would not predict any special phonological patterning of vowels with these consonants.

3.5.1 Round implies back, back implies round

I will begin with some cases which have been analyzed under the three-place model, but which have clearly equivalent treatments under the two place model.

Clements & Hume 1995, following Itô 1984, argue that in order to account for vowel dissimilation in Ainu, Coronal and Dorsal are required. Ainu has the stem vowel inventory in (67).

(67) i e a o u

Stems can take a vowel suffix. In the regular case, this vowel is a copy of the root vowel. In what Itô terms irregular stems, the suffix vowel is a high vowel with the opposite value of the feature [back] than the root vowel, as schematized in (68).

(68) ‘irregular’ stems: CVC + V, where +V is a high vowel with opposite value of [back] from root vowel
(e.g. ket-u ‘to rub’, pok-i ‘to lower’)

Itô, using the feature [back], argues that in the irregular stems, the suffix vowel has the opposite value for backness than the root vowel. Clements & Hume, using Labial, Coronal, and Dorsal rather than [back] and [round], propose that Coronal and Dorsal are both required, and that if the stem vowel is marked Coronal then the suffix vowel will be Dorsal, and vice versa. While this analysis works, they provide no answer to the question of why Coronal and Dorsal are involved rather than Coronal and Labial. Assuming (as does Clements 1991) that the central vowel /a/ is unmarked for frontness or backness, labiality and velarity are completely predictable one from another in Ainu, and no way exists within the language to determine which feature is primary: one could just as well say that a coronal vowel takes a labial vowel and vice versa.

The two-place theory accounts for these data in a straightforward way: the only feature available is Peripheral. An analysis along the following lines is possible.

The vowels in Ainu have the phonological representations in (69).

---

5 This is not quite correct. They suggest that Coronal and Dorsal might form a constituent, Lingual, accounting for their patterning together.
I assume that the suffix vowel is marked Peripheral in the irregular class. Note that this differentiates the representation from the regular class, which can be unmarked for place, receiving its feature by spreading from the vowel of the root. In a front vowel root, nothing happens. In a root with a back round vowel, on the other hand, a sequence of two peripheral vowels is found. The morphologically derived representation violates the OCP (e.g. Leben 1973, Goldsmith 1976, McCarthy 1986); in Ainu rather than fusing the vowel representations, the feature of the final vowel is not licensed, and thus the only alternative, a front vowel, arises.

In Ainu-type inventories, Dorsal is sometimes called upon to differentiate i/e from u/o; at other times Labial is used to distinguish these vowels. In such languages, it is difficult to find phonological evidence for either features being primary since one is predictable from the other. In the three-place model, it is arbitrary whether one, the other, or both are chosen. Only two features are available in the two-place model and only two features are required. Thus the two-place model is always able to account for such cases.

3.5.2 Back harmony without round harmony

The second type of case concerns languages with what has been analyzed as back harmony but no round harmony; some such languages are Finnish and Hungarian. This language type is expected under the three-place hypothesis: the feature Dorsal spreads but Labial does not. This is problematic under the two-place hypothesis because Dorsal and Labial are not independent features in the representation.

A solution to these problems can be found by reanalyzing the harmony trigger. While it is often proposed that the velarity feature must spread in these languages or that both palatality and velarity features must spread (e.g. Steriaide 1987 on Finnish and Hungarian; Farkas & Beddor 1987 on Hungarian), an alternative analysis has been proposed for these languages, one in which only palatality spreads; see, for example, Goldsmith 1987 and Rose 1993 on Finnish and Goldsmith 1987 on Hungarian.

3.5.3 Back harmony and round harmony under separate conditions

Another test case of the two-place model are those languages that have been argued to have independent back and round harmony. If a language has both, it is impossible to use Peripheral to replace Labial and Dorsal since it would not be possible to separate out the two effects. In this section I examine one such language, Turkish, arguing after Walker 1993 that Turkish has two harmony processes, Coronal harmony and Peripheral harmony; there is no Dorsal harmony. Given this, two features are sufficient.

Turkish has the vowel inventory in (70).

(70) i ü i u
     e ö a o

The basic facts of Turkish harmony are illustrated in (71), abstracting away from round harmony; see section 2.1.1. If a stem has a front vowel, it takes a front vowel suffix; if it has a central vowel, it takes a central vowel suffix, and if it has a back vowel, it takes a back vowel suffix.
(71)  
\begin{align*}
\text{ip} & \quad \text{ip-i} & \text{‘rope’} \\
\text{kiz} & \quad \text{kiz-i} & \text{‘girl’} \\
\text{ek} & \quad \text{ek-i} & \text{‘joint’} \\
\text{tak} & \quad \text{tak-i} & \text{‘arch’}
\end{align*}

In two cases, an unexpected vowel is found. In the first set, the final vowel of the stem is central, so a central vowel suffix is predicted. However, a front vowel suffix is found. What characterizes these cases is the fact that a consonant following the final stem vowel is contrastively palatal, as in (72).

(72)  
\begin{align*}
\text{sual} & \quad \text{sual-i} & \text{‘question’} \\
\text{harf} & \quad \text{harf-i} & \text{‘letter’} \\
\text{idrak} & \quad \text{idrak-i} & \text{‘perception’}
\end{align*}

In a second set of exceptional cases, the final vowel of the stem is a front vowel, so a front vowel suffix is predicted. However, a central vowel suffix is found. What characterizes these cases is that the stem-final consonant is the velarized counterpart of a palatalized consonant, symbolized as [K] (as opposed to the front velar in (72)).

(73)  
\text{tasdiK} \quad \text{tasdiK-i} \quad \text{‘confirmation’}

Clements & Hume 1995 argue that in the regular class, Coronal spreads from the front vowels, and Dorsal from the non-front vowels. Thus, the critical feature of their analysis is that they differentiate the front, central, and back vowels as in (74), i.e. they treat the central stem vowels as back unrounded vowels.

(74)  
\begin{align*}
\text{front vowels} & \quad \text{central vowels} & \quad \text{back vowels} \\
\text{Place} & \quad \text{Place} & \quad \text{Place} \\
\text{Coronal} & \quad \text{Dorsal} & \quad \text{Labial Dorsal}
\end{align*}

They offer no evidence for this representation of central vowels, and in fact Clements assumes elsewhere (Clements 1991) that central vowels are without place features.

For the opaque [-back] forms in (72), Clements & Hume 1995 propose that the palatalized consonants are specified as Coronal, blocking the spread of Dorsal from the preceding vowel. For the opaque [+back] consonants, they argue that these are specified as Dorsal, and this feature blocks the spread of Coronal from the preceding front vowel.

This is a plausible analysis, but an equally plausible one is available under the two-place model. Under this model, the vowels have the place representations in (75).

(75)  
\begin{align*}
\text{front vowel} & \quad \text{central vowel} & \quad \text{back vowel} \\
\text{Place} & \quad \text{Place} & \quad \text{Place} \\
\text{Coronal} & \quad \text{Peripheral}
\end{align*}

Front-back harmony is accomplished through the spreading of Coronal and rounding harmony through the spreading of Peripheral. The regular forms are derived as in (76).
(76) V-Place vs. V-Place
l
Coronal
Coronal spreads, front vowel results
no spreading, central vowel results

For the forms in (72), I assume an analysis along the lines of Clements & Hume. The palatalized consonants have an underlying V-Place node with a Coronal dependent. These consonants block harmony from a stem vowel because they have a specified place feature, Coronal; this feature spreads, and creates the front vowel suffixes.

(77) s u a l - I
VP V-P V-P
Coronal

The major difference between the analyses lies in the forms in (73), those with opaque back consonants. Walker observes that this class has disharmonic stems. The stem in (73) has both a central and a front vowel. However, generally in Turkish the place of the first vowel determines that of the second vowel (low central vowels may appear after back vowels because of constraints on the spreading of labiality). Thus (73) does not meet the structural conditions of Turkish stems. Walker argues that these stems have Coronal associated to the second vowel rather than to the morpheme. Given this, the Strict Cycle Condition blocks the spreading of the specified feature Coronal within the stem; it thus cannot spread to the stem-final consonant, a consonant with a V-Place node but no dependent. If spreading in Turkish is strictly local, the feature cannot spread to the suffix vowel. Thus the central vowel occurs in the suffix.

(78) t a s d i K - I
V-P V-P V-P
Coronal
Coronal spreading blocked within a morpheme by SCC

Under this analysis, only front and round harmony occur in Turkish; Dorsal harmony is not required. Coronal and Peripheral are sufficient to account for the harmony system.

3.5.4 Palestinian Arabic

I briefly mention one final case that Clements 1991 uses to argue for Dorsal being present on back vowels. In Palestinian Arabic, if a root contains an emphatic or uvular consonant, a different stem vowel is found in the imperfective than with other consonants: while [i] is generally found, [u] is present with an emphatic or uvular. Clements suggests that the class of emphatic consonants, uvular consonants, and the vowel [u] can be captured through the use of Dorsal. However, since the consonantal class in question excludes dorsal consonants, the prototypical consonants marked by the feature Dorsal, it is not clear that this is evidence for Dorsal in the vowel.

3.5.5 Summary

In this section I have dealt with cases involving place harmony. The three-place and two-place models make different predictions as to the kinds of vowel harmony processes
that might exist in languages. These are summarized in (79), where attested patterns are underlined in the two place column.

(79) | predicted processes - 3 place theory | predicted processes - 2 place theory |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>spread Coronal: Finnish</td>
<td>spread Coronal: Finnish, Turkish</td>
</tr>
<tr>
<td>spread Labial: Arapaho</td>
<td>(low vowel targets)</td>
</tr>
<tr>
<td>spread Dorsal: ?</td>
<td>spread Peripheral: Arapaho</td>
</tr>
<tr>
<td>spread Coronal, Labial: ?</td>
<td>(spread Peripheral)</td>
</tr>
<tr>
<td>spread Labial, Dorsal: ?</td>
<td>spread Coronal, Peripheral: Turkish</td>
</tr>
<tr>
<td>spread Coronal, Dorsal: Turkish (low vowel targets)</td>
<td>(high vowel targets)</td>
</tr>
<tr>
<td>spread Coronal, Dorsal, Labial (Turkish high vowel targets)</td>
<td>(spread Peripheral)</td>
</tr>
</tbody>
</table>

The three-place model predicts systems of spreading rules that may not be attested; for instance, I have found no languages which must be analyzed as having Coronal and Labial spreading without Dorsal spreading, nor any that appear to have separate Labial and Dorsal spreading. This model thus overgenerates the types of harmony systems that occur. The two-place model, on the other hand, predicts exactly three types of harmony systems: Coronal alone can spread, Peripheral alone can spread, and Coronal and Peripheral can both spread. This system thus generates the attested cases in languages.

### 3.6 Consonant/vowel interactions

Several of Clements’ arguments for dorsal in vowels are based on interaction between consonants and vowels. He argues that if certain vowels have the feature Dorsal, it is possible to account for their patterning with Dorsal consonants. More generally, he predicts the following patterns.

(80) | front vowel | coronal consonant |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>round vowel</td>
<td>labial consonant</td>
</tr>
<tr>
<td>back vowel</td>
<td>dorsal consonant</td>
</tr>
</tbody>
</table>

The two-place model predicts the following classes.

(81) | front vowel | coronal consonant |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>peripheral vowel</td>
<td>labial, dorsal consonant</td>
</tr>
</tbody>
</table>

I examine three cases, Maxacalí, the historical development of French, and Barra Gaelic.

### 3.6.1 Maxacalí

Clements 1991 argues from epenthesis in Maxacalí that dorsal consonants and back vowels form a natural class. This is problematic for the two place model: it is impossible to refer to Dorsal in vowels phonologically. In Maxacalí, a consonant is inserted after a vowel under certain conditions that are not of relevance here. What is important is the relationship between the vowel and the inserted consonant. This is illustrated in (82).
(82) if the first vowel is: then C is:
i  y
o  w
i, a  y
e  none

Clements proposes the following analysis. The vowels have the representations in (83).

(83) front vowel central vowel back vowel

<table>
<thead>
<tr>
<th>Place</th>
<th>Place</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal</td>
<td>Dorsal</td>
<td>Labial Dorsal</td>
</tr>
</tbody>
</table>

The [y] glide is achieved by the spreading of Coronal and the [w] by the spreading of Labial and Dorsal. The gamma results from the spreading of Dorsal. Clements does not offer an account of the patterning of /e/.

Assuming the vowel system in (84), the representations of the vowels should by now be non-controversial, and are given in (85).

(84) i i
    e a o

(85) i i o c a

<table>
<thead>
<tr>
<th>V-P</th>
<th>V-P</th>
<th>V-P</th>
<th>V-P</th>
<th>V-P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cor</td>
<td>Per</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The vowel place dependents spread to the epenthetic consonant, giving [y] after Coronal (i.e. /l/) and [w] after Peripheral (/o/). The remaining vowels have no place dependent to spread, and a velar glide results (this, like Clements, offers no account of /e/). I suggest, following Trigo 1987 and Rice 1993, that the glide is not a phonological dorsal, but is a placeless segment; it is velar only by phonetic interpretation.

3.6.2 Dorsal consonants and back vowels: development of French

Another case that Clements 1991 cites as evidence for Dorsal on back vowels comes from deletion of consonants in the historical development of French. A labial or velar obstruent deleted intervocically when one of the surrounding vowels was /u/ or /o/. Clements argues for two processes: a dorsal consonant is deleted in the environment of a dorsal vowel (u, o) and a labial consonant is deleted in the environment of a labial vowel (u, o). Notice that Peripheral defines the class of labial and dorsal consonants and the vowels /u, o/. Thus, an alternative is that a peripheral consonant is deleted in the environment of a peripheral vowel.

3.6.3 Barra Gaelic

Barra Gaelic has a process of epenthesis by which a vowel is inserted to break up certain consonant clusters. The quality of the epenthetic vowel is of interest: it is front after a distinctively front consonant, central following a consonant that is not front but has a front counterpart, and a copy following a vowel that has no front counterpart. Clements argues that the facts of Barra Gaelic require that [back] and [round] must function independently. This is similar to Ainu: if central vowels are unmarked for place, then the spreading of marked features alone is sufficient to guarantee appropriate
assimilation. While this language is not of great interest in the two- versus three-place controversy, it is worth examining the facts of Barra Gaelic because of its controversial status in the literature (e.g. Clements 1986, 1987, Halle 1995, Odden 1991, Sagey 1986).

Barra Gaelic has the consonant inventory in (86). C' indicates a palatalized consonant, capital letters fortis consonants, and small letters their lenis counterparts.

(86) \[ p t t' k k' \]
\[ b d d' g g' \]
\[ f s s' x x' \]
\[ v z' gh \]
\[ m n \]
\[ N N' \]
\[ r r', l' \]
\[ R, L L' \]

The vowel inventory of Barra Gaelic is given in (87).

(87) \[ i i u \]
\[ e a o \]
\[ æ æ o \]

Following earlier discussion, I assume the following representations for the vowels.

(88) \[
\begin{array}{ccc}
\text{front} & \text{central} & \text{back} \\
\text{V-Place} & \text{V-Place} & \text{V-Place} \\
\mid & \mid & \\
\text{Coronal} & \text{Peripheral} & \\
\end{array}
\]

I assume the following representations for consonants.

(89) \[
\begin{array}{ccc}
\text{plain consonants} & \text{plain consonants, palatalized counterpart} & \text{palatalized consonants} \\
C\text{-Place} & C\text{-Place} & C\text{-Place} \\
\mid & \mid & \\
\text{V-Place} & \text{V-Place} & \\
\text{Coronal} & & \\
\end{array}
\]

Some examples of the epenthetic vowel are given in (90).

(90) a. after plain consonant, no palatalized counterpart: copy vowel
\[ t'\text{im[i]}x'aL \quad \text{‘round about’} \]
\[ æm[æ]s'ir' \quad \text{‘time’} \]

b. after plain consonant, palatalized counterpart: central vowel
\[ al[a]pæ \quad \text{‘Scotland’} \]
\[ s'er[a]v \quad \text{‘bitter’} \]
\[ s'æn[a]xæs \quad \text{‘conversation’} \]

c. after palatalized consonant: front vowel
\[ bul'[i]k' \quad \text{‘bellows’ (gen. sg.)} \]
\[ sir'[i] \quad \text{‘wooing’} \]
\[ mar'[e]v \quad \text{‘the dead’} \]
\[ dir'[i] \quad \text{‘fishing line’ (gen. sg.)} \]
Assuming strict locality in the spreading of place features, Coronal can spread from a palatalized consonant to the epenthetic vowel. Following a plain consonant with a palatalized counterpart, a central vowel will necessarily result since the consonant has a V-Place node, blocking spreading of place features from the previous vowel under conditions of strict locality. Finally, following a consonant without a palatal counterpart, the two vowels are adjacent, and the features of the first vowel can spread to the second. This system thus provides no evidence for back vowels having internal structure.⁶

3.7 Summary

I have argued that the arguments adduced for vowels being marked for labiality and velarity both must be reinterpreted in order to avoid the overgeneration of possible vowel systems in languages. If the proposed analysis is correct, i.e. if the feature Peripheral is sufficient and Labial and Dorsal are unnecessary, a major question remains. How do the different phonetic vowel qualities that are phonologically simply peripheral come to be differentiated? In the following section, I examine the general question of relating the phonological representation to the range of possible phonetic realizations.

4. The phonetic realization of vowels

In the previous sections I have provided standard phonological evidence that front vowels pattern in two different ways and that peripheral vowels are not further specified for features. A consequence of the phonological representations proposed for the various places of articulation is that the phonological representation underdetermines the phonetic realization of the sound: a phonologically placeless vowel may be phonetically front or central while a phonologically Peripheral vowel may be phonetically back and round, back only, round only, or simply peripheral. In this section I develop a model to account for the relation between the more abstract phonological representation and its phonetic

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⁶ One type of form is deserving of further discussion. The epenthetic vowel with N is, unexpectedly, a copy of the preceding vowel, as in (i).

i. duNuxay 'Duncan'

Since this vowel apparently contrasts with N', a central vowel rather than a copy vowel is expected. I suggest that this form is only an apparent counterexample. Consider the coronal nasals found in Barra Gaelic.

ii. n
    N    N'

[n] is lenis, like [m], while [N] and [N'] are fortis. Note that fortition on [N'] is redundant: it is the only palatalized coronal nasal in the system. It thus could be thought of as having predictable tenseness. If so, then the phonological system is shown in (iii).

iii. Coronal    N    N'    n
    Nasal      √    √    √
    Tense      √

If this system is correct, then it is the nasals that are unmarked for tenseness that contrast in palatality: /n/ and /N'/ (better thought of as /n'/) have a V-Place node, while /N/ does not. /N/ is thus expected to pattern like /m/, allowing complete vowel copy. The patterning of the coronal nasals is not as unexpected as it initially appears to be once the contrasts in the system are understood.
implementation. In particular, this model accounts for the range of phonetic variability allowed to a particular phonological representation. I argue for the following point.

(91) A non-contrastive feature may function as an enhancement feature.  

In order to illustrate see how enhancement works, consider an inventory with two vowels, a peripheral vowel and a non-peripheral vowel. These vowels have the phonological representations in (92).

(92)  

\[
\begin{array}{c|c|c}
\text{non-peripheral vowel} & \text{peripheral vowel} \\
\hline
\text{Place} & \text{Place} \\
& \text{Peripheral} \\
\end{array}
\]

The non-peripheral vowel in this system may be enhanced by Coronal; if it is, [i] will be found. It need not be enhanced; if it is not, the vowel [i] is found. Before examining how the peripheral vowel is realized in this system, consider the three place system in (93).

(93)  

\[
\begin{array}{c|c|c}
\text{non-peripheral vowels} & \text{peripheral vowel} \\
\hline
\text{front vowel} & \text{central vowel} \\
& \text{Place} & \text{Place} \\
& & \text{Peripheral} \\
\end{array}
\]

In this system, Coronal and Peripheral are contrastive and the placeless central vowel is not enhanced. (91) functions to prohibit neutralization through enhancement, a not

7 See Dyck 1995 for discussion of constraints on enhancement with respect to vowel height. Dyck also argues that the constraint must be relativized to domain: for instance, affix vowels may contrast a different set of vowels than stem vowels, metricaly strong vowels may contrast a different set than metricaly weak vowels, and so on.

8 This statement is too strong. Constraints on enhancement are best stated through the use of two distinct constraints, as in (i).

\[
i \quad \begin{array}{l}
a. \quad \text{Enhance.} \\
b. \quad \text{Avoid neutralizing contrasts.}
\end{array}
\]

The languages that I discuss in the sections that follow order these constraints such that no neutralization is found, guaranteed by ranking the second constraint higher than the first. In a second set of languages, the enhancement constraint is ranked first, at the cost of neutralization. This provides an account of languages with abstract underlying forms and ‘rules’ of absolute neutralization. One example of a language that falls into this second category is Hungarian. It has long been argued that Hungarian has two types of high front vowels, those that pattern like a front vowel and those that pattern like a central vowel (e.g. Vago 1974, etc.). If the first type is Coronal and the second is unmarked, then this patterning falls out. If, furthermore, the enhancement constraint is more highly ranked than the neutralization constraint, absolute neutralization of the central vowel with the front vowel will occur. The Barrow Inupiaq data (Kaplan 1981, reanalyzed by Archangeli & Pulleyblank 1994) is a second instance. This language has two kinds of [i]’s, those that trigger palatalization of a preceding consonant and those that do not. If the first is Coronal and the second unmarked, the facts of the phonology follow; if the enhancement constraint is ranked above the neutralization constraint, the two will surface as a single vowel. In the languages that I discuss, the neutralization constraint is ranked higher than the enhancement constraint, guaranteeing that underlying contrasts are maintained on the surface (modulo operations of the phonology).
unexpected result since the function of enhancement is to make phonological contrasts more salient phonetically. Enhancement of the central vowel would result in decreased contrasts (in fact, in neutralization) in the system, thus being a marked phonetic option.

In a system with only a single vowel at a particular height, this vowel has the representation in (94).

(94) Place

No place feature is contrastive in the system. Given this, such a vowel is open to coloring from neighboring segments. In the absence of such coloring, one might expect that either Coronal or Peripheral could be as an enhancement feature since neither is contrastive.

Now consider the vowels with the feature Peripheral. The features Labial and Dorsal can serve as enhancement features for this vowel, as illustrated in (95).

(95) enhancement feature(s)  result
Labial, Dorsal  [u]  back rounded vowel
Dorsal  [u]  back unrounded vowel
Labial  [y]  rounded peripheral vowel
none  [u̇]  neither round nor back

One might expect to find phonetic differences in the realization of underlyingly placeless vowels depending upon whether or not a phonologically front vowel is present in the system. This is the topic of section 4.1. One might also expect to find both within and between language variation in the realization of vowels marked by the feature Peripheral; this is the topic of section 4.2.

4.1 The phonetic realization of placeless vowels

In this section I examine the phonetic representation of vowels that are unspecified for place phonologically. I make the assumption that the degree of specification of a segment is related to the degree of variability in its phonetic realization. If a segment is highly specified phonologically, it will exhibit little phonetic variation; if, on the other hand, a segment is little specified phonologically, it is capable of exhibiting phonetic variation. That variation is bounded, being limited by contrasts in the inventory. Thus the width of the window of realization of each place is determined by its contrasts. If there are no contrasts, the placeless vowel can potentially occupy a wide window; if there is a two way contrast for place, the window of the placeless vowel is narrowed, and if there is a three way contrast for place, the window is narrowed even more.

4.1.1 Placeless vowels in a system with a peripheral/non-peripheral contrast only

In this section I give phonetic evidence for the representations proposed based on phonological facts. I begin by examining systems without a front/central contrast at a height. In such languages, the sole non-peripheral vowel has the representation in (96).

(96) V-Place

In such a system, one might expect that the vowel that is phonemicized as a front vowel might show a range of variation between central and front; it simply will not be peripheral. This is borne out in a number of languages, and I report on some here.

In a number of Spanish dialects, variation is found between [e] and [ə]. Dyck 1995, based on Penny 1969, reports on the dialect of Pasiego, which has the inventory in (97).
The vowel that is phonemicized as /e/ varies in realization between [æ] and [ε]. Roughly, [ε] is realized in metrically strong positions and either schwa or [e] in metrically weak positions; see Dyck 1995. Under the proposal made here, this vowel has a placeless underlying representation. It is enhanced for place by the addition of the feature Coronal in a metrically strong position; in a weak position, enhancement fails to occur and [a] is realized. This is diagrammed in (98).

(98) /e/       no enhancement  enhancement with Coronal
         V-Place  V-Place
          |    Coronal
      [a]  [ε]

Enhancement by Peripheral is blocked by the presence of [o] in the system.

Greenlandic Eskimo (Crothers 1978:109, based on Thalbitzer 1904) has a three vowel inventory, as in (99). The /i/ has a range of variation, shown in (99).

(99) inventory:  i, a, u
          realization of /i/: [i, e, a]

The sound phonemicized as /i/ can be realized as a high front vowel, a mid front vowel, or a mid central vowel. This vowel thus shows variation for place between front and central, as predicted in a two-place system. It also shows variation for height between high and mid. Such variation is predicted in a system with a single non-low vowel height; see Dyck 1995 for detailed discussion.

In Gonja (Niger-Congo, Painter 1970) the front vowel is reported to have three allophones. This is shown in (100).

(100) i        u
      e  o
      ε  o

range of variation of vowels
/i/ has three allophones, [i], [I], [i], covering front and central range
The central vowel results if no enhancement takes place; the front vowel allophones arise from Coronal enhancement.

Klamath has a slightly different inventory shape than the languages examined so far. Barker (1964) reports the following.

(101) i o
e a

/i/ ranges from front vowels of different heights to a centralized vowel, as expected under the proposed representations.

The range of variation of the vowels in James Bay Cree (Algonquian, Ellis 1983:19) varies as in (102).

(102) short vowel inventory: /i, a, o/
    range of /i/

The facts of Murut (Austronesian, Prentice 1971) are summarized in (103) and those of Djapu (Austronesian, Morphy 1983) and Goonyiandi (Austronesian, McGregor 1990) in (104).

(103) Murut
    Inventory: /i u o a/
    /i/ ranges between front and central

(104) Djapu, Goonyiandi
    Inventory: i a u
    /i/ varies in height, may be front or central

Again, these languages receive an account: central allophones result from failure to enhance (105a); front allophones are a consequence of Coronal enhancement (105b).

(105) a. central  b. front
  V-Place            V-Place
                       i
                       Coronal

4.1.2 Placeless vowels in a system with no contrasts at their height

I have shown that in a language with a contrast between a peripheral vowel and a single non-peripheral vowel, the non-peripheral vowel may vary in its place of articulation between a front vowel and a central vowel. Before turning to languages with a front/central contrast, I would like to examine briefly languages with a single place of articulation at a particular height. Based on the discussion above, if a language has only a single vowel at a particular height, one might expect this vowel to be realized anywhere
throughout the range of place of articulations: its phonetic realization is unconstrained by its phonological representation since it has no specified place feature. This is often the case. First consider systems with only a single place of articulation at a particular height. In Kabardian (Caucasian, Colarusso 1992), the inventory has only two vowels.

(106) ə
     a

Colarusso reports that these vowels can be realized at any place of articulation, depending on the consonants in the environment. Lass 1984a reports that the Caucasian languages of Abkhaz, Abaza, Adyghe, and Ubykh are similar. Assuming the representation in (107), this variation is not surprising.

(107) V-Place

Consonants can provide their place of articulation to the vowel which is not itself specified for place.

In the New Guinean language Ndu (Laycock 1965), the vowel system is reported to have three heights, but no differentiation within heights in terms of place. Ndu vowels can be phonetically front, central, or back, depending on the environment. A placeless representation accounts well for this: the various phonetic places are all possible through assimilation and enhancement. Wichita (Caddoan, Rood 1976) has a three height inventory. Rood reports that the non-low vowels are fixed in place while the low vowel is variable in place of articulation, depending on environment.

Low vowels offer a fertile testing ground for the claim that the phonological contrasts in a system are important in determining the phonetic range of variability of a vowel because in many cases, languages have only a single low vowel. In many languages, the low vowel exhibits a tremendous range of variability; I discuss some such cases.

In Greenlandic Eskimo (Crothers 1978, based on Thalbitzer), there is a single low vowel, /a/. It has both front and back allophones [æ, ø].

The Flamingo Bay dialect of Asmat (Papuan, Voorhoeve 1965) has a single low vowel. This vowel has the allophone [a] in final position and [ø] elsewhere. It is optionally fronted in the environment of a high front vowel (recall from section 2.4.3 that this is the only vowel that is specified as coronal), as illustrated in (108).

(108) jismak / jismæk 'fire'
      bawit / bawit / bawit 'star' (progressive further fronting)

In James Bay Cree (Algonquian, Ellis 1983), the single low short vowel /a/ is reported as having a tremendous range of variation, as illustrated in (109).

(109) ![Diagram]

In Klamath (Barker 1964), with the inventory /i e o a/, the low vowel has front, central, and back allophones.
In Diyari (Australian, Austin 1981), the vowel inventory has two high vowels, but there is only a single low vowel. The inventory and the range of variation of the low vowel illustrated in (110).

(110) Inventory: i a u
    range of variation of low vowel

    /i/  /i/>  /u/<  /u/
    /æ/  /ɛ/  /a/  /æ/  /ɛ/  /a/
    /u/  /i/  /u/  /æ/  /ɛ/  /a/

In Djapu (Austronesian, Morphy 1983), there are three vowels /i a u/. The low vowel has a range of realizations, depending on the surrounding consonants.

If the low vowel has no specified place, it can receive place by assimilation to neighboring consonants or by enhancement, allowing it to span the entire range.

4.1.3 Summary

In languages with just a peripheral/non-peripheral contrast, the non-peripheral vowel has a wide window, being realized anywhere within the non-peripheral zone. In languages with no contrast for place at a particular height, the single vowel can occupy the entire range of places of articulation.

4.1.4 Placeless vowels in systems with front/central/peripheral contrasts

I now turn to languages with central vowels. Recall that in these languages, the front and central vowels have the phonological representations given in (111).

(111)  front vowel       central vowel
       V-Place          V-Place

In these languages, the front vowel should show little range for place of articulation since it is phonologically marked as Coronal: if it varies, it will be only in the front range. The central vowel likewise is restricted: it can vary phonetically within the non-front, non-peripheral zone, but enhancement by Coronal is not expected, nor is enhancement by Peripheral, assuming the presence of a back vowel.
Several languages provide support for this hypothesis. In Yimas (Papuan, Foley 1991), with the inventory in (112), the front vowel is very high and front, while the central vowel has a wider range of places of articulation, but does not overlap with either the front or peripheral vowel.

(112) \textit{i ia u}

In Nimboran (Austronesian, Anceaux 1965), the inventory is as given in (113). No variation is reported in the positions of the vowels.

(113) \textit{i e i a w o}

In Sierra Miwok (Broadbent 1964), the inventory is as in (114).

(114) \textit{i e i a u o}

The front and back high vowels vary in height but not in place. The central vowel can be fronted in certain environments.

4.1.5 Summary

In summary, when there is a central vowel at the same height as a front vowel, the front vowel varies only within the front range. This is in sharp contrast to the languages discussed in section 4.1.1, where the ‘front’ vowels could vary within the non-peripheral range. In fact, what we find in these languages are vowels that are phonologically simply non-peripheral; they are phonetically front. These facts are summarized in (115).

(115)

<table>
<thead>
<tr>
<th>language type</th>
<th>realization</th>
<th>representations</th>
</tr>
</thead>
<tbody>
<tr>
<td>single place of articulation</td>
<td>variable realization:</td>
<td>V-Place</td>
</tr>
<tr>
<td></td>
<td>Coronal enhancement is possible, as is Peripheral enhancement</td>
<td></td>
</tr>
<tr>
<td>non peripheral/peripheral contrast</td>
<td>non peripheral vowel may vary between central and front by absence or presence of Coronal enhancement</td>
<td>non peripheral peripheral V-Place V-Place Peripheral</td>
</tr>
<tr>
<td>front central peripheral contrast</td>
<td>vowels are relatively fixed in their places of articulation since no enhancement is possible</td>
<td>front central peripheral V-Place V-Place V-Place Peripheral</td>
</tr>
</tbody>
</table>
In section 2 I presented evidence to show that phonetic front vowels can have two phonological representations: if there is a central vowel at the same height, the phonetically front vowel is underlyingly marked as such; if, on the other hand, there is simply a single non-peripheral vowel, that vowel is unmarked for place. Fine-grained phonetic patterning correlates with this phonological patterning: within the non-peripheral vowels, coronal enhancement is possible only when there is no contrast in the non-peripheral zone; it is not found if such a contrast exists. Thus a strong correlation is found between the relatively abstract phonological representations and the degree of variation allowed in the more concrete phonetic representations.9 10

4.2 Peripheral vowels

A vowel with Peripheral is always be peripheral in realization. Articulatorily, peripheral vowels share the property that they are articulated in the periphery of the vowel space, unlike front and central vowels, which are articulated in the central part of the space. Acoustically, they are well-defined, sharing the property that they have minimal energy above the middle of the frequency band containing the most significant information relating to vocalic contrasts (Harris & Lindsay forthcoming). While Peripheral provides an adequate phonological description for these vowels, it is inadequate to describe the actual phonetic realization of the vowel: the ‘periphery’ is a large region, and the vowel may be articulated with the back of the tongue only, the lips only, both, or neither: it simply must be Peripheral. Variability in the realization of a phonologically Peripheral vowel can be found both across and within languages.

The first kind of evidence for Labial and Dorsal being enhancement features comes from the inventories discussed in section 3.1. Recall that in all inventories only a single back vowel is found. This vowel is may be round or not, however, indicating a need for a distinction between these vowels phonetically. Similarly the secondary articulation of peripherality varies across languages - it may be labiality alone, velarity alone, or both. Again, further distinctions are required phonetically than phonologically.

Within language variability reinforces this point, and I report on the variability below.

In Yimas (Foley 1991), /u/ is generally back and round, but it is unround preceding a labial consonant. These vowels share a phonological representation (116); they differ phonetically in terms of enhancement features, as in (117).

(116)  V-Place
       Peripheral

9 Enhancement of a central vowel when a front vowel exists is a source of neutralization historically, often leading to abstractness. See note 8.
10 One might argue that, a front vowel is always coronal and that the phonetic variation is a phonetic property based on vowel space. Such a model faces two problems. First, it does not account for the differences in phonological patterning between the two types of front vowels discussed in section 2. And second, if the first model is to be criticized on the basis that it involves a kind of globality, the second model is open to the same criticism. Consider how the variation facts would be treated under the two models. I have argued that there are two types of [i]'s, one specified Coronal and one not. The one that is Coronal must always be front while the one that is not specified can vary between central and front. Specification is dependent on inventory contrasts. Under the phonetic model, all front vowels would be specified as Coronal. In order to account for their different patterning with respect to variation, one must look non-locally at whether there is a central vowel or not. Just in case there is no central vowel, the front vowel can lose its place feature; if there is a central vowel, the place feature must be retained. This model too requires access to contrasts; this access is simply displaced to the phonetics.
(117) \[ \begin{array}{c|c}
[u] & [\mathbf{w}] \\
\text{V-Place} & \text{V-Place} \\
| & | \\
\text{Peripheral} & \text{Peripheral} \\
/ \ \setminus & / \\
\text{Labial} & \text{Dorsal} \end{array} \]

In Kannada (Dravidian, Schiffman 1983), \(/u/\) is back rounded or back and slightly unrounded (this pronunciation is reported to be stigmatized). Again, the representations in (116) and (117) are relevant. In Diyari (Austronesian, Austin 1981), \(/u/\) is slightly more central and less rounded than the cardinal vowel \(8\); it may approach the high back unrounded vowel.\(^{11}\) In Gooniyandi (Austronesian, McGregor 1990) the vowel \(/u/\) is reported to have allophones \([u \, w \, o \, a]\). These vary in place and height, with the allophones for place being represented as in (117).

I have shown examples of vowels with enhancement by Labial and Dorsal \([lu]\) and enhancement by Dorsal alone \([wu]\). The former representation is common, being the most reported. This is not surprising: since enhancement features function to increase saliency, one would expect to find the fully enhanced version frequently. However, it should be kept in mind that in reporting vowel inventories, the symbol used for the phoneme is often the one found in metrically strong or other salient positions, with other allophones regarded as reduced in some way. A survey of the variability of the peripheral vowel in a full range of domains may well reveal a greater degree of variability than is often suggested; compare with the discussion of Pasiego vowel height where only \([i]\) occurs in tonic position while in non-tonic position often \([a]\) surfaces.

Two other phonetic realizations of a representation with Peripheral are expected, one has just Labial added as an enhancement feature and the other has no enhancement features. In American English (de Jong 1993), the vowel \(/u/\) in a word like ‘kook’ has been shown to have three realizations, depending on dialect: \([u], [w], \) and \([y]\). The first has Labial and Dorsal and the second Dorsal. The third is reported to be a vowel with rounding, but without particular fronting; I suggest that this is the vowel that results if only Labial functions as an enhancement feature, and I use the symbol \([y]\) to differentiate this vowel from a front rounded vowel; this is a vowel with rounding, but not fronting.

The final predicted vowel is one with no enhancement features. Dyck 1995, following Lass 1984a, suggests the symbol \([u]\): the vowel is an extremely lax non-front, non-central vowel, but without marked features of backness or roundness.

5. Conclusions and consequences

5.1 Summary

I have proposed the following:

a. In vowels only Coronal and Peripheral are required to mark place phonologically.
b. Non-Peripheral vowels may not be subdivided at a height, in which case Coronal is not present. Alternatively, non-peripheral vowels may be subdivided at a height, in which case Coronal is present on the front vowel. The place representation of a vowel cannot always be determined from its phonetics alone; information as to what it is in opposition with is required.
c. Labial and Dorsal are enhancement features for peripheral vowels. These features play no role in the phonology but increase the perceptual salience of the sound.

\(^{11}\) I abstract away from the finest level of phonetic detail, which I do not attempt to account for.
Coronal is an enhancement feature if no vowel with the feature Coronal is found phonologically at the vowel height.

d. A close correlation is found between phonological specification and possible phonetic variability.

5.2 Consequences

In this section I would like to look at several implications of the proposed analysis.

5.2.1 Consequences for the phonetics/phonology relationship

In recent phonological work, it has been proposed that the phonetic representation of the vowel determines its phonological representation under most conditions; see, for example, Steriade 1995. This paper argues against that position: the proposed analysis requires that Coronal be absent unless it is contrastive at a height and Labial and Dorsal always be missing underlyingly as their presence is never triggered by contrasts. If the conclusions of this paper are accepted, some degree of abstractness must be allowed in phonological representations. Most interesting, perhaps, is the fact that all systems have a phonological ‘central’ vowel; rather than a system with /i u/ having a front/back distinction, this system has a central/back distinction phonologically; it is only phonetically that the system is realized as involving features of frontness and backness.

While the phonological and phonetic representations are not isomorphic, the analysis is nevertheless true to a principle argued for by proponents of a what-you-see-is-what-you-get theory: the representation, be it phonological or phonetic, is always fully interpretable (see, for example, Kaye, Lowenstamm, & Vergnaud 1985, Harris & Lindsay forthcoming, and Steriade 1995 for different instantiations of this principle). Rather than requiring isomorphism, the theory must tolerate some ambiguity. First, there is phonetic ambiguity: a single phonological representation may have more than one phonetic realization, as we saw in the case of both ‘central’ and peripheral vowels.

(118) phonological          V-Place
                   /       \
phonetic          [i]     [i]

Arapaho, Korean,
Yawelmani Turkish

And second, there is phonological ambiguity: a single phonetic realization may have more than one phonological representation, as we saw in the case of front vowels.

(119) phonological          V-Place       V-Place
                   |       \    \    
phonetic          [i]     Coronal        [i]

Arapaho, Korean,
Yawelmani Turkish

This ambiguity is highly constrained: within a system it is always possible to assign a unique representation to a particular vowel, but the vowel alone may not be sufficient to guarantee knowledge of its representation. Thus a certain amount of non-local information is required, namely information about contrasts in the system.
5.2.2 Consequences for markedness

The claim is sometimes made that a theory that relies on markedness built into representations is bound to fail because not all systems include an unmarked vowel (e.g. Steriade 1995). If the claims made in this paper are adopted, this claim can be seen to be false: all systems do have an unmarked vowel phonologically; phonetic enhancement simply obscures this fact. Thus, no matter what the system, a phonologically non-peripheral vowel is unmarked for place, be it realized as a front vowel or as a central vowel phonetically.  

5.2.3 Enhancement and other features

In addition to contrast playing an important role in constraining enhancement, other factors can also be involved. For instance, metrically strong vowels are very likely to be enhanced, probably because a metrically strong position is a highly salient position. In addition, vowel height can affect enhancement: high vowels often vary between [u] and [u] while a mid vowel is more likely to be rounded, i.e. [o]. In non-peripheral vowels, Coronal enhancement of the high vowel is extremely common, while enhancement of the mid vowel is somewhat less frequent. In a vowel system /i a u/, the non-peripheral vowel is often enhanced by Coronal while the low vowel is less often enhanced.

5.2.4 Similarities/differences between consonant and vowel features

I would like to end with a brief discussion of similarities and differences between consonants and vowels. I begin by discussing a similarity. If the conclusions of this paper are accepted, vowels are like consonants in terms of feature marking. With consonants the available set of features may be used contrastively in a language, in which case they are phonologically present; they may also be non-contrastive in a language, in which case they are phonologically unmarked but may be present phonetically as a result of enhancement. I have proposed a similar model for vowels. The features are available and are phonologically activated as motivated by contrasts; in the absence of a contrast, a feature does not play a phonological role. In vowels, contrasts between peripheral vowels are simply not found. The reason that Labial and Dorsal serve only as enhancement features for vowels is that they play no contrastive role in this system.

Thus while I have assumed that consonants and vowels share the same set of place features, Labial, Coronal, and Dorsal, I have argued that they differ in the number of features required phonologically: vowels require only Coronal and Peripheral, but consonants require three place features, Coronal and Peripheral, which dominates Labial and Dorsal (see Avery & Rice 1989, Iverson & Lee 1994, Rice forthcoming for recent discussion of constituency). Place of articulation is more fully developed phonologically in consonants than in vowels. Why might this be? The simple answer is that more contrasts are found in the consonant system than in the vowel system. One might ask

---

12 The model proposed by van der Hulst 1993 perhaps comes closest to the one argued for here in its assumptions. However, this model overgenerates possible places of articulation in a system. While van der Hulst uses a different set of primitives than those I employ, he predicts a five vowel contrast, as below.

<table>
<thead>
<tr>
<th></th>
<th>Fu</th>
<th>Fr</th>
<th>Cr</th>
<th>Bu</th>
<th>Br</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>i</td>
<td>u</td>
<td>u</td>
<td>i</td>
<td>u</td>
</tr>
</tbody>
</table>

While only two place features Cc and Cv are involved van der Hulst also allows for features to function as either heads or dependents, creating the larger set of vowels.
another question: why should this be so? It is well known that there is a correlation
between the number of allowed places of articulation and sonorancy in consonants: less
sonorant consonants tend to show a greater range of possible places of articulation while
more sonorant consonants allow a lesser range of places of articulation. For example,
most languages have stops at the three basic places of articulation, but liquids at only a
single place of articulation. The facts are similar in vowels: the more sonorant vowels
(low vowels) tend to show less of a range of places of articulation than the less sonorant
vowels (high vowels); see Rice & Avery 1993 for discussion. How is this relevant to
consonants and vowels? It is not surprising that vowels, which are more sonorant than
consonants, are phonologically more restricted in the possible places of articulation,
allowing only a subset of those found in consonants. Following Rice & Avery 1991,
1993 a segment is constrained in its complexity, where complexity is an overall measure
of place, sonority, and stricture. Increased sonority implies decreased options in terms of
place. Thus, the fact that vowels allow fewer places of articulation than consonants is a
direct consequence of their higher sonority. Interestingly, the high vowels, which are
more consonant-like, show a greater range of possibilities of place of articulation than the
low vowels do. Comparing vowels of different heights, we find the following figures,
from Maddieson 1984). I consider just the tense short vowels. The symbols used are
those in Maddieson. (F=front, C=central, B=back, U=unround, R=round).

(120)  | FU | FR | CU | CR | BU | BR |
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>/i/</td>
<td>271</td>
<td>/y/ 21</td>
<td>/a/ 40</td>
<td>/u/ 6</td>
<td>/u/ 20</td>
<td>/u/ 254</td>
</tr>
<tr>
<td>/e, ‘e’/ 196</td>
<td>/o/ 15</td>
<td>/e, ‘o’/ 73</td>
<td>/e/ 5</td>
<td>/e, ‘y’/ 10</td>
<td>/o, ‘o’/ 221</td>
<td></td>
</tr>
<tr>
<td>/æ, a/ 52</td>
<td>/a/ 274</td>
<td>/a/ 22</td>
<td>/æ/ 5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The numbers of front vowels are inflated and the numbers of central vowels deflated,
given the discussion in section 2. However, even when this taken into account, we see a
difference in the number of places of articulation used by low vowels as compared with
other vowel heights. Further, the numbers of low vowels of places of articulation other
than central are quite small; those of high and mid vowels are much larger.

5.3 Summary

I have challenged several common assumptions about phonological representations,
arguing that features commonly thought to belong to underlying representations in fact
play no role phonologically because they are never required to mark contrasts. These
features can be present phonetically, being added by enhancement. The phonological
model receives interesting support when phonetic variability is examined, with the range
of possible variability relating to the degree of specification. Overall, the facts discussed
suggest the need for relatively abstract phonological representations, but representations
that are determinable based on knowledge of contrasts in the inventory coupled with a
hierarchy for determining which features are marked first.

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