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*Vowel features and umlaut in Djingili, Nyangumarda and Warlpiri**

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0 Introduction

In this article we will analyse a number of phonological processes occurring in three Australian Aboriginal languages, all of which involve changes of vowels or sequences of vowels under the influence of neighbouring vowels or consonants. The rules which we will propose will be referred to as UMLAUT rules.[1] Our goal is to investigate how these rules and the forms to which they apply can best be described in an autosegmental model.

We will present an analysis which makes use of a feature system differing from that of *SPE* (Chomsky & Halle 1968) in two fundamental respects. With respect to vowel features, Chomsky & Halle use a system which Rennison (1984) characterises as BIDIRECTIONAL BINARY VALUED. It is binary because all features have two values, and bidirectional because vowels are classified along two axes: front–back and high–low. Here we will use a TRIDIRECTIONAL SINGLE-VALUED system. The presence of a single-valued feature in the representation of a segment expresses the presence of a particular phonological property, while segments lacking this property simply lack the feature in question. Our system here is tridirectional in that vowels are classified along three dimensions: front–unrounded, back–rounded and low.[2] As feature names we will use the phonetic symbols for the vowels which represent these three dimensions in their 'purest' forms: [i], [u] and [a].[3]

These two parameters (bidirectional *vs.* tridirectional, and single-valued *vs.* binary) are independent, so that it is theoretically possible to have four types of system:

(1)	*binary*	*single-valued*
bidirectional	*SPE*	Lass (1984: § 11.2)
tridirectional	Rennison (1984)	Anderson & Ewen (forthcoming: § 1.5)

It is also possible to have a 'mixed' system, in which some features are single-valued and others binary. A system of this type is proposed by Goldsmith (this volume).

Single-valued tridirectional systems similar to that which we will utilise here have been proposed elsewhere, for example in the frameworks of dependency phonology (Anderson & Ewen forthcoming) and particle phonology (Schane 1984), and by Goldsmith (this volume), although these differ in various respects from the system here. Kaye *et al.* (this volume) also propose a not dissimilar system with three basic elements I, U and A; in their proposal, however, these elements are themselves made up of binary features.

The structure of this paper is as follows. In §§ 1–3 we offer analyses of the umlaut phenomena in Djingili, Nyangumarda and Warlpiri, respectively, providing in each case a survey of the relevant data, followed by a formulation of the rules. In § 4 we briefly consider an alternative approach, based on different assumptions about autosegmental association.

1 Djingili[4]

1.1 The data

There are two umlaut processes in Djingili, which we will refer to as I-UMLAUT (IU) and U-UMLAUT (UU). IU is a nonlocal process; UU is local. All the data discussed here are taken from Chadwick (1975), who devotes some attention to IU, but does not explicitly mention UU. Djingili has a three-vowel system (if length is left out of consideration).

1.1.1. *Unbounded I-umlaut.* I-umlaut involves a change from /a/ to [i] before /i/. We illustrate the effect of the process in (2). Limitations of space prevent us from discussing our morphological analysis, which differs in various respects from that given by Chadwick. However, we do not believe that the differences would in any way affect the rules which we will propose:[5]

(2)	*stem*	*stative case*
a. 'branch' (masc.)		
singular	galal	galal-ji→gililị
dual	galal-ji-il-a	galal-ji-ji-a-ø → gililị iila
plural	galal-ji-wala-(ga)	galal-ji-wala-(ga)-ø → gililị wala(ga)
b. 'eel' (fem.)		
singular	gara	gara-ṇa-ji→giriṇi
dual	gara-il-a	gara-il-a-u→garailu
plural	gara-ala-(ga)	gara-ala-(ga)-ṇa-ji→ giriili(gi)ṇi

c. 'kite' (fem.)

singular	dilgu	dilgu-ṇa-ji→dilguṇi
dual	dilgu-il-a	dilgu-il-a-u→dilgulu
plural	dilgu-ṇa-ala-(ga)	dilgu-ṇa-ala-(ga)-ṇa-ji→ dilguṇiili(gi)ṇi

d. 'lizard' (fem.)

singular	ḷaŋura	ḷaŋura-na-ji→ḷaŋuriṇi
dual	ḷaŋura-il-a	ḷaŋura-il-a-u→ḷaŋurailu
plural	ḷaŋura-ala-(ga)	ḷaŋura-ala-(ga)-ṇa-ji→ ḷaŋuriili(gi)ṇi

e. 'galah' (fem.)

singular	galagalaḍ	galagalaḍ-ṇa-ji→giligiliḍi
dual	galagalaḍ-ṇa-ji-il-a	galagalaḍ-ṇa-ji-il-a-u→ giligiliḍiilu
plural	galagalaḍ-ṇa-ala-(ga)	galagalaḍ-ṇa-ala-(ga)-ṇa-ji→ giligiliḍiili(gi)ṇi

f. 'face' (neut.)

singular	guja	guja-ø → guja
dual	guja-il-u	guja-il-ø → gujailu
plural	guja-ala-(gu)	guja-ala-(gu)-ø → gujaala(gu)

g. 'nose' (vegetable neut.)

singular	gala	gala-ma-ji→gilimi
dual	gala-ma-il-i	gala-ma-il-i-ma-ji→ galamailimi
plural	gala-ma-ala-gi	gala-ma-ala-gi-ma-ji→ galamailigimi

Consider now the main features of IU. It can work its way through a number of suffixes, as in the stative plural forms of (2b–c). It is therefore UNBOUNDED. It is also anticipatory, i.e. a suffixal or root /a/ is changed under the influence of /i/ in the following morpheme. The stative plural form of (2a) shows that the change does not take place if /i/ is followed by a suffixal /a/, so that we do not get *[gililiili(gi)]. There are apparently no restrictions on the number of vowels that can be affected. In the stative plural form in (2e) eight /a/s are changed to [i]. Intervening consonants do not block the change, but an intervening /u/ does. This vowel is therefore OPAQUE. In the normal case (but cf. (5) below), /u/ itself does not trigger a change, as shown by the stative plural form of (2d).

IU is governed by morphological structure. It apparently does not apply if both the determiner and the focus are part of the underlying representation of a *single* morpheme. So we find roots with /aCi/ sequences which are not affected by IU, as in (3):

(3) 'rib' (masc. stat. sg.)
galimad-ji→galimid-ji (*gilimid-ji)→galimiḍi

In addition, morphemes may behave unexpectedly in any of three respects:

(4) a. some morphemes with /u/ trigger IU
b. the vegetable morpheme /ma/ is not affected by umlaut
c. some morphemes with /i/ fail to trigger IU

(4a) is illustrated by the example in (5):

(5) ŋaḍa-guṇu-nu→ŋiḍiguṇunu 'you two were looking'

while the stative plural form of (2g) shows not only that the element /ma/ is unaffected by umlaut, but also that it stops the whole process spreading further to the left. Thus we might say that such affixes are opaque. It has been suggested to us that it might not be an accident that the sequence which blocks IU consists of two adjacent vowels ([ai]), especially as the same sequence is involved in other cases where either IU or UU appears to be inapplicable.

(4c) is illustrated by the stative dual form of (2b), where we would otherwise expect *[giriilu]. Here again the sequence [ai] is involved. Either this particular sequence is opaque, or a consonant is required for umlaut to take place (but this cannot hold if spreading is regarded as iterative). There appears to be no formal explanation available to account for this, and we leave the matter unresolved here. As we will see below, the lexical status of the umlaut rules means that their having arbitrary lexically determined expectations raises no problem for the theory in any case.

1.1.2 *Local U-umlaut.* In UU /i/ becomes [u] before /w/ or /u/ in a following syllable (note that IU was not triggered by /j/, but only by /i/). UU involves one segment only – it is a LOCAL process, in contrast to IU. The operation of UU is shown in (6):

(6) *triggered by /u/*
a. 'chest' (neut. stat. dual)
maŋali-il-u→maŋali-ul-u→maŋaliwulu
b. 'foot' (neut. stat. dual)
jungu-il-u→jungu-ul-u→jungulu
c. 'deaf' (neut. stat. sg.)
ḷaŋa-ḍiḍ-ɪ:→ḷaŋaḍuḍu→ḷaŋaḍuḍu
triggered by /w/
d. 'snake' (masc. instr. sg.)
miga-ṇi-aṇḍi→miga-ṇi-waṇḍi→migaṇuaṇḍi

The sequence /iu/ occurs only once morpheme-internally (/biuŋa/ 'child'), but /iCu/ is frequent. This indicates that UU, like IU, is not applicable if both the determiner and the focus are part of the same morpheme. We shall refer to this kind of application as morpheme-internal application, or application in a non-derived environment.

The following examples show that UU applies locally:

(7) ŋaḍa-ŋiri-ṇu-nu→ŋaḍaŋiruṇunu 'we all (excl.) saw me'
ulugaḍa-ŋiri-ŋi-nu→ulugaḍaŋiriŋunu 'we all (excl.) washed ourselves'

UU seems to operate obligatorily in some cases and optionally in others. The full details of the behaviour of UU are not clear, but the rule certainly applies locally, when it applies at all, deriving [u] in the context of /u/, while other occurrences of the same morpheme have [i].

There is one systematic exception to UU: /i/ directly following /a/ is not subject to UU:

(8) 'face' (neut. stat. dual)
guja-il-u→*guja-ul-u→gujailu

Observe that in this case we again have a vowel cluster [ai] which resists umlaut.[6]

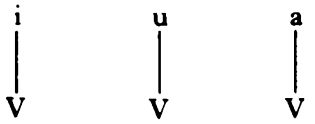
1.2 Theoretical background

1.2.1 *Lexical Phonology.* As we have seen, neither umlaut rule applies if its input string is part of the underlying representation of a single morpheme, i.e. if the string which meets the SD of the rule is non-derived. This suggests that both rules are lexical rules in the sense of Kiparsky (1982, this volume), Mohanan (1982) and Rubach (1984). Lexical rules have several characteristic properties. They may apply either cyclically or postcyclically (Booij 1981; Halle & Mohanan 1985). Cyclic lexical rules differ both from postcyclic lexical rules and from postlexical rules in being subject to a restriction which prevents their application in non-derived environments (see further below). A second characteristic property of (all) lexical rules is that they are more likely to be lexically governed (in the sense that they have exceptions). Finally, lexical rules are 'structure preserving'. This does not mean that a lexical rule cannot change information (it can, provided that the Strict Cycle Condition is not violated – cf. Kiparsky this volume), but it does mean that lexical rules do not create new segment types or new sequential or suprasegmental configurations, i.e. lexical rules do not violate constraints on lexical representations. If a language has a lexical constraint which bars a segment type A from the inventory of underlying segments, then a lexical rule rule is blocked in those cases where its application would create A. Similarly if there is a sequential constraint barring the sequence AB, then no lexical rule can apply to create AB.[7]

1.2.2 *Autosegmental phonology and underspecification.* We assume that consonant and vowel features are normally represented on distinct, non-interfering (sets of) tiers, and that consonantal and vocalic features are associated with a central tier, the CV-skeleton (cf. McCarthy 1979; Clements & Keyser 1983).

A three-vowel system can be characterised by the three single-valued features or components [i], [u] and [a], each associated with a V slot on the central tier:

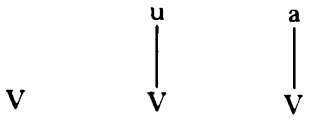
(9)



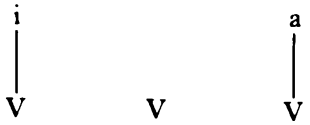
One advantage of this system as opposed to a system using the binary features [high] and [back] (or [high] and [round]) is that we are not forced to decide on the question of the value of /a/ for [back] (or [round]). Such a decision would be arbitrary, given the amount of allophonic variation in Djingili reported by Chadwick (1975: 5–6).

It is clear that the representation in (9) is still unduly 'complex'. There are at least three logically possible ways of representing a three-vowel system more economically:

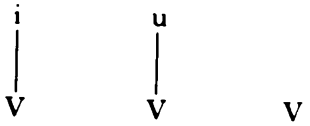
(10) a.



b.

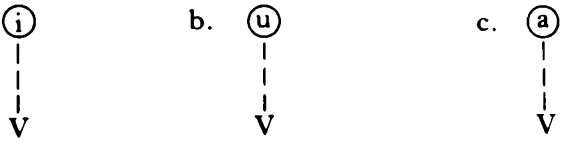


c.



In each case the redundancy rule filling in the specification omitted in the underlying representation can be derived mechanically, so that the feature not used lexically is filled by the rule:

(11) a. (i) b. (u) c. (a)



(where the circle round the feature denotes that it is inserted and associated by rule to the V node).[8] Clearly, (a)–(c) are equally economical. One way to decide which representation should be used in a particular language would be to invoke considerations of markedness. This would allow us to select (10c), since /a/ could be considered to be universally the least marked vowel. Given that we have decided which vowel is to be unspecified, we must then ask what the representation of a vowel would be at the point where phonological rules apply.

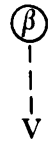
One approach would be that found in *SPE* – that all underspecification is eliminated before the application of any phonological rule; while a second possibility would be to allow phonological rules to apply to representations which are still unspecified. What would be the advantage of the second approach? We claim that, all other things being equal, a phonological rule which adds information (a FEATURE-FILLING rule) should be preferred to a rule which changes lexically specified information (a FEATURE-CHANGING rule). By representing alternating vowels as lexically unspecified, we achieve this result. So in Djingili, either IU or UU (but not both; cf. below) could be formulated as a rule which adds a feature ([i] or [u] respectively) to an empty V slot to its left. Empty V slots which do not undergo this rule (because they do not occur in the appropriate environment) will be specified by a redundancy rule, functioning as a default rule.

We noted above that we have to choose which of IU and UU will be feature-filling, since we cannot leave unspecified both those vowels which alternate between [a] and [i] and those which alternate between [i] and [u], as this would give us two types of non-distinct V slots. Before deciding which of the two rules is to be feature-filling, let us consider the matter of underspecification in greater depth. We can distinguish three reasons for leaving a segment underspecified:

Type I
A feature may be left unspecified if its presence depends on the application of a phonological rule. If the SD of the rule is not met, a default rule fills another feature. In this case underspecification is DIRECTLY motivated by alternation:

(12) a. 

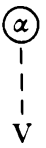
(phonological rule applies in environment X)

b. 

(default rule)

Type II
A feature may be left unspecified because it can be filled in by the default rule of Type I, although the segment in question is never involved in an alternation. In this case underspecification is INDIRECTLY motivated by alternation.

Type III
A feature may be left unspecified because its presence is unmarked. The rule filling in the unmarked value does not function as the default counterpart of a P-rule. In this case underspecification is motivated by markedness alone:

(13) 

Type I underspecification should be favoured in the input to phonological rules, purely on grounds of economy; the rules need not be feature-changing. But what about Type II underspecification? On the assumption that IU rather than UU is the feature-filling rule (a choice we will defend below), the redundancy rule in (11c) fills in the necessary feature if an unspecified segment does not occur in the proper environment for IU. This rule should be seen as a default clause of IU, and as such its domain of application is minimally that of IU; i.e. it may not apply before IU. How, then, do we deal with those instances of [a] which never alternate with [i]? Suffixal non-alternating /a/s which do not undergo IU (i.e. the suffix /ma/) must be specified as V—[a]; i.e. as lexically linked to the feature [a]. But how do we handle a root-internal /a/ preceding a root-internal /i/ (cf. (3))? If the lexically unspecified feature of these segments must be filled in before the umlaut rule applies, we run into the problem that the redundancy rule cannot distinguish between those segments which will undergo IU and those which will not. Hence we must assume either that non-alternating segments remain underspecified until after the application of the umlaut rule or that they are not underspecified at all.

We claim that non-alternating /a/s can be left underspecified, for the following reasons. In general, it would not be desirable to maintain that segments which never alternate must be fully specified underlyingly. In vowel harmony, for example, we often encounter cases in which the same regularity holds both within morphemes and across morpheme boundaries; e.g. Hungarian root vowels agree in their value for backness, and suffixes also harmonise with their root with respect to backness. If we were to specify non-alternating segments fully, this would force us to express a regularity twice, once as a morpheme structure condition (for the roots),

and once as a phonological rule (for the suffixes). This has become known as the DUPLICATION PROBLEM. To avoid this duplication, the same rule should apply in both domains, but this can only be allowed if application inside a root (a non-derived environment) is feature-filling. If rules were to be feature-changing inside a root, this would lead to absolute neutralisation, and hence the use of abstract segments (cf. Kiparsky 1968). But, as is argued by Ringen (1977), feature-filling root-internal rules do not encounter this objection. (14) is a slightly adapted formulation of Ringen's condition on rule application:

(14) A feature-*changing* application of a phonological rule is allowed only in a derived environment, whereas in a non-derived environment the rule may apply only in a feature-*filling* fashion

(Notice that (14) can be taken as a formulation of the Strict Cycle Condition, if 'phonological rule' is replaced by 'cyclic lexical rule'.)

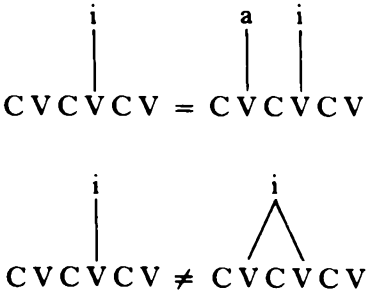
We might conclude that it is both desirable and possible for phonological rules to apply in non-derived environments. But this raises a slight problem. If we allow the redundancy rule V---ⓐ to apply morpheme-internally as a feature-filling rule, we must explain why IU cannot apply morpheme-internally, where it would also be feature-filling.

A solution can be found by reformulating (14) along the following lines:

(15) A cyclic lexical rule cannot apply in a non-derived environment if it neutralises a lexical contrast

(15) accounts for the absence of root-internal umlaut, if we assume first that (16) holds for the Djingili lexicon and second that it expresses knowledge concerning the lexicon which is available to the grammar:

(16)



(where '=' denotes 'does not contrast with' and '≠' 'contrasts with'). A rule which fills in [a] in the first syllable of the sequence CVCiCV, then, does not neutralise a lexical contrast, while a rule spreading [i] leftwards would.

It is clear that if all non-alternating /a/s were to be fully specified, (14) (or (15)) would lose its relevance for Djingili. However, this would be of

no advantage, since a condition of this type is required in universal grammar anyway to account for those cases where a regularity holds both inside and across morpheme boundaries.

Finally, we must say something about Type III underspecification. In general, we claim that all rules, including redundancy rules, apply as early as possible, with the smallest possible domain of application. The reason for this is that, as we will argue below, underspecification triggers spreading, and this is precisely what does not happen if a segment does not alternate. In fact, we doubt whether underspecification which is not motivated by alternation but only by markedness should play any role at all.

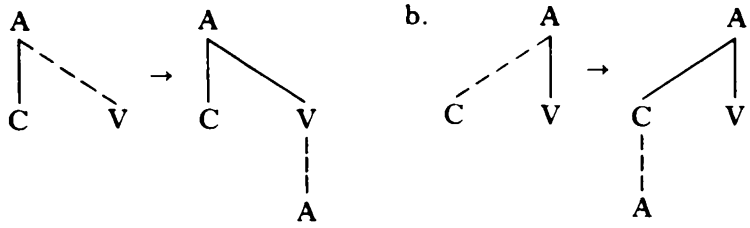
1.3 The analysis

Let us now consider the formulation of the umlaut rules. IU and UU can be formulated as in (17):

(17) a. *I-umlaut* b. *U-umlaut*

As we have seen, both /w/ and /u/ cause UU. Recall that we have assumed that consonantal and vocalic features are represented on different tiers. We assume that /w/ is the only consonant which has the vocalic feature [u]. Back consonants are specified as [K], one of the single-valued consonantal features of the theory.[9] UU must be interpreted in such a way that it is irrelevant whether or not [u] is present as a vocalic or as a consonantal feature. If it is consonantal, and is associated to a V slot, the result will be interpreted as a V associated with [u] on the vocalic tier, by means of a convention which we will call the OSMOSIS PRINCIPLE, which stipulates the following.

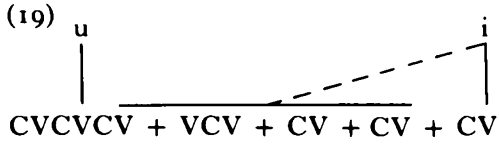
(18) a. b.



i.e. if a consonantal feature becomes associated to a vocalic slot, it is interpreted as the corresponding vocalic feature, and vice versa.

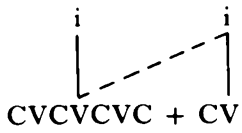
(19) and (20) illustrate the application of IU:

(19)



laŋura – ala – ga – ṇa – ji → ḷaŋuriiligiṇi
'lizard' (fem. stat. pl.)

(20)

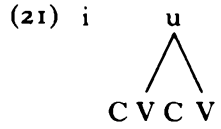


galimad – ji → galimiḍi 'rib' (masc. stat. sg.)

Following a suggestion of Rennison (ms), we assume that the three features are represented on the same tier. Thus we account straightforwardly for the fact that the presence of [i], [u] or [a] blocks spreading of [i].

The /u/s that trigger IU (e.g. in the suffix /–guṇu/) can be represented as in (21):

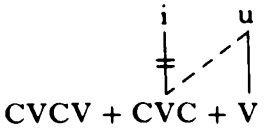
(21)



i.e. with a floating feature [i]. Being a lexical rule, IU is allowed to have (positive) lexical exceptions.

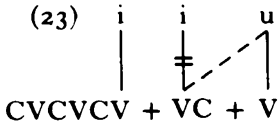
Consider now some examples of UU:

(22)



ḷaŋa – ḍiḍ – u → ḷaŋaḍuḍu 'deaf' (neut. stat. sg.)

(23)



maŋali – il – u → maŋaliulu → maŋaliwulu
'chest' (neut. stat. dual)

UU, in this analysis, is the rule which *changes* phonological information. Recall that we suggested that it would in principle also be possible to view UU as the feature-filling rule. The following considerations support our

choice. The local nature of UU results from its being feature-changing. We claim that iterative rules do not exist, so that spreading is regarded not as an iterative process, but as the simultaneous linking of an autosegment to all V slots in its scope. It then follows automatically that UU applies locally. In other words, whether a rule applies locally or in unbounded fashion is not seen as a property of the rule itself, but of the representation to which it applies. This parallels the situation in syntax (cf. Chomsky 1973).

This concludes our analysis of Djingili umlaut. Both IU and UU have been characterised as lexical rules, and no decision has been taken as to whether they apply cyclically or postcyclically. As far as we can see, both modes of application are possible. In this analysis we have motivated the use of underspecification in terms of alternation and from the point of view that feature-filling rules should be favoured over feature-changing rules. The choice of /a/ as the underspecified vowel (wherever possible), rather than one of the other vowels, rests on the fact that IU has an unbounded effect, whereas UU is local. One might suggest that the fact that /a/ is the vowel which triggers unbounded umlaut can be associated with its universally unmarked status in vowel systems, but we believe this to be a coincidence. We will see that in Warlpiri /a/ does not alternate at all.

2 Nyangumarda[10]

Hoard & O'Grady (1976; henceforth H&O) offer an analysis of Nyangumarda vowel alternations which involves two phonological rules. We will refer to these rules as PROGRESSIVE UMLAUT (PU), which is an unbounded rule, and REGRESSIVE UMLAUT (RU), a local rule.

2.1. The data

2.1.1 *Unbounded progressive umlaut.*[11] The following examples illustrate the class of facts for which the rule of PU is invoked:

(24) a.	*1st sg. fut.*	b. *1st sg. unrealised actual*	
	yurpa-lama-rna	yurpa-rna-ma-rna	'rub'
	wirri-limi-rni	wirri-rni-mi-rni	'put'
	kalku-lumu-rnu	kalku-rnu-mu-rnu	'care for'

As H&O observe, PU starts with the last vowel of the stem, and proceeds rightwards through the entire word. PU differs from IU not only in its direction, but also in the fact that spreading is restricted to just one of the vowels of the language.

Consider the following set of examples:

(25) a. *1st dual incl. unrealised actual*
yurpa-rna-ma-li 'rub'
wirri-rni-ma-li 'put'
kalku-rnu-ma-li 'care for'
b. *remote actual and 2nd sg. ind. obj.*
wurra-rna-lpa-ŋu 'tell'
wirri-rni-lpa-ŋu 'put'
kaku-rnu-lpa-ŋu 'forget'

Certain suffixes apparently have a non-alternating vowel, namely the inclusive dual suffix /li/ and the 2nd person singular indirect object suffix /ŋu/. Moreover, a vowel which alternates in other contexts surfaces as [a] when it immediately precedes a non-alternating vowel. H&O (1976:65) remark with reference to the forms in (25): 'a "buffer" vowel is left unassimilated if an underlying non-*a* is encountered'. We will again refer to vowels in non-alternating suffixes as opaque.

2.1.2 *Local regressive umlaut.* Let us now look at the facts that motivate the other rule that H&O propose, RU:

(26) a. yurpa-lapa-li 'we two (incl.) will rub'
b. wurra-lapi-yi 'they will tell'
c. wurra-lapi-ya-ŋu 'they will tell you'

The forms in (26a) and (26b) show that there is an alternation [lapa] ~ [lapi]. This alternation is conditioned by the initial consonant of the following suffix. (26c) shows that the precise nature of the vowel of the following suffix is not relevant.

H&O therefore posit a rule that turns /a/ into [i] before a palatal consonant. The form in (26b) suggests that palatal consonants also trigger PU, because the vowel following the palatal consonant is [i] in this case. Indeed, (26c) shows that rightward umlaut caused by /y/ obeys the 'buffer vowel' constraint, since /yV/ is [ya] before /ŋu/. But this interpretation of the data encounters a few problems, as H&O observe (1976: 65):

> Vowel assimilation due to a palatal consonant does not proceed, however, across consonants: *kulpu* + *rlinjpa* + *rna* + *ngu* 'It will return itself / come back on itself (as line onto reel)'. We do not get *rlinjpi* because the *p* blocks vowel assimilation from the palatal *nj*. The /i/ of *rljinpa* does not cause assimilation either since it is due to regressive 'palatalization' of underlying *a*.

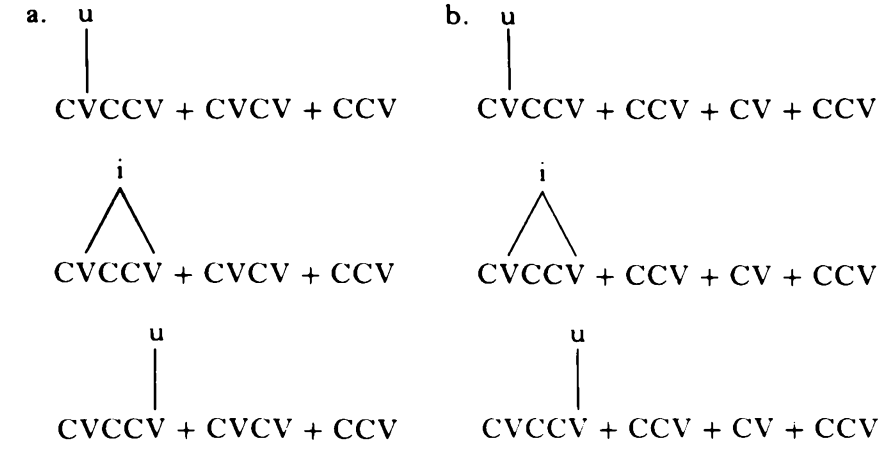
We will claim that palatal consonants do not trigger nonlocal progressive umlaut at all. We return to this point below.

2.2 The analysis

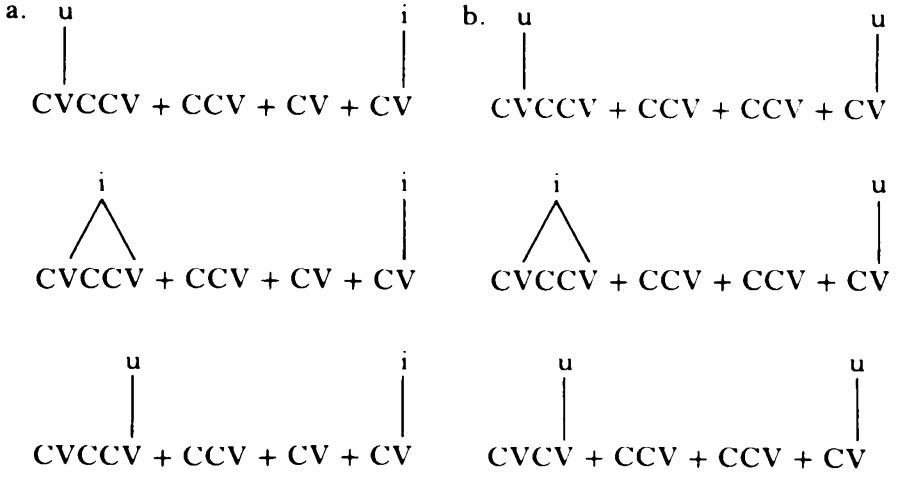
Let us assume that the vowel representations which form the input to the umlaut rules for Nyangumarda are the same as those posited for Djingili.

The forms in (24) and (25) can be represented as in (27) and (28) respectively (we again ignore the consonantal tier):

(27)

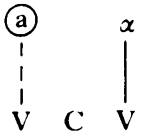


(28)



The presence of a buffer vowel suggests an insertion rule:

(29) *Buffer vowel insertion* (BVI)



(where α generalises over [i] and [u])

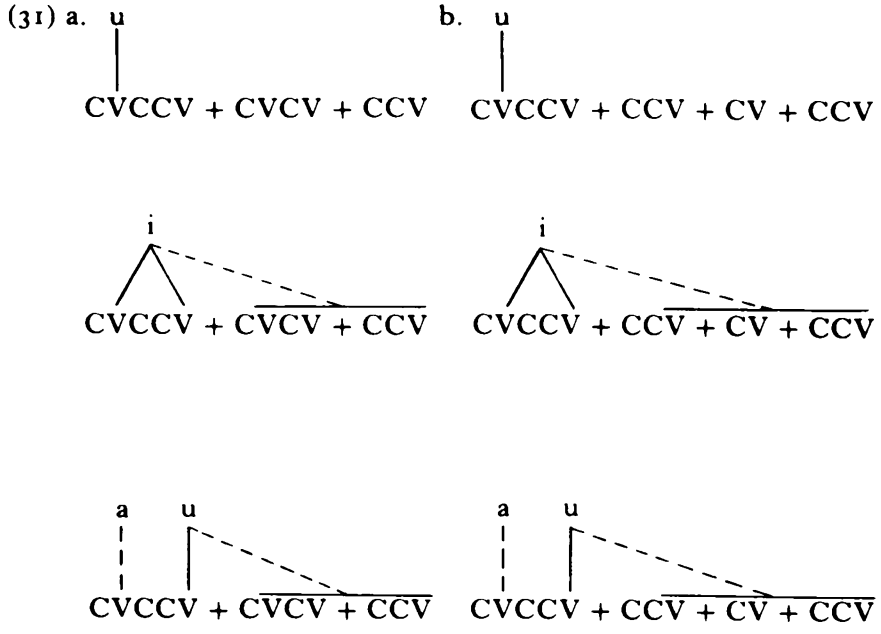
The umlaut process itself can be seen as simple bidirectional spreading:

(30) SPREAD (= *unbounded progressive umlaut*)

(29) must apply before (30). In its effect, SPREAD appears to be directional (i.e. rightward). Given BVI, however, we could also say that it is bidirectional, i.e. we might even assume that a buffer vowel spreads leftwards. In cases where an ambiguity arises (as in (28)), rightward spreading takes precedence over leftward spreading. This is the unmarked option, in the theory outlined by Clements & Sezer (1982).

In general it appears impossible to decide whether unspecified slots adjacent to a slot which happens to be associated with the default feature acquire their feature through spreading or through the application of the default rule. In Djingili, too, we might also consider the possibility that an underlyingly present [a] feature can spread leftwards, just like the [i] feature (cf. the stative plural form in (2g) where the root /gVlV–/ appears as [gala] before the opaque suffix /ma/).[12] The same point could be made with respect to Warlpiri (cf. § 3), because we can either assume [i]-spreading as well as [u]-spreading, or [u]-spreading only, with [i] being supplied by the default rule which we need in any case.

The rules map the representations in (27) and (28) on to those in (31) and (32). As in Djingili, a V slot which remains unattached to any feature is specified as V--- a (the effect of this rule is not indicated in (31) and (32)):



(32) a. u a i b. u a u

CVCCV + CCV + CV + CV CVCCV + CCV + CCV + CV

i a i i a u

CVCCV + CCV + CV + CV CVCCV + CCV + CCV + CV

a u a i a u a u

CVCCV + CCV + CV + CV CVCV + CCV + CCV + CV

In our analysis of Djingili, we did not specify whether or not the umlaut rules apply cyclically. In Djingili, both IU and UU could apply in either mode. In Nyangumarda, however, BVI (and SPREAD) apply postcyclically. BVI cannot otherwise operate: in (32) the rule inserting the buffer vowel in the V slot of the second suffix must be able to see that the vowel of the next suffix is linked to a vocalic feature.

There is another difference between IU and PU. It can be shown that PU applies inside roots. Consider the following example:

(33) a. waljpili 'white man' b. waljpila-lu 'white man–ERG'

This stem has a buffer vowel before the opaque suffix /lu/, but has an [i] instead if no opaque vowel follows. The fact that root-internal spreading is allowed in Nyangumarda provides extra evidence for the claim that umlaut applies postcyclically, since postcyclic rules are not subject to the Strict Cycle Condition. H&O point out, however, that PU does not apply inside bisyllabic roots. This can be seen from the first two examples in (32): the features associated with the first V of the stem do not spread to the second stem vowel, and also fail to reach the suffixes. The question then is why spreading does not take place in bisyllabic roots.

We suggest that this problem can be solved by assuming that the first syllable is EXTRAHARMONIC, thus giving the following representations for *yurpa* and *waljpili*:

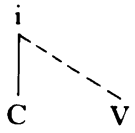
(34) a. u b. i

(CVC) CV (CVC) CVCV

The fact that the first syllable is extraharmonic prevents the first vowel in bisyllabic stems like *yurpa* spreading to the second syllable, or to following non-opaque morphemes.

Let us now return to the claim that palatal consonants trigger unbounded progressive umlaut. We must account for the fact that the [i] linked to a C behaves differently from an [i] linked to a V. Recall that spreading from a palatal consonant is blocked by a following consonant. We assume that palatal consonants are associated with an [i] on the consonantal tier, which is spread by the rule in (35). Thus umlaut caused by palatal consonants cannot spread if a consonant follows, because a following consonant will simply block spreading, as in (36):

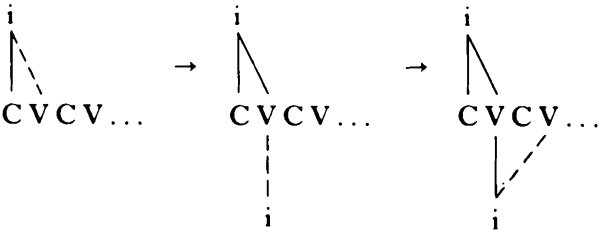
(35) *Local progressive umlaut* (LPU)



(36)

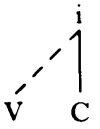
Once a neighbouring V is associated with the consonantal feature [i] it starts behaving like a vowel which is associated with that melody on the vocalic tier, in accordance with the Osmosis Principle, and triggers further unbounded umlaut:

(37)



Now, as H&O point out, palatal consonants trigger not only PU, but also RU (cf. §2.1.2). However, a vowel which is palatalised due to regressive assimilation does not trigger unbounded PU. To explain why a V preceding the sequence /njC/ will become [i] (see again §2.1.2), but cannot cause unbounded progressive harmony, we must assume that leftward umlaut is due to a separate rule, which applies *after* spreading. This ordering is necessary, as umlaut would otherwise be triggered by the affected vowel:

(38) *Regressive umlaut*



This rule seems to be optional. In some cases, no application is reported; in others there are doublets. Evidence that RU applies after PU is that a buffer vowel is obliterated by (38), as shown by (39):

(39) kalku-rnu-mi-nji 'care for' (incl. pl. unrealised actual)

The buffer vowel which we would expect before /nji/ is absent. Perhaps, then, (38) can be regarded as a postlexical rule, which often apply optionally (cf. Kiparsky this volume).

3 Warlpiri[13]

Our discussion of umlaut in Warlpiri is based on Nash (1979), where four umlaut processes are distinguished. Here we shall consider only three.[14]

3.1 The data

3.1.1 *Unbounded progressive umlaut.* A change very similar to Nyangumarda PU occurs in the (a) and (b) forms in (40):

(40) a. kurdu-kurlu-rlu-lku-ju-lu 'child–COMIT–ERG–then–me–they'
b. maliki-kirli-rli-lki-ji-li 'dog–COMIT–ERG–then–me–they'
c. minija-kurlu-rlu-lku-ju-lu 'cat–COMIT–ERG–then–me–they'

(/kurlu/ forms nominal stems, /rlu/ 'ergative' is a nominal case, and the other alternating morphemes are enclitics.) (41) shows that alternating suffixes behave consistently following other, opaque suffixes:

(41) maliki-kirlaŋu-kari-kirli 'dog–POSS–other–COMIT'

The most notable difference from Nyangumarda PU is that in this case we find that the alternating suffixes have [u] (and not [a]) after /a/. This is shown in (40c) and also in (42):

(42) maliki-kirli-kirra-lku-ju-lu 'dog–COMIT–ALL–then–me–they'

Another difference involves consonantal influence. After labial consonants alternating vowels appear *consistently* as [u]:

(43) ŋamirni-puraji 'uncle–your'
ŋali-wurru 'we two (incl.)–EMPH'

3.1.2 *Unbounded regressive umlaut.* The second umlaut process is regressive. It only occurs in verb stems, and is triggered by the past (nomic) suffix:

(44)	paŋi-rni	'dig–NONPAST'	kiji-rni	'drop it–NONPAST'
	paŋu–rnu	'dig–PAST'	kuju-rnu	'drop it–PAST'
	paŋi-ka	'dig–IMP'	kiji-ka	'drop it–IMP'

Observe that /a/ does not trigger a harmonic change. Rather, in the environment of /a/ alternating vowels show up as [i]. There are also stems which end consistently in [a]:

(45)	yirra-rni	'place–NONPAST'
	yirra-rnu	'place–PAST'
	yirra-ka	'place–IMP'

This process operates across derivational affixes:

(46)	kiji-rninji-ni	'throw–INCEPTIVE–NONPAST'
	kuju-rnunju-nu	'throw–INCEPTIVE–PAST'
	kiji-rninji-nta	'throw–INCEPTIVE-IMP'

3.1.3 *Local progressive umlaut.* Nash discusses a second progressive umlaut rule. There are four relevant monosyllabic morphemes with the vowel [i], given in (47a). Three of them have a variant with [u], which occurs after [u]:

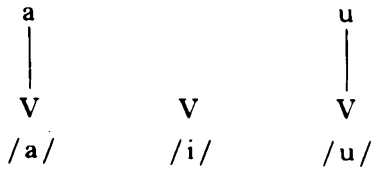
(47)	a.	nji ~ nju	'characterised by'
		rli ~ rlu	'1st nonsg. subject'
		rni ~ rnu	'towards speaker'
		yi	'continuative'
	b.	yanu-rnu-rlu-jarra	'go–PAST–hither–we two (excl.)'
		yani-rni-rli-jarra	'go–NONPAST–hither–we two (excl.)'
		parnkaja-rni-rli-jarra	'ran–hither–we two (excl.)'
		mururru-nju	'a comical fellow'
		lani-nji	'coward'
		kura-nji	'larrakin'

The rule may affect more than one vowel in a sequence, as shown by the forms in (47b). Nash accounts for this by assuming a cyclic derivation. We will see below that there are good reasons for following Nash in distinguishing between the two progressive umlaut processes.

3.2 The analysis[15]

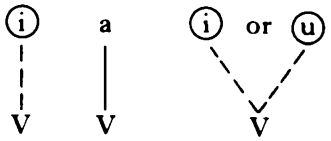
As in the previous two cases, we will assume that alternating vowels are underlyingly unspecified. Since in this case /a/ is not involved in any alternation, we represent it as opaque, i.e. as in (48):

(48)



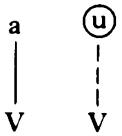
This implies, then, that the lexical representation of the vowels must be different from that in Djingili and Nyangumarda. The vowel /a/ must be lexically V—[a], and the empty V-slot is used for the underlying representation of the [i]~[u] alternation. Thus underlying representations, as well as representations which are the input to phonological rules, are governed by the type of alternation that we find in a language, not by considerations of allegedly universal markedness. The fact that the alternation in Djingili and Nyangumarda involves the 'universally unmarked' vowel /a/ is no more than coincidental.

We now have to explain the fact that next to /a/ alternating vowels show up as either [i] or [u] in those cases where there is no [u] which can spread to them:

(49) 

To explain the occurrence of a [u] to the right of [a] we will assume the rule in (50):

(50) *U-insertion* (UI)



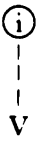
The occurrence of [u] after labial consonants is seen as the result of the following process:

(51) *Labial spread* (LS)

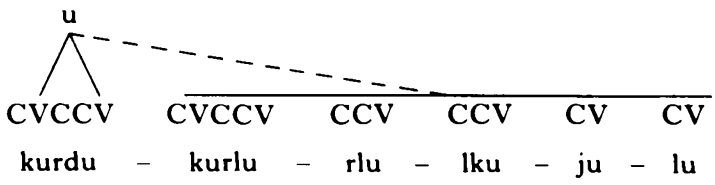
Given the intrinsic relation between the vocalic feature [u] and the consonantal feature [P], this process can be viewed as spreading followed by application of the Osmosis Principle (cf. note 9). The actual spreading rule can be seen as bidirectional spreading of [u]:

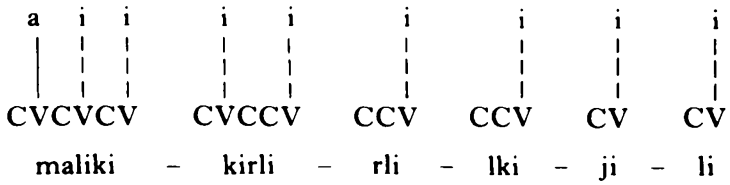
(52) SPREAD [u]

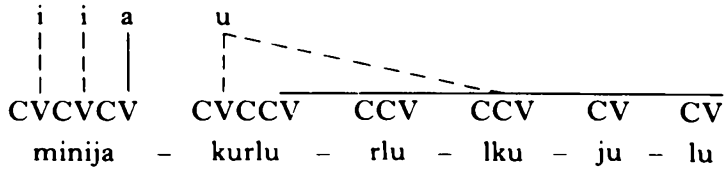
The redundancy rule needed for Warlpiri is:

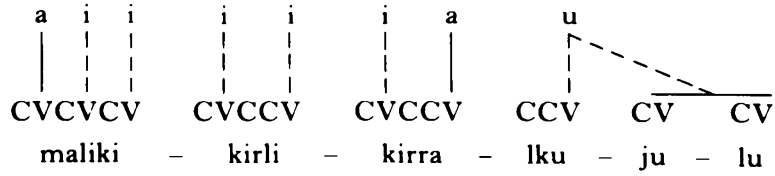
(53) 

Rightward application is found in the forms given in (40) and (42), as shown in (54):

(54) a. 

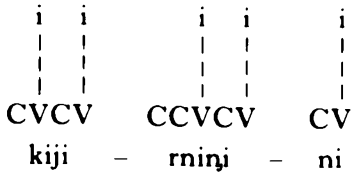
b. 

c. 

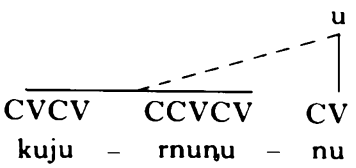
d. 

In (54b) and (54d) the correct result will also be obtained if we allow [i] to spread. This makes no difference, as noted above, since [i] is the default vowel. In (55) we show cases where spreading is leftward (cf. (45)). Where no spreading takes place, [i] is provided by the default rule:

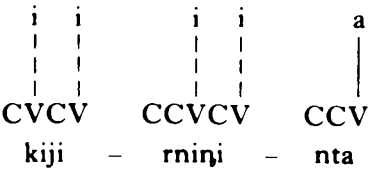
(55) a.



b.

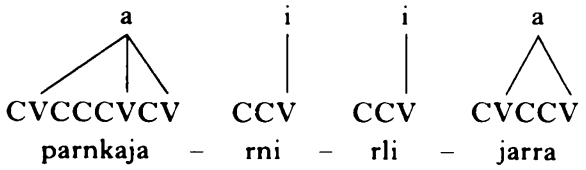


c.

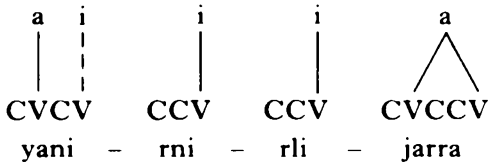


Let us now turn to the second progressive umlaut process, discussed in §3.1.3. Our analysis is illustrated by the representations in (56):

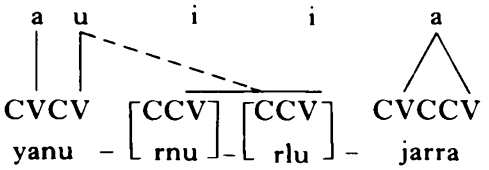
(56) a.



b.



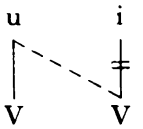
c.



The suffixes here are apparently not subject to [u]-insertion. If they were, we would expect to find [rnu] and [rlu] after /a/. Nash (1979) reports that in related dialects these suffixes always surface with [i]. We assume, in line with the foregoing, that non-alternating /i/s in those dialects result if they are fully specified. Being fully specified, they cannot be affected by the spreading or insertion of [u].

To account for the different behaviour of the three suffixes, we might adopt Nash's idea that the spreading here is due to a feature-changing (and thus local) rule, applying cyclically. We can then say that in the relevant dialect the /i/ of the three suffixes is also associated with [i]:

(57) *U-umlaut* (UU)



This is a minor rule, restricted to the suffixes concerned.

We conclude that the umlaut processes of Warlpiri differ from those of Djingili and Nyangumarda in that the alternating vowel is not /a/. /a/ in Warlpiri is consistently specified as [a]. This shows that the alleged unmarkedness of /a/ does not imply that the vowel is bound to be the alternating vowel.

4. An alternative analysis

In this section we consider whether the spreading rules can be simplified and made more uniform.

The phonological rules of the three languages proposed above differ as follows:

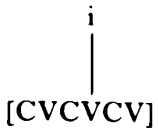
(58) Djingili: SPREAD [i] leftwards
Nyangumarda: SPREAD
Warlpiri: SPREAD [u] (and [i]; cf. above)

We can conclude therefore that the spreading rule may be parametrised both in terms of what spreads and the direction it spreads in.

It would, however, be possible to attempt to eliminate these two parameters. Consider first Djingili. Suppose that suffixal [i]s are floating, whereas [i]s in stems (as well as all [u]s) are associated. Suppose further that spreading applies only to floating features, and that it applies cyclically. We thus account for the fact that there is no rightward spreading:

(60)

cycle 1

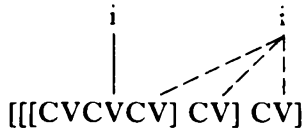


no spreading because [i] is associated

cycle 2

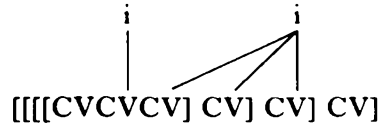
no spreading because [i] is associated

cycle 3



spreading applies to floating [i]

cycle 4



no spreading because [i] is associated

Notice too that we need no condition to prevent root-internal application.

What would the consequences of this approach be for the analysis of Nyangumarda and Warlpiri? In Nyangumarda, root features (except that in the first syllable) would be floating, in contrast to suffixal features, and spreading would apply postcyclically. In Warlpiri, all spreading [u]s would be underlyingly unassociated.

This approach, which requires further investigation, is interesting for two additional reasons. Firstly, condition (15), although apparently needed for other languages, would no longer be necessary for the analysis of Djingili. Secondly, the spreading rule can now be so formulated that we no longer need to make reference to specific features in Djingili or Warlpiri.[16]

NOTES

* A number of people helped us to arrive at this final version by commenting on earlier versions or oral presentations: Nick Clements, Colin Ewen, John Goldsmith, Paul Kiparsky, John Rennison, Catherine Ringen, Robert Vago, Jean-Roger Vergnaud, and three anonymous *Phonology Yearbook* reviewers.

[1] The terms 'harmony' and 'vowel assimilation' are also used for the processes we analyse here. Nothing hinges on our choice of the term 'umlaut', but in practice the term harmony is used when there are two sets of vowels involved, which differ in terms of a single feature.

[2] We agree with Rennison (1984) that the three dimensions should be interpreted as specifying 'directions', not absolute points in the vowel triangle.

[3] Although the languages which we consider here all have three-vowel systems, involving only /i/, /u/ and /a/, more complex vowels can also be characterised within the kind of tridirectional system employed here. Thus, /e/ might be interpreted as involving both the [i] and the [a] feature. A theory concerning the precise way in which this kind of 'compromise' vowel is arrived at (to our mind a part of the theory of phonetic interpretation) is offered by Kaye *et al.* (this volume).

[4] Djingili is the westernmost language of the Barkly Tablelands group.

[5] In (2) we give underlying representations and surface representations, to which a number of other phonological rules have applied, such as:

a. *J-deletion:* $j \rightarrow \emptyset / V—i$
b. *Stative truncation:* $a \rightarrow \emptyset / —V$ $[+stat]$
c. *W-insertion:* $\emptyset \rightarrow w / i—a, u$
d. *W-deletion:* $w \rightarrow \emptyset / u—V$

We will not discuss these rules here, and will not mention them explicitly each time their application is assumed.

[6] In this example the vowel cluster [iu] is immune to UU. Cf. /barad-ṇa-ji-il-a-u/ 'diver duck' (fem. stat. dual) → (J-deletion/Stative truncation) [baraḍ-ṇ-i-il-u] →(UU) *[baraḍ-ṇ-i-ul-u]→[biriḍiilu], where [ii] resists UU.

[7] Where lexical constraints are absent, rules may add structure freely. A case in point would be syllable structure in those languages where this is completely predictable.

[8] These rules are like Archangeli's (1984) complement rules. The value inserted is predictable in that it is the value which is not used. To mark exceptional opaque morphemes, however, the value *is* used, so that it may be necessary to formulate the redundancy rule explicitly. Archangeli (1984) reached us when this paper was nearly completed. Nevertheless, it helped to make possible a clearer exposition of our own views on underspecification. Although we disagree with Archangeli's proposals in various ways, we will not compare the two approaches here.

[9] We assume here a system of consonantal single-valued features which parallels that of the vocalic features, but is not identical. In the overall system we stipulate equations between pairs of vocalic and consonantal features: [a]↔[K], [i]↔[T], [u]↔[P]. See Smith (in preparation) for discussion.

[10] Nyangumarda is a language spoken in northwest Australia. The phonological facts discussed here are relevant to the northern dialect. Nyangumarda belongs to the Marnu sub-group of the Nyungic branch of Pama-Nyungan.

[11] Hale (1973) discusses the same process in Warramunga, a language related to Nyangumarda.

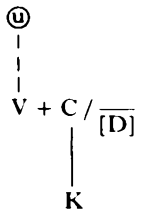
[12] Rennison (ms) suggests this point, and also offers an analysis of Nyangumarda umlaut employing a different morphological analysis.

[13] Warlpiri is a language spoken in the Northern Territory.

[14] Nash discusses another regressive umlaut process. The underlying form we have to choose here appears to be the one with /i/, as Nash also assumes. /i/ then changes to [u] before a velar consonant:

pi-nyi	non-past	pu-ngu	past (nomic)
pi-nja	infinitive	pu-ngka	imperative

The alternation [i] ~ [u] occurs in one other verbal stem, namely [yi] ~ [yu]. Nash points out that either the [i]-form or the [u]-form can be taken as underlying. If the [u]-form is underlying then these two verbs would be the only verbal forms ending in /u/. Taking the underlying form to be /i/, we would need the following rule:



The roots /pV/ and /yV/ will be marked [D].

[15] The analysis proposed here is inspired by ideas expressed by Paul Kiparsky in unpublished work. Our analysis is different from his, so Kiparsky is to be credited for its merits, and absolved of blame for its defects.

[16] In this paper, we have utilised a single-valued feature system. One question which arises is whether a system of this sort will be adequate to characterise harmony in languages with more complex vowel systems. Goldsmith (this volume), working within a system with both single-valued and binary features (based on Trubetzkoy's distinction between privative and equipollent oppositions), adopts an analysis of vowel harmony in Hungarian in which [u] functions as a binary feature. Ewen & van der Hulst (1985), however, suggest that a single-valued interpretation is appropriate for the analysis of the Hungarian system.

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