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Yoruba Vowel Harmony

1. Introduction

Lexical representations must include sufficient information to distinguish between phonologically distinct lexical entries. This is uncontroversial. Of more interest is the issue of whether certain types of predictable information should also be included in such entries: should underlying phonological representations be restricted to the encoding of distinctive properties, or should they be characterized in some less restrictive manner?

In this article we address this issue through a consideration of vowel harmony in Yoruba, a Niger-Congo language of Nigeria.[1] We argue that the harmony system of that language requires a theory of radical underspecification whereby all predictable information is excluded from underlying representations. Such predictable information includes distinct classes of properties. First, redundant values for the harmonic feature ([ATR]) must be excluded from underlying representations, both when assigned by context-free rules and when assigned by context-sensitive rules.[2] For Yoruba, this means that context-free redundant specifications of [+ATR] to mid and high vowels as well as context-sensitive assignment of [−ATR] to low vowels must be excluded. Of particular interest is the demonstration that one value of a feature must be excluded underlyingly even for a class of segments for which the feature is used contrastively. That is, a single value of [ATR] is present underlyingly for mid vowels even though there is a surface [ATR] contrast for that class of harmonic anchors. A second type of redundancy that must be systematically excluded is information concerning autosegmental associ-

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[1] Earlier discussion of Yoruba harmony includes Awobuluyi (1967), Awobuluyi and Bamgboṣe (1967), Bamgboṣe (1967; 1986), Capo (1985), Courtenay (1968), Fọlarin (1987), Fresco (1970), George (Madugu) (1973), Owolabi (1981), Oyelaran (1971; 1973), and Salami (1972).

[2] The acronym "ATR" refers to the feature "advanced tongue root" or "expanded pharynx." Lindau (1978) provides a discussion of the phonetic properties of this feature and Clements (1981) is an example of phonological motivation. Although we are not familiar with any phonetic studies demonstrating that [ATR] in Yoruba has the articulatory properties discussed in work such as Lindau's, it is clear that Yoruba makes both a phonological and a phonetic distinction of the type characterized by [ATR].

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ations. We argue that [ATR] values are morphemic in Yoruba in that a single value is present in the lexical entry of appropriate morphemes and that the assignment of [ATR] values to particular vowels constitutes a completely predictable pattern derived by the interaction of universal conventions and language-specific rules.

Three specific results emerge from the analysis of Yoruba harmony presented here. First, association of the morphemic [ATR] value argues strongly for a right-to-left parametric option in the linking of unassociated autosegmental features. Second, constraints on feature combinations are shown to play a central role in the harmonic system by governing initial associations and determining possible cases of exceptional prelinking as well as constituting the core of an adequate account of opaque harmonic elements. Finally, the Yoruba data argue in favor of allowing underspecification to be determined in part on a language-specific basis.

1.1. The General Harmony Pattern

Standard Yoruba has seven oral vowels: [i, e, ẹ, a, ọ, o, u]. The feature values that distinguish these vowels are shown in (1), (1a) giving fully specified representations and (1b) the underspecified representations that we assume underlyingly (see Pulleyblank (1988)).[3]

(1) a.

	i	e	ẹ	a	ọ	o	u
[high]	+	−	−	−	−	−	+
[low]	−	−	−	+	−	−	−
[back]	−	−	−	+	+	+	+
[ATR]	+	+	−	−	−	+	+

b.

	i	e	ẹ	a	ọ	o	u	
[high]		−	−		−	−		
[low]				+				
[back]					+	+	+	
[ATR]			−		−			(floating)

The crucial aspect of the underspecified representations in (1b) for the analysis here is that only [−ATR] is specified in underlying representation. We argue for this point extensively below. For the present, it should be noted that only nonhigh vowels can bear the specification [−ATR] (mid vowels contrastively and low vowels redundantly); high vowels can never be specified [−ATR]. To capture this aspect of the Yoruba vowel system, one might imagine that the grammar of Yoruba includes a list of (oral) vowel phonemes (that of (1b)) and that all lexical entries select vowels from that set. It turns out, however, that such an approach is impossible for Yoruba since (as we demonstrate below) specifications for [ATR] are not assigned to individual vowels in underlying rep-

[3] Orthographic conventions that are relevant for the following discussion are as follows: *ẹ* = [ɛ], *ọ* = [ɔ], *ṣ* = [š], *p* = [kp]; a vowel followed by a "tautosyllabic" *n* is nasalized; ´ = high tone, ` = low tone; unmarked for tone = mid tone.

resentations. As a consequence, the fact that [−ATR] is restricted to nonhigh vowels cannot be derived by reference to some underlying alphabet of phonemes but must be captured by a constraint on feature combinations such as the following (see Kiparsky (1985), Archangeli (to appear a), Archangeli and Pulleyblank (in preparation)):

(2) A [−ATR] specification can be linked only to a vowel that is [−high].[4]

In addition to ruling out unattested [−ATR] high vowels, this constraint is shown below to play an active role in determining both correct patterns of association and correct application of phonological rules in Yoruba. Thus, the function of such a constraint is basically that of defining the structure to be preserved via the application of rules and conventions (Kiparsky (1982; 1985)).

The basic distributional facts of [ATR] harmony for disyllabic vowel-initial nouns are summarized in (3) (see Awobuluyi (1967), Bamgboṣe (1967), Awobuluyi and Bamgboṣe (1967)). The horizontal axis of the table indicates the second vowel of a disyllabic noun, and the vertical axis indicates the first vowel. A plus (+) in the table represents a sequence that occurs, and Ø indicates a sequence that does not.[5]

(3)

		V_2						
		i	e	ẹ	a	ọ	o	u
V_1	i	+	+	+	+	+	+	+
	e	+	+	Ø	Ø	Ø	+	+
	ẹ	+	Ø	+	+	+	Ø	+
	a	+	+	+	+	+	+	+
	ọ	+	Ø	+	+	+	Ø	+
	o	+	+	Ø	Ø	Ø	+	+

In the discussion that follows we classify the harmonic properties observed in this table according to the height of the vowels concerned, high, low, and mid.

1.2. High Vowels

There are no distributional restrictions on high vowels with respect to [ATR]. High vowels cooccur with all vowels, both when the high vowel is in V_1 position and when it is in V_2 position, as exemplified in (4).

[4] Note that the [−high] value may be represented in underlying representation in the case of mid vowels or redundantly specified (and so not present in underlying representation) as in the case of the low vowel [a]. See section 4 for discussion.

[5] Since there are no *u*-initial words in Standard Yoruba, [u] is excluded from V_1 position in the table. Also, at the lexical phonological level there are nasal vowel counterparts for the high and low vowels only, nasalized mid vowels being possible only as the result of postlexical processes. See Bamgboṣe (1966), Pulleyblank (1988). We assume that with respect to harmony, the behavior of nasal vowels is comparable to that of oral vowels; but note Fresco (1970) and Oyelaran (1973). Finally, Oyelaran (1973) argues that a number of other morpheme-internal vowel-cooccurrence restrictions obtain in Yoruba; we do not address these restrictions here.

(4)

	i-initial		i-final		u-final	
i	igi	'tree'	igi	'tree'	iṣu	'yam'
e	ilé	'house'	ebi	'hunger'	eku	'bush rat'
ẹ	ilẹ̀	'land'	ẹ̀bi	'guilt'	ẹ̀wù	'clothing'
a	ilá	'okra'	àmì	'sign'	àrún	'five'
ọ	itọ́	'saliva'	ọ̀kín	'egret'	ọ̀run	'heaven'
o	ìgò	'bottle'	orí	'head'	ojú	'eye'
u	iṣu	'yam'	—		—	

One of the problems for an account of Yoruba [ATR] harmony is explaining why the high vowels neither undergo nor trigger [ATR] assimilation, particularly since there are polymorphemic cases where it might appear that high vowels function as triggers (see section 2.4). We argue here that the behavior of high vowels is a result of the lack of [−ATR, +high] vowels in Standard Yoruba—that is, a result of [ATR] being non-distinctive on high vowels (see section 2.1 and footnote 33). Formally, this property is expressed by the constraint in (2). Because [−ATR] specifications are not permitted on high vowels, high vowels can neither trigger nor be targeted by the harmony rule.

1.3. Low Vowels

The distribution of [−ATR] on words containing low vowels is restricted only with respect to cooccurring mid vowels, a low vowel (always [−ATR]) being permissible both to the left and to the right of a high vowel (as seen in (4)) and also cooccurring with itself (as seen in (6)). Although it is possible to have [−ATR] mid vowels both to the left and to the right of the [−ATR] low vowel (5a,b) and to have a [+ATR] mid vowel to the *right* of the [−ATR] low vowel (5c), it is impossible to have a [+ATR] mid vowel to the *left* of a low vowel (5d).

(5)

a.	b.	c.	d.
ẹ . . . a	a . . . ẹ	a . . . e	*e . . . a
ọ . . . a	a . . . ọ	a . . . o	*o . . . a

Examples of initial [a] followed by all vowels and of final [a] with initial [−ATR] mid vowels are provided in (6).[6]

(6)

	a-initial		a-final	
i	àdí	'palm nut oil'	ilá	'okra'
e	ate	'hat'	—	
ẹ	àjẹ̀	'paddle'	ẹ̀pà	'groundnut'
a	ara	'body'	ara	'body'
ọ	aṣọ	'cloth'	ọjà	'market'
o	àwo	'plate'	—	
u	atú	'type of dress'	—	

[6] Recall from footnote 5 that the absence of [u . . . a] words results from an independent prohibition against initial [u]. With C-initial words, [u] does occur in the initial syllable, as for example in *pupa* 'red'.

We argue in section 2 that the asymmetric patterning of low vowels is a result of ATR Spread being a directional rule, operating from *right to left* exclusively. (The rule is formulated informally in section 2.1 and more formally in section 3.3.)

1.4. Mid Vowels

With respect to tautomorphemic sequences of mid vowels, the values of [ATR] must agree. That is, the sequences in (7a) are possible, whereas those in (7b) are impossible (Awobuluyi (1967), Bamgboṣe (1967), Awobuluyi and Bamgboṣe (1967)).

(7) a.	e . . . e	e . . . o	b.	*e . . . ẹ	*e . . . ọ
	o . . . e	o . . . o		*o . . . ẹ	*o . . . ọ
	ẹ . . . ẹ	ẹ . . . ọ		*ẹ . . . e	*ẹ . . . o
	ọ . . . ẹ	ọ . . . ọ		*ọ . . . e	*ọ . . . o

The possible sequences are illustrated in (8), where impossible sequences are indicated by "—":

(8)		e/o		ẹ/ọ	
	e-initial	ebè	'heap for yams'	—	
		epo	'oil'	—	
	o-initial	olè	'thief'	—	
		owó	'money'	—	
	ẹ-initial	—		ẹsẹ̀	'foot'
		—		ẹ̀kọ	'pap'
	ọ-initial	—		ọbẹ̀	'soup'
		—		ọkọ̀	'vehicle'

The problem to be addressed in accounting for the behavior of mid vowels is the apparent bidirectional nature of such harmony. If such harmony is accounted for via a bidirectional rule of spreading, then we are forced to conclude that [ATR] harmony in Yoruba is the result of two independent rules, one for low vowels (right to left) and one for mid vowels (bidirectional). We argue instead that this bidirectional effect results from the right-to-left application of a single [ATR] harmony rule (the one independently required for low vowels). To make this possible, representations are required in which all specifications of [ATR] are unassociated (floating) in underlying representation and the convention for associating free [ATR] specifications to free vowels proceeds from right to left, a proposal for which there turns out to be considerable additional evidence. The subsequent application of the rule spreading [−ATR] leftward then creates spans of mid vowels with uniform [ATR] specifications. ([ATR] values on low vowels are assigned not by underlying specifications but by redundancy rule, since *all* low vowels are [−ATR]. This accounts for the fact that low vowels (but not mid vowels) can receive a [−ATR] specification in nonfinal position. See section 4 for discussion.)

In the following sections we motivate the above analysis in some depth. We begin (section 2) by examining the patterns of autosegmental association and rule operation

in morphologically simple and complex forms, arguing that (i) the Universal Association Conventions must apply from right to left in Yoruba for [ATR] and (ii) that both initial associations and subsequent rule applications are governed by the constraint in (2) that prohibits [−ATR] from being assigned to a high vowel. Next we demonstrate (section 3) that a hierarchical model of feature organization (see, for example, Clements (1985)) provides the necessary tier structure for [ATR], a biplanar structure where [ATR] links directly into the skeleton being inadequate (see, for example, Archangeli (1985)). We conclude (section 4) by considering two types of implications for a general theory of underspecification (see, for example, Archangeli (1984; to appear a), Pulleyblank (1986a,b; 1988)). First, all redundant specifications of [ATR] must be excluded from underlying representations, both in the case of segments (low and high vowels) for which the surface [ATR] value is noncontrastive and in the case of the segments (mid vowels) for which [ATR] does exhibit a surface contrast. In the case of low vowels the redundant [−ATR] specification is shown to be absent underlyingly but assigned prior to the application of ATR Spread. Second, we show that the only value of [ATR] that should appear underlyingly is [−ATR]. The value [+ATR] not only does not appear underlyingly but indeed must not be assigned until after the application of ATR Spread. In fact, there is no clear evidence that [+ATR] specifications are ever assigned prior to phonetic implementation.

2. Directionality of Association

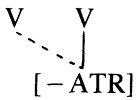
In this section we argue that it is possible for the Universal Association Conventions to apply from right to left. To this end, we argue that the asymmetric patterning of [ATR] in words with both mid vowels and low vowels is a result of three properties: (i) [ATR] specifications in underlying representation are unassociated; (ii) initial association of the free [−ATR] specification proceeds from right to left; and (iii) the harmony rule is directional, applying from right to left. The first point follows from the demonstration that nonredundant values for [ATR] are best represented as a property of particular morphemes, not a property of particular vowels, and we propose that the directionality necessary in (ii) and (iii) is a result of setting values for a directionality parameter on the Universal Association Conventions and on rules, respectively.[7]

2.1. Monomorphemic Cases: Disyllabic

As illustrated in (6), mid vowels may be either [+ATR] or [−ATR] when following a low vowel but may only be [−ATR] when preceding a low vowel. We account for this distributional asymmetry by assuming (i) that only [−ATR] is represented lexically (a point we address further in section 4) and (ii) that the rule of ATR Spread applies in a directional fashion, spreading [−ATR] from right to left.

[7] Fresco (1970) argues that for the Ifaki dialect of Yoruba, an assimilation rule working from right to left is required to account for [ATR] patterns, although he sees no motivation for directionality of the similar process in Standard Yoruba, the dialect we are examining. Our analysis demonstrates that there actually is strong motivation for such directionality, even in Standard Yoruba.

(9) *ATR Spread* (nonhierarchical version)

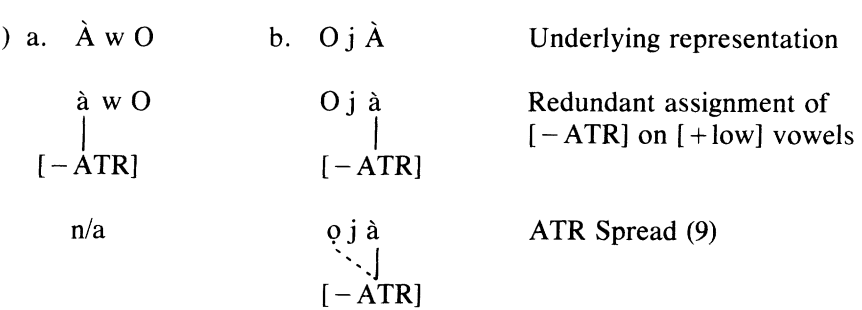


Because of the rule's directionality, vowels following a [−ATR] specification are unaffected, but vowels preceding such a specification are obligatorily [−ATR].[8]

The directional rule in (9) provides an account of the low vowel asymmetries only if /a/ is specified as [−ATR] prior to the application of the harmony rule. The [−ATR] specification on low vowels is assigned by a redundancy rule, not in underlying representation, since the [−ATR] specification on low vowels is a property dependent on the vowel's being [+low].

(10) [−*ATR*] *Redundancy Rule* (for [+low] vowels)
[+low] → [−ATR]

Hence, the examples in (11) actually begin their derivation with no [ATR] specification; the low vowels receive [−ATR] prior to application of ATR Spread.[9,10]



[8] Note that representing ATR Spread graphically necessitates including that both target and trigger are vowels as well as the directionality of spread. However, independently of this rule the only [ATR]-bearing units in Yoruba are vowels, and one of the inescapable properties of a spread rule is that a direction of spread (or bidirectionality) must be assigned to it. Thus, although the representation in (9) expresses the operation that takes place in Yoruba, a representation of the rule showing only properties actually manipulated is the following: *Spread [−ATR]; Direction: right to left.* (The rule function "spread" should be understood to indicate an operation extending the domain of a feature, notationally through the addition of association lines.) For a parametric approach to harmony, see Clements (1981), Clements and Sezer (1982); for a general application of a theory of parameters to phonological rules, see Archangeli and Pulleyblank (in preparation), Steriade (1987a), Yip (1988), Archangeli (to appear b).

[9] Throughout this article we use capital letters in derivations to indicate vowels not yet assigned an [ATR] value: A = [a], E = [e,ẹ], I = [i], O = [o,ọ], U = [u].

[10] For discussion of the principles by which the correct ordering of redundancy rules with respect to ATR Spread is ensured, see section 5. Also, note that as presented at this point, two possible derivations exist for any surface sequence of [−ATR] vowels, namely, one involving a single lexical autosegment that spreads and a second involving two lexical autosegments that simply associate to the two available vowels. We propose in section 2.2 that the possibility of two [ATR] autosegments is ruled out by the Obligatory Contour Principle (OCP). Note, though, that whether or not the OCP account is correct does not affect the necessity for ATR Spread since the rule is still necessary to account for the absence of . . . [+ATR] . . . [−ATR] . . . sequences of mid and low vowels that would otherwise be derived from a representation with a single [−ATR] specification. (See Leben (1973), McCarthy (1981; 1986), Yip (1988) for discussion of the OCP; see Odden (1986; 1988) for arguments against the universality of the OCP.)

Because ATR Spread applies only from right to left, it cannot apply in a case like *àwo*; hence, the sequences [a . . . o] and [a . . . e] are derived without spreading.

Vowels still not assigned values for [ATR] surface as [+ATR]. One way to achieve this is to posit a redundancy rule assigning [+ATR].[11]

(12) *ATR Redundancy Rule*

[ ] → [+ATR]

The two redundant values for [ATR] are of a very different status in Yoruba. Redundant [−ATR] specifications undergo spreading, as just seen. Redundant [+ATR] specifications, on the other hand, do not manifest themselves in any way other than appearing on the surface. As a consequence, there is no real evidence in Yoruba for the actual *phonological* presence of the value [+ATR]. Correct surface forms are equivalently achieved by assuming either (i) that [+ATR] autosegments are redundantly assigned in the phonology by (12) or (ii) that surface [+ATR] pronunciation is the result of the phonetic implementation of vowels not assigned [−ATR], whatever the appropriate formal account of such phonetic implementation. Because of the absence of phonological evidence for a [+ATR] autosegment, we leave open the issue of whether the ATR Redundancy Rule applies in the phonology, with the final stage of our derivations simply showing the assignment of [−ATR] to all appropriate vowels.

2.1.1. Directionality of the Universal Association Conventions. The [−ATR] . . . [+ATR] sequences (seen above with low and mid vowels) are not possible if both vowels are mid. We propose that this follows from two further properties of underlying [−ATR] specifications in Yoruba: (i) they float and (ii) they associate from right to left.

Recall from section 1 that whether a mid vowel surfaces as [−ATR] or not depends on the morpheme it is in and is not an idiosyncratic property of individual mid vowels (see Clements (1981)). This is not true of vowel heights that are consistently assigned redundant [ATR] specifications. Low vowels are always [−ATR], high vowels are always [+ATR]: the features of such vowels themselves determine their [ATR] specifications. To encode the property that nonredundant specifications of [ATR] are a feature of morphemes, we propose that underlying [−ATR] specifications are unlinked—that is, not assigned to particular vowels (the first of the two properties noted above). Underlyingly linked features, on the other hand, are required only when the specified features are a property of a particular segment—as occurs in Yoruba loanwords (section 2.1.2). (See Steinberger and Vago (1987) for a somewhat different approach to similar phenomena.) The morphemic specification hypothesis allows the following two underlying representations for a VCV word:

(13) a. V C V b. V C V
[−ATR]

[11] We assume (12) to be a complement rule in the sense of Archangeli (1984), although nothing depends on such status.

If, contrary to this proposal, [−ATR] were taken to be a property of specific mid vowels, the following four underlying representations would be possible:

(14) a. V C V b. V C V c. V C V d. V C V

[−ATR] [−ATR] [−ATR]

The representations in (14c) and (14d) would produce identical uniformly [−ATR] surface forms, whereas (14b) would predict the unattested mid vowel sequence *[−ATR] . . . [+ATR]. To avoid the latter problem while maintaining segmental specifications of [ATR], ATR Spread would have to be *bidirectional,* an analysis that makes two undesirable claims. First, the asymmetric [ATR] patterns in words with both low and mid vowels must be expressed by a second, directional rule, despite the fact that all other harmonic properties are identical. Second, indeterminacy of underlying representations is introduced. (14b), (14c), and (14d) would all be possible underlying representations for a form that surfaces with only [−ATR] vowels.

By analyzing [ATR] as a morphemic feature (and therefore underlyingly unassociated), indeterminacy is avoided and all [ATR] harmony in Yoruba is represented by a single rule. This of course requires some means to associate the underlying unlinked [−ATR] specification, association that is usually assumed to be the result of automatic conventions (see, for example, Goldsmith (1976), Clements and Ford (1979), Halle and Vergnaud (1982), Pulleyblank (1986a)). To determine the appropriate mechanism for linking in Yoruba, consider the properties exhibited: (i) a floating [−ATR] specification is linked to a segment unspecified for [ATR], and (ii) association is from the right edge, where (iii) high vowels are skipped until the first available nonhigh vowel is encountered (see section 2.1.3). These properties could be the result of a Yoruba-specific rule of Initial ATR Assignment (analogous to rules of Initial Tone Association discussed in works such as Clements and Ford (1979)); however, they are simply the mirror image of the version of the Universal Association Conventions proposed in Pulleyblank (1986a) whereby unlinked autosegments are assigned to free eligible targets in a one-to-one fashion from left to right. If we assume that the directionality of initial association is subject to parametric variation from language to language and from feature to feature, then the universal aspects of association are as follows:

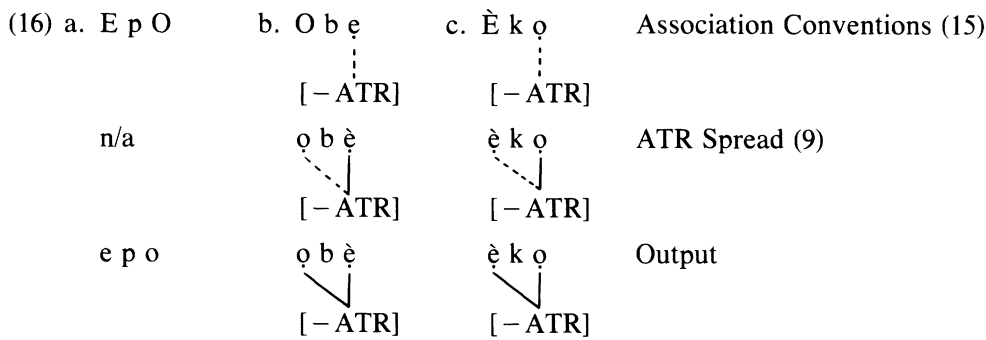
(15) *Universal Association Conventions* (automatic)
Wherever possible, associate autosegments to anchors in a manner that is
a. directional (left to right/right to left) and
b. of a one-to-one nature.

In Yoruba, initial association must take place from right to left because it feeds ATR Spread, a rule already established as applying from right to left.

There are other cases that suggest that linking by the Universal Association Conventions does not necessarily occur from left to right, notably the discussions by Marantz (1982), Broselow and McCarthy (1983), and McCarthy and Prince (1986) of linking to

reduplicative affixes and the discussions by Clark (1987) and Lieber (1987) involving tone and nasality. The Yoruba evidence supports the position that in addition to morphologically determined direction of association, the direction of linking due to the Universal Association Conventions may be determined on a language-particular basis for specific autosegments. Thus, direction of initial association, along with direction of spread, is parameterized, with left to right as the default direction, but with right to left available as a marked option.[12] Such parameter setting is specific to particular feature tiers since direction can be different within the same language for different features (for example, Yoruba tone is associated from left to right; see Pulleyblank (1986a)).

Thus, in addition to the morphemic [ATR] specification, the second proposal crucial to our account of Yoruba harmony is that the Universal Association Conventions apply from right to left in Yoruba. As illustration, consider the derivations of words like *epo* 'oil', *ọbẹ̀* 'soup', and *ẹ̀kọ* 'pap'. In such cases application of ATR Spread is fed by right-to-left application of the Association Conventions, as in (16).



Under this analysis, the bidirectionality observed with [ATR] harmony in Yoruba is only apparent, not formal. The apparent bidirectionality observed with sequences of mid vowels is the result of unidirectional spreading applying to autosegments located at the right periphery of the harmonic domain.

To conclude this discussion of the Association Conventions, we consider two final types of cases: (i) cases in which an [ATR] autosegment is exceptionally prelinked and (ii) cases in which the initial mapping of [ATR] autosegments skips certain potential anchors.

2.1.2. Prelinked [−ATR] Specifications. Support for the analysis presented so far whereby [−ATR] specifications present underlyingly are unlinked comes from a consideration of a restricted class of cases in which prelinking is necessary. As Bamgboṣe

[12] An interesting point to explore is whether the direction of initial association and the direction of spread are connected, a point addressed in Broselow and McCarthy (1983) and Archangeli and Pulleyblank (in preparation).

(1967, 273) observes,

> . . .English nouns of CVCV shape when borrowed into Yoruba may have a sequence of vowels which contravenes the vowel harmony rules, e.g. *fọ́tò* 'photo', *télọ̀* 'tailor', *bébà* 'paper', *mọ́tò* 'motor car' (all of which have vowel sequences not permissible in native words).

Not only are the sequences impermissible ones, but both impermissible orders occur, [−ATR] . . . [+ATR] and [+ATR] . . . [−ATR]. In the nonnative vocabulary, then, [ATR] specifications are a property of individual vowels, not a property of the morpheme as a whole. This is expressed by associating [−ATR] underlyingly with the specific vowel of which it is a property.

(17) a. f ọ́ t Ò b. t É l ọ̀

[−ATR] [−ATR]

The structural description of ATR Spread is not met in (17a); hence, the [ọ . . . o] pattern is correctly derived. As for the [+ATR] . . . [−ATR] pattern in (17b), the strict cycle (Mascaró (1978), Kiparsky (1982; 1985)) prevents application of ATR Spread if the feature is prelinked because the environment for the rule is not met in a phonologically or morphologically derived environment. Following Levergood (1984) and Pulleyblank (1986a), we assume that application of the Association Conventions on a given cycle creates the derived environment necessary to facilitate application on the same cycle of a rule like ATR Spread (as in (16)).[13] In addition, we propose that the application of redundancy rules creates a derived environment as in (11). As a final point, note that prelinking of [−ATR] is possible only with nonhigh vowels, a property that is explained by the condition in (2), discussed further in the next section.

2.1.3. Constraints on Feature Combinations. As noted in section 1.2, a [−ATR] autosegment can never link to a high vowel in Yoruba. Since, as we have just seen, [ATR] autosegments are underlyingly unlinked, this prohibition must be accounted for by the presence of a Cooccurrence Constraint on linkings (such as (2), repeated here as (18) for convenience), not simply by reference to an underlying alphabet.

(18) *Yoruba High:ATR Cooccurrence Constraint*

A [−ATR] specification can be linked only to a vowel that is [−high].

Of interest with respect to the Association Conventions is what happens when a high vowel is the rightmost vowel in a domain undergoing scansion for association of

[13] This account of the nonnative disharmonic words extends to representing a word like *bébà* 'paper' with an underlying [−ATR] specification linked to the vowel /a/, despite our general analysis of underlying /a/ as being without specifications for [ATR]. See Salami (1972) and Akinlabi (1987) for further discussion of borrowings in Yoruba as they concern harmony.

[−ATR]. In such cases the [−ATR] specification skips the high vowel because of the Cooccurrence Constraint and links to the rightmost eligible bearer of a [−ATR] specification. Hence, in words like *ẹ̀bi* 'guilt' and *ẹ̀wù* 'clothing' the morphemic [−ATR] specification (which distinguishes these morphemes segmentally from, for example, *ebi* 'hunger' and *ewù* 'grey hair') links according to the established right-to-left direction to the rightmost eligible anchor, the initial mid vowel.

Similarly, the application of ATR Spread is restricted by the Cooccurrence Constraint to apply only when the target is [−high]; thus, it is blocked in cases like *ilẹ̀* 'land' and *itọ́* 'saliva'. The rule itself need not identify conditions on the target; such conditions are provided by the presence of the Cooccurrence Constraint.

The net result if a condition such as the Cooccurrence Constraint is not posited is that three separate statements must be made prohibiting the cooccurrence of [−ATR] with high vowels, (i) concerning initial association, (ii) concerning the application of ATR Spread, and (iii) concerning the unpredictable prelinking of [−ATR] in loanwords discussed in section 2.1.2. By requiring three independent statements, such an approach treats as accidental the consistent behavior of [−ATR] as it interacts with high and nonhigh vowels. We interpret this as strong evidence in favor of the independent status of the condition allowing [−ATR] to exist on nonhigh vowels only.

2.2. *Monomorphemic Cases: The Two-Domain Pattern*

It was stated above that [−ATR] vowels appear freely to the left and right of high vowels in monomorphemic forms. Though correct for disyllables, this is incorrect for monomorphemic sequences with high vowels flanked by mid vowels, that is, cases with two harmonic domains. As shown by the representative examples in (19), if one of the mid vowels is [−ATR], it is always the final vowel, never the initial vowel.[14]

(19) *The Two-Domain Pattern*

a.	èlùbọ́	'yam flour'
b.	òwúrọ̀	'morning'
c.	òkùrọ́	'palm kernel'
d.	orúkọ	'name'
e.	erùpẹ̀	'earth'
f.	ewúrẹ́	'goat'
g.	odídẹ	'Grey Parrot'

This asymmetry is the automatic consequence of right-to-left association of the mor-

[14] These cases have sometimes been taken as evidence that Yoruba vowel harmony is limited to the first two syllables in words longer than two syllables (for example, in Fresco (1970)). Such a restriction is incorrect: the existence of forms like *ẹ̀bùrú* 'shortcut' shows that harmony does not necessarily obtain between the first two syllables of a longer word, and the absence of forms like **eberẹ* or **ẹbẹre* (vs. the existence of forms where the three mid vowels agree in [ATR] values) shows that harmony is not restricted to the initial two syllables of longer words. The two-domain pattern creates the appearance of this constraint in many forms, but the effect is derived straightforwardly from our analysis.

phemic specification of [−ATR]. To derive an unattested monomorphemic form such as **ẹlubo* or **ẹlubọ*, either of two things would have to happen. First, a [−ATR] specification could be prelinked to the first vowel (for **ẹlubo*). This is impossible in the native vocabulary since lexical specifications of [−ATR] are the property of morphemes, not of individual vowels. Second, a morpheme could be assigned two [−ATR] specifications (for **ẹlubọ*). These would link to the final and initial vowels, skipping the medial high vowel because of the Cooccurrence Constraint. The latter possibility is easily ruled out by a general prohibition against sequences of underlying identical [ATR] specifications.

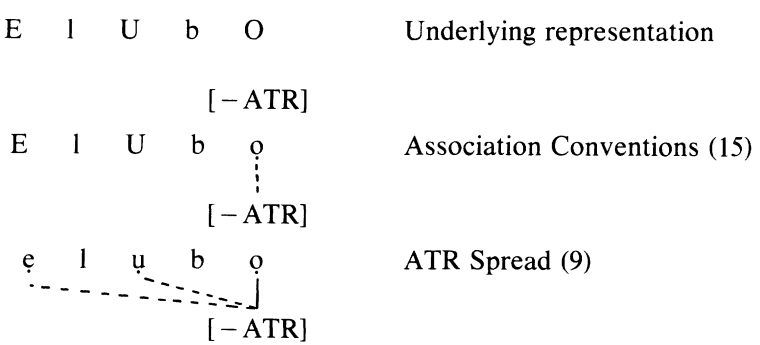
(20) *[−ATR] [−ATR]

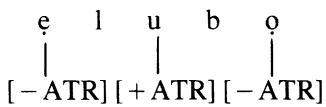
Though we note that (20) is plausibly the result of the Obligatory Contour Principle (OCP) (see, for example, Leben (1973), McCarthy (1986)), we do not address the question of the source of this constraint in the grammar. What is important here is that the inclusion of (20) not only contributes to an account of the distribution of [ATR] in polysyllabic forms but also removes a degree of indeterminacy from the analysis of disyllabic words, one of the central aims of the OCP. In a monomorphemic [−ATR] . . . [−ATR] sequence, such as *ọbẹ̀* 'soup' and *ẹ̀kọ* 'pap', the initial [−ATR] specification on the surface can only be the result of spreading (see (16)).

2.2.1. Constraints Again. The two-domain forms in (19) provide additional evidence that the Cooccurrence Constraint governs derivations, not simply initial association. As a constraint on derivations, the Cooccurrence Constraint prevents [−ATR] from ever associating to a vowel that is not specified as [−high], with the result that a [+high] vowel blocks application of ATR Spread. As (19) demonstrates, high vowels are indeed opaque in just this way.

If the Cooccurrence Constraint were not a constraint on derivations, then ATR Spread could affect high vowels, requiring a subsequent neutralization rule changing [−ATR, +high] vowels into [+ATR] vowels on the surface. However, if ATR Spread applied to the high vowels of (19), the initial mid vowels should surface as [−ATR], not as [+ATR].

(21)





Putative neutralization

*ẹ̀lùbọ́ (compare *èlùbọ́* 'yam flour')

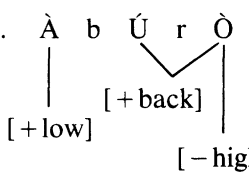
Since [−ATR] mid vowels do not appear in this environment, we conclude that high vowels are opaque, blocking the harmony process. We attribute this opacity to the Cooccurrence Constraint, which permits [−ATR] to associate only to [−high] vowels throughout the derivation, and to our assumption that the trigger and target of a rule must be adjacent at the appropriate level: the first and third vowels of *èlùbọ́* are separated by the high vowel, with the result that ATR Spread is blocked. This result argues against a "repair strategy" approach to the high vowels' behavior (such as that proposed in Calabrese (1987) and Paradis (to appear)).

2.2.2. Exceptions. There is a class of exceptions to the two-domain generalization just made: if the initial vowel is low, it is possible to have a [−ATR] . . . [+high] . . . V pattern.

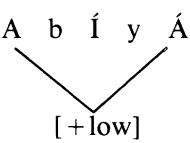
(22)	a.	àbúrò	'younger sibling'	d.	abíyá	'armpit'
	b.	àdúgbò	'neighborhood'	e.	àgùtàn	'sheep'
	c.	àtíkè	'makeup powder'	f.	àkùrọ̀	'a type of farmland'

The existence of such examples is predicted in an approach in which low vowels receive the value [−ATR] only following the initial application of the Association Conventions. Examples such as those in (22a–e) are derived with no underlying specification for [ATR], whereas forms like (22f) have a single underlying [−ATR] specification (note the underlying specifications given in (1)).[15]

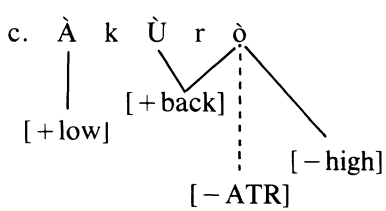
(23) a.



b.



c.



[15] Whether the [+back] and [+low] specifications are multiply linked (as shown), or whether multiple [+back] and [+low] specifications are posited, is an issue orthogonal to the representation of [ATR]. The multiple linking of [back] in examples like *àbúrò* and *àkùrọ̀* is unnecessary underlyingly, given a rule of back harmony that we do not discuss here. See Awobuluyi (1967).

In (23c) the lexical specification [−ATR] associates from right to left by the Association Conventions as discussed in section 2.1.1, as shown by the dashed line.

Up to this point the derivations are analogous to examples composed entirely of mid and high vowels, with or without an underlying [−ATR] specification. The possibility of a sequence [−ATR] . . . [+high] . . . [±ATR] is ruled out at this stage of a derivation provided that low vowels are not specified underlyingly for [ATR]. But after the application of the Association Conventions the low vowels in such words receive redundant [−ATR] values. Hence, the difference between the low vowel cases in (22) and the mid vowel cases in (19) is that subsequent to the Association Conventions for [ATR], low vowels are assigned [−ATR] via the redundancy rule in (10), thereby deriving the [−ATR, +low] . . . [+high] . . . V pattern.[16]

2.3. Spreading by Rule or by Convention?

A consideration of certain cases largely comparable to the two-domain cases provides evidence in favor of the rule-governed approach to harmony taken here as opposed to an alternative in which spreading would result from the automatic application of a convention. The relevant examples involve sequences that are disharmonic on the surface, involving a long [+ATR] mid vowel followed by a [−ATR] vowel. (Except for Consonant Deletion, which makes Progressive Vowel Assimilation possible, these forms are entirely comparable to those in (19).)

(24)	a.	oódẹ	*ọ́ọ́dẹ	'Grey Parrot'	(odídẹ)
	b.	eèpẹ̀	*ẹ̀ẹ̀pẹ̀	'earth'	(erùpẹ̀)
	c.	yoòbá	*yọ̀ọ̀bá	'Yoruba'	(yorùbá)

Each of these cases of apparent disharmony is derived from a trisyllabic form with a medial high vowel via Consonant Deletion and Progressive Vowel Assimilation (see Abímbọla and Oyelaran (1975)). Since [ATR] harmony does not cross high vowels, the [−ATR] specification of the final vowel cannot spread onto the medial high vowel, as seen in the alternants where the intervocalic consonant is retained. To derive the correct results for the cases in (24), ATR Spread simply needs to be ordered either before Progressive Vowel Assimilation or before both Consonant Deletion and Progressive Vowel Assimilation. On the assumption that rules but not conventions can be extrinsically ordered, ATR Spread must therefore be a rule, and not the effect of an automatic convention.

2.4. Polymorphemic Cases

There are two types of polymorphemic cases that we examine here, affixation and compounding.

[16] Note that the Cooccurrence Constraint, which allows a [−ATR] value to link only to a [−high] segment, permits the linking of [−ATR] to a low vowel since being [+low] implies being [−high]. That is, the existence of the redundancy rule [+low] → [−high] means that any [+low] segment satisfies a constraint referring to [−high].

2.4.1. Affixation. The directional analysis sketched above predicts that ATR Spread should apply between stems and prefixes but not between stems and suffixes, a prediction that is only half-testable because of the virtual absence of suffixes in Yoruba. With prefixes, the prediction is borne out. The following examples illustrate heteromorphemic harmony of nominalizing prefixes on verbs.[17]

(25)	a.	ọdẹ	'hunter'	dẹ	'hunt'
	b.	èrò	'a thought'	rò	'think'
	c.	ẹ̀rọ	'machine'	rọ	'fabricate'
	d.	ọta	'person who is a good shot'	ta	'shoot'
	e.	òkú	'corpse of person'	kú	'die'

When the nominalizing prefixes attach to a base whose first vowel is high ([+ATR]), the prefix is [+ATR].[18]

(26)	a.	òṣìṣẹ́	'workman' < ṣe 'do' + iṣẹ́ 'work'
	b.	òjíṣẹ́	'messenger' < jẹ́ 'answer' + iṣẹ́ 'message'
	c.	òpìtàn	'historian' < pa 'relate' + ìtàn 'story'
	d.	òṣùká	'porter's head-pad' < ṣù 'make into a ball' + ká 'encircle'

The pattern in (26) might be thought to constitute evidence for including [+ATR] vowels as triggers for harmony. Nothing in these sequences requires such an analysis, however, since [+ATR] can simply be assigned redundantly (phonologically or phonetically) to all vowels not in the domain of [−ATR]. (In sections 4.1 and 4.3 we argue that assigning [+ATR] redundantly is the necessary analysis.) A typical derivation would therefore proceed as follows:[19]

[17] Awobuluyi (1967) is, to the best of our knowledge, the first to recognize the significance of nominalizing constructions for Yoruba [ATR] harmony.

[18] This statement is based on an examination of the agentive/instrumental prefix *o, ọ*; see the Appendix and Owolabi (1981), cited in Bamgboṣe (1986) (we have not yet obtained a copy of Owolabi's work), as well as Ẹkundayọ (1976) and Pulleyblank and Akinlabi (1988) for discussion of general properties of this construction. In Standard Yoruba some exceptions to the general pattern are found (for which there is dialectal evidence in at least some cases for a [−ATR] high vowel; see Bamgboṣe (1986)) where a [−ATR] prefix appears before a high vowel—for example, *ọ̀mùtí* 'drunkard' (*mu* 'drink', *ọtí* 'liquor'). A possible synchronic analysis is that such high-voweled roots are underlyingly represented with a floating [−ATR] autosegment. The floating autosegment docks when a mid vowel is included, creating the disharmonic effect. We suggest this account tentatively, for it makes predictions about compounds with mid vowels to the right of such roots that we have been unable to test, mainly because the number of such exceptional cases appears very small. The floating [−ATR] analysis might also account for cases like *rú/ẹ̀rú* 'to haft/the haft'.

[19] There is a further point to clarify about the derivations of the forms in (26), a point not brought out in (27). As shown by (26b,c), as well as by various forms in the Appendix, harmony follows Vowel Deletion. That is, the post–Vowel Deletion value for [ATR] is the one that serves as the harmony trigger, not the pre–Vowel Deletion value. As a result of this ordering, the forms in (26) demonstrate once again that high vowels block the harmony process (see also the discussion of (19)).

(27) Ò + ṣ E + I ṣ É — Underlying representation

[−ATR]

Ò + ṣ E + I ṣ é — Association Conventions (15)

[−ATR]

Ò ṣ I ṣ ẹ́ — Vowel deletion

[−ATR]

n/a — ATR Spread (9)

ò ṣ ì ṣ ẹ́ — Output

[−ATR]

2.4.2. Compounds. A second type of bimorphemic sequence possible in Yoruba is the compound. In examining whether ATR Spread applies between the constituents of a compound, the compounds of concern are of the following form: . . . mid vowel][vowel. . . . There are four underlying sequences to consider, the four logical combinations of [−ATR] and [+ATR]. Two of these, . . . [−ATR][−ATR] . . . and . . . [+ATR][+ATR] . . . , provide no insights into the interaction of harmony and compounding. The cases of interest are those in which the [ATR] values of the constituents in isolation disagree.

The prediction made about a . . . [−ATR][+ATR] . . . sequence is that there will be no harmony between the two members of the compound, because ATR Spread applies exclusively from right to left. Furthermore, given the proposal that only the value [−ATR] is affected by harmony, the value [+ATR], even if specified, does not spread. This prediction is borne out:[20]

(28) a. ẹyẹlé 'pigeon' < ẹyẹ 'bird' + ilé 'house'

b. ṣẹ́wó 'to change money/to engage in prostitution' < ṣẹ́ 'to change' + owó 'money'

c. ọkọlóbìnrin 'married man' < ọkọ 'husband' + olóbìnrin 'married man'[21]

If the differing [ATR] values are in the opposite order, the environment for ATR Spread is met. Such cases then test the applicability of ATR Spread within compounds.

[20] One set of compounds seems to contradict this prediction. Words like *omidan* 'Miss' < *ọmọ* 'child' + *idan* 'virgin' and *omiye* 'sibling' < *ọmọ* 'child' + *iye* 'mother' appear to have undergone [ATR] harmony, with a [+ATR] specification replacing a [−ATR] specification. The analysis of such words is problematic, however, since the vowel /i/ of *idan* and of *iye* should delete, not the second vowel of *ọmọ* (by the application of regular rules; see Pulleyblank (1988)). Moreover, the compositionality of these compounds is not obviously synchronic, nor indeed is the morphological composition uncontroversial (see Akinlabi (1986)).

[21] *Olóbìnrin* is itself derived from *oní* 'possessor of' and *obìnrin* 'woman'.

As it turns out, the results are somewhat split. In certain cases harmony appears to take place (29); in others it does not (30).

(29) a. ọ̀gbẹ́ni 'sir' < ògbó 'old' + ẹni 'person'
b. ọgọ́ta 'sixty' < ogún 'twenty' + ẹ̀ta 'three'

(30) a. òkèbàdàn 'a hill in Ibadan' < òkè 'top of' + Ìbàdàn
b. ewébẹ̀ 'any pot herb used for making soup' < ewé 'leaf' + ọbẹ̀ 'soup'

The cases in (30), where harmony has not applied, constitute surface violations of harmony. Depending on the structure of the Yoruba lexicon, however, they need not be considered exceptions to ATR Spread. Compounding in Yoruba might take place at two different lexical strata, as proposed by Fọlarin (1987), or the forms in (29) might not be synchronically compositional, as implied by Akinlabi (1986), who claims that the only systematic behavior of compounds is that exhibited by forms such as (30a,b).[22] For the purpose of this discussion, the precise mechanism that is appropriate for deriving these effects is independent of the formal properties of the rule itself; the important point is that ATR Spread is inapplicable in at least one class of compounds. Such cases provide additional support for the claim that the spreading of [ATR] is the result of a rule rather than of a convention. Moreover, if spreading were by convention, then it should take place from left to right in examples like those in (28). In fact, no spreading occurs—as predicted by the rule approach.

Compounds include more than one morpheme, each of which may introduce its own [−ATR] specification. Thus, compounds frequently result in sequences that have surface patterns of the type [−low, −ATR] . . . [+high] . . . [−low, −ATR], an apparent violation of the two-domain pattern.

(31) a. ọ̀tíkà 'guinea corn wine' < ọ̀tí 'wine/beer' + ọ̀kà 'guinea corn'
b. ẹ̀rúnlá/ọ̀rúnlá 'okra seed' < ẹ̀rún 'particle' + ilá 'okra'
c. ẹyinná 'live coal' < ẹyin 'egg' + iná 'fire'
d. ẹnìtàn 'personal name' < ẹni 'person' + ìtàn 'story'
e. ọ̀túnba 'chieftaincy title' < ọ̀tún 'right side/right hand' + ọba 'king'

Since all examples of this type that we know of are polymorphemic (as indicated in (31)), they do not constitute violations of the general Yoruba harmony pattern we have established, that is, leftward spreading of [−ATR] from both low and mid vowels, blocked by [+high] vowels.

[22] Should Akinlabi's hypothesis be correct, then the nonapplication of ATR Spread in (30) could be the result either of assigning compounding to a lexical stratum distinct from the one on which ATR Spread applies (see Akinlabi and Oyebade (1987), Akinlabi (1986), Fọlarin (1987)) or by imposing a structural condition on the version of ATR Spread given in (38) such that compounds are excluded (see Kiparsky (1982), Selkirk (1982)).

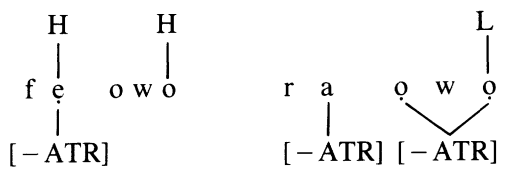
3. Autosegmental Representations: The Feature Hierarchy

In this section we contrast two possible autosegmental analyses of Yoruba harmony, the first a biplanar analysis and the second a hierarchical analysis. A *plane* is a set of linked tiers docking as a single set into a skeletal tier, following Archangeli (1985). In a *biplanar* representation at least two sets of features dock independently into the skeletal tier. We show that the distribution of stability effects that result automatically from hierarchical theory would require ad hoc stipulations in the biplanar approach.

3.1. Biplanar Representations

Within a biplanar approach, a feature or set of features that spreads as a unit is assigned to an independent plane (see also Hayes (1986)). For Yoruba ATR Spread, this would mean that the feature [ATR] would have to be assigned to a separate plane, linking directly to vowel positions of the skeleton. Phrases like *fẹ́ owó* 'want money' and *ra ọwọ̀* 'buy a broom' would therefore be represented as follows (where appropriate letters indicate skeletal positions, and tonal and [ATR] planes are indicated):[23]

(32)



Because of the assignment of [ATR] to a separate plane, [ATR] harmony can be formulated as a spreading rule (as in (9)), deriving the correct results when [ATR] harmony is considered in isolation. It turns out, however, that the biplanar approach makes exactly the wrong prediction about certain facts concerning other features, notably vowel deletion.

There is a well-known rule of Yoruba that deletes a vowel in a certain class of vowel-vowel sequences (see, for example, Courtenay (1968), Bamgboṣe (1965; 1966), Oyelaran (1971), Pulleyblank (in press; 1988)). In the most general type of case it is the first vowel in the sequence that deletes.[24] Examples such as the following illustrate this rule:

[23] We assume here a tonal representation where M-tones are underlyingly unspecified. For general motivation of such underspecified tonal representations, as well as for specific arguments in favor of applying such representations to Yoruba, see Pulleyblank (1986a) and Akinlabi (1984). The stage shown in (32) is the input to the postlexical component: redundant [−ATR] values are present (10); ATR Spread has applied; redundant [+ATR] and M-tone specifications have not been assigned.

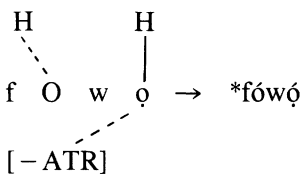
[24] See Pulleyblank (in press; 1988) for arguments that it is *always* the first V-slot that deletes. But note that the argument being made here is independent of whether or not it is possible in some cases for the second vowel in a relevant sequence to delete. The crucial point for the present discussion is simply the uncontroversial fact that the first vowel (at least sometimes) deletes.

(33) a. kọ́ ẹ̀kọ́ → kẹ́kọ̌ 'learn'
b. lo aṣọ → laṣọ 'use cloth'
c. ta epo → tepo 'sell oil'
d. jẹ ewé → jewé 'eat leaves'
e. gé olú → gólú 'cut mushrooms'
f. bu ata → bata 'pour ground pepper'
g. ra ọwọ̀ → rọwọ̀ 'buy a broom'
h. fẹ́ owó → fówó 'want money'

Two points are important to note about these cases of deletion: (i) a H-tone on the vowel to be deleted always survives even after deletion, as in (33a,e,h)[25] and (ii) the [ATR] specification of the vowel to be deleted never survives, instead deleting along with the vowel as in (33d).[26] This difference between the behavior of tone and [ATR] can only be derived by stipulation within a biplanar analysis.

Consider the case of *fẹ́ owó/fówó* 'want money', shown in (32), (33h). Deletion of the vowel of the verb *fẹ́* in such a case would free up both the verb's H-tone and the verb's [−ATR] specification. Given automatic application of the Association Conventions (Goldsmith (1976)), it would be expected that both free autosegments would relink, creating a representation such as the following:[27]

(34)



The tonal result of assuming such an analysis is correct, whereas the [ATR] effect of such a representation is incorrect. And the point appears to be a completely general one. Stability effects are observed with tonal phenomena in Yoruba but never appear in conjunction with the single feature [ATR]. The problem, then, is how to retain the tonal effect while eliminating the harmonic effect, without introducing ad hoc stipulations such as "Only tones relink freely." Note that the problem in such a case is directly attributable to the biplanar analysis. Assigning [ATR] to a separate plane endows it with a status *comparable to that of tone*—and yet comparable behavior is not observed.

[25] Independent of whether or not deletion takes place, the L-tone of a verb deletes in such a context. (Recall that M-tone vowels are unspecified for tone: see footnote 23.)

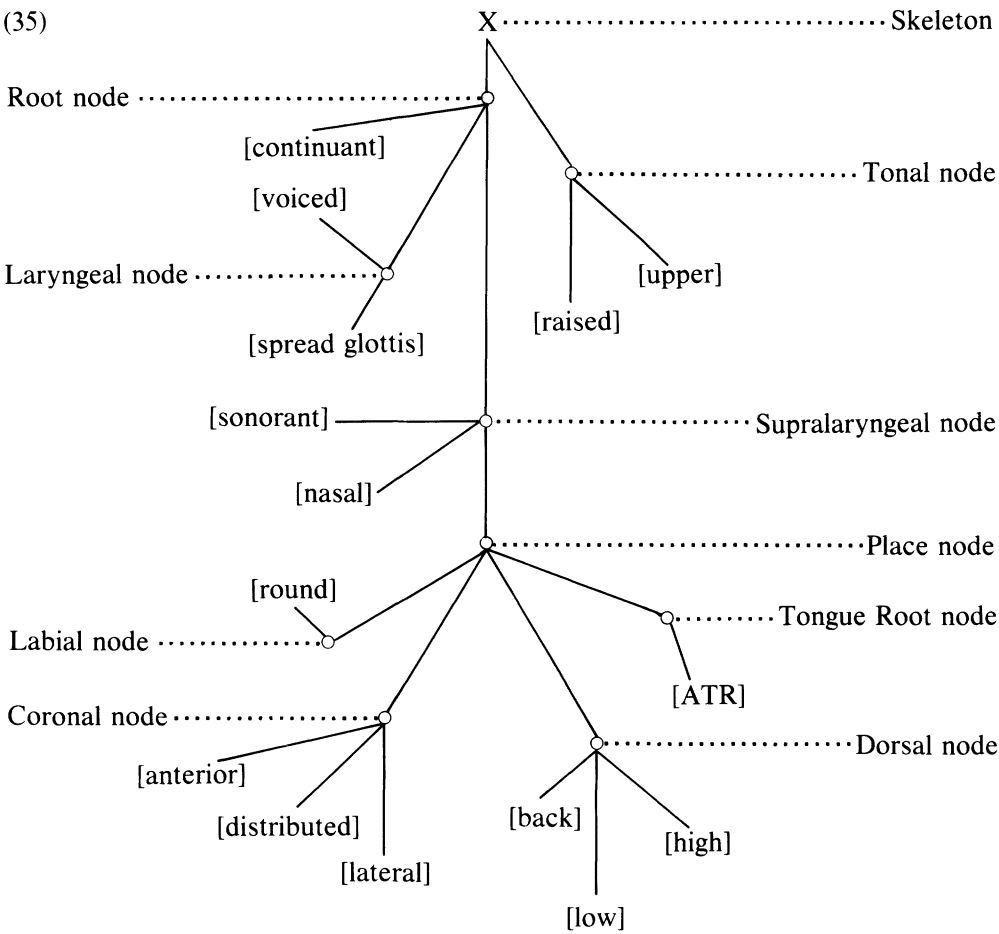
[26] In cases where the vowel quality of the first vowel survives instead of the vowel quality of the second vowel (for example, *ṣẹ́ owó → ṣẹ́wó* 'change money/engage in prostitution', *gbá ewé → gbáwé* 'sweep leaves'), it is always the *entire* first vowel melody that survives, not just a [−ATR] specification. Hence, a phrase like 'change money' could not be realized as **ṣọ́wó* or as **ṣọ́wọ́*.

[27] We have assumed in this figure that the [−ATR] autosegment links by right-to-left convention and that ATR Spread does not apply because the concatenation of verb and noun is postlexical. After deletion, however, if [−ATR] were to link and to spread, or were to link by left-to-right convention (in which case ATR Spread would again be inapplicable), then the results are equally incorrect: **fọ́wọ́, *fọ́wó,* respectively.

3.2. Hierarchical Representations

Within a hierarchical approach, the required difference is an automatic result of the different locations of tone features and [ATR] within the feature geometry. Consider (35), which shows one possible (and partial) instantiation of the segment-internal organization of features.[28]

(35)

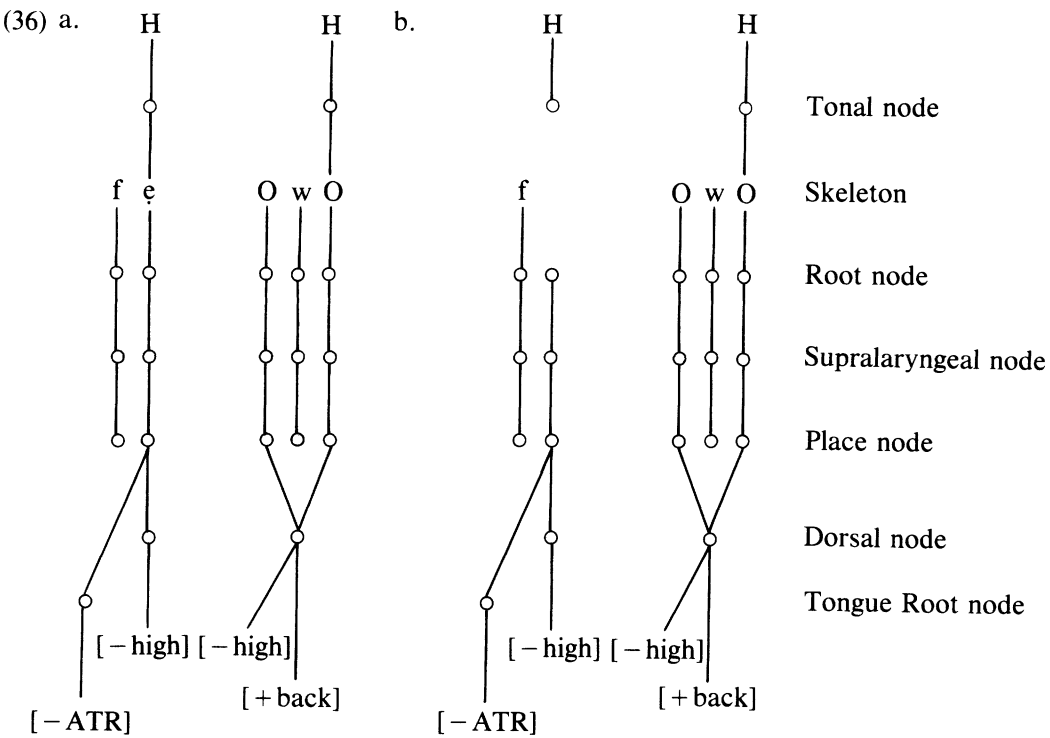


[28] There has been a great deal of research on the internal structure of segments since preliminary work by Mohanan (1983), developed in Clements (1985). In particular, in the representations assumed here, we incorporate Sagey's (1986) proposal that the Place node is divided into several "articulator" tiers—that is, tiers that dominate sets of features bearing some relation to phonetic articulators and are subordinate to the Place node. However, since we incorporate Steriade's (1987a) proposal for a "Velar" node, relabeling it the "Tongue Root node," the relation between phonological class and phonetic articulator is not necessarily a trivial one. In the following discussion we do not attempt to justify the general properties of the feature hierarchy; instead, we refer the interested reader to works such as Clements (1985), Schein and Steriade (1986), Archangeli and Pulleyblank (1987; in preparation), Sagey (1986), Steriade (1987a).

Three aspects of this hierarchy are crucial as far as our argument is concerned: (i) terminal and nonterminal nodes of the hierarchy constitute independent tiers that can be affected by rules (spreading, and so on), (ii) the Tonal node links directly into the skeletal tier,[29] and (iii) [ATR] is embedded under some class node that includes all features relevant in Yoruba for vowel specifications.[30] Given these three independently motivated aspects of hierarchical feature theory (see references cited in footnote 28), it is possible to derive the contrast observed between tone and [ATR] with respect to deletion.

Consider again the example shown in (34) within a hierarchical approach (where, for expositional ease, letters again stand for skeletal positions and the Tonal node has been shifted graphically to appear above the coordinating level of the skeleton). In (36) only vowel specifications are shown in detail. The vowel [ẹ] has both dorsal and tongue root specifications, whereas the two instances of [o] have only dorsal features. When the vowel slot of *fẹ́* in (36a) is deleted, the result is (36b).

(36)

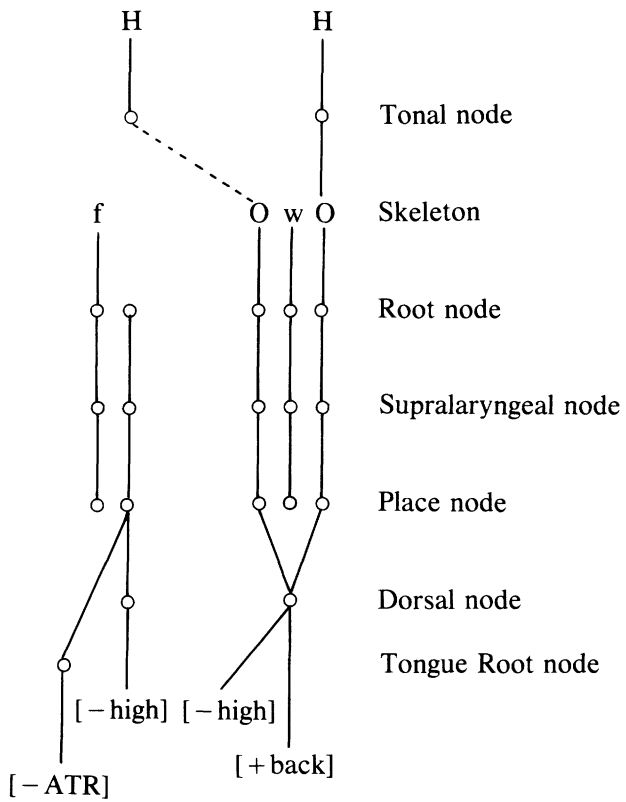


[29] Following Yip (1980) and Pulleyblank (1986a), we assume the tonal features of Yoruba to be [upper] (a feature that divides the pitch-range into two registers) and [raised] (a feature that divides each register into two subregisters). Our assumption that tonal features dock into the skeletal tier depends on a theory in which the CV- or X- skeleton represents the terminal level of prosodic structure (see, for example, McCarthy (1981; 1982), Levin (1985)). If the terminal level of prosodic structure is more correctly analyzed as a level of moraic structure (Hyman (1985), McCarthy and Prince (1986)), then that could constitute the level of structure into which tonal features dock. Nothing in our arguments here depends on the choice between these prosodic alternatives.

[30] The three crucial properties listed here are the only properties of the hierarchy about which we are

Two nodes are set afloat as a result of deletion: the Tonal node and the Root node of *ẹ́* in *fẹ́*. Since both Tonal nodes and Root nodes take the skeleton as their anchoring tier, both are eligible for automatic relinking by the Association Conventions if a *free* skeletal position is available. In the case of tone there is indeed a toneless vowel, and relinking takes place, as in (37); but in the case of the free Root node there is no available skeletal position that is not already associated to a Root node, and automatic relinking is blocked.

(37)



Hence, in a hierarchical approach the stability effect observed with tone and the absence of stability with [ATR] are derived from the position of the two features in the hierarchy. Unlike a biplanar approach, a hierarchical approach requires no ad hoc stipulations.

The approach to stability effects taken here is one where a feature's propensity for stability varies as a function of (i) the feature's position in the hierarchy and (ii) the node deleted by the relevant rule. Features other than tone could survive in a situation where some level other than the skeleton undergoes deletion. For example, Hualde (to appear)

making claims: locations of some features (in particular [continuant], [sonorant], and [nasal]) remain controversial, as pointed out to us by an *LI* reviewer.

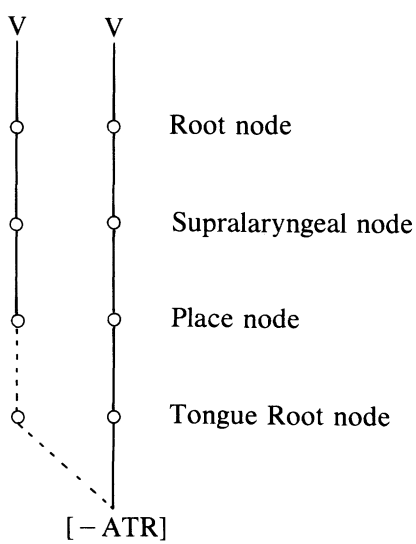
argues that the Laryngeal node exhibits stability effects in Basque when a rule deletes the Supralaryngeal node.

The central result of the feature hierarchy in this type of case is that no statement independent of the hierarchical representation is required to derive stability effects. The hierarchy does not need to be supplemented by assigning individual (structurally undifferentiated) features some property that will trigger or block relinking, whichever is appropriate. This hypothesis requires that the independence of a feature like tone be formally represented in the hierarchy, making impossible a position such as that taken in Sagey (1986) according to which tonal features are simply a subset of laryngeal features. As a result, our hypothesis governing stability is consistent with a hierarchy in which a combination of phonetic and phonological considerations determines the overall feature geometry.

3.3. ATR Spread

Before leaving this discussion of hierarchical representation, we make explicit the formal representation of ATR Spread that our adoption of the hierarchy entails. As seen in (9), harmony targets vowels, spreading the value [−ATR] from right to left. Within the feature hierarchy, this means that a triggering [−ATR] specification generates an appropriate node structure between it and the targeted Place node:[31]

(38) *ATR Spread* (hierarchical version)



Although at first glance this formulation looks somewhat more complex than the

[31] On the automatic generation of node structure, see Archangeli and Pulleyblank (in preparation) and Sagey (1986).

nonhierarchical formulation given in (9), it should be stressed that the *nonredundant* information specified in the two formalizations is basically the same. The essential characterization of ATR Spread requires (i) element affected = [−ATR], (ii) operation = spreading, (iii) direction = right to left. (See footnote 8.) Other aspects of the rule formulation are completely redundant. For example, since tier structure cannot be manipulated by rule, it does not actually need to be included in the formulation of ATR Spread. Also, since only nonhigh vowels are permitted to bear [−ATR] in Yoruba, only those vowels may serve as targets—neither consonants nor high vowels are eligible.

4. Underspecification

Investigators such as Halle (1959) and Kiparsky (1982) argue against the inclusion of redundant feature specifications in underlying representation. However, even if redundant features are excluded in a principled manner, various approaches are possible—for instance, (i) *universal markedness:* only marked specifications (in the sense of markedness theory; see Chomsky and Halle (1968), Kean (1975)) can occur underlyingly (for example, Pulleyblank (1986a), Grignon (1984)), (ii) *radical underspecification:* only one value (per specifiable context) may occur underlyingly, but this value may not always be the marked one (for example, Archangeli (1984; to appear a), Pulleyblank (1985, 1986b), Archangeli and Pulleyblank (in preparation)), (iii) *contrastive underspecification:* feature values are indicated underlyingly only if necessary to distinguish at least two segments in underlying representation, in which case contrasts are expressed in terms of a ± distinction (for example, Steriade (1987b), Clements (1987)). The Yoruba data provide evidence for radical underspecification: (i) only one value for [ATR] may be present underlyingly, and (ii) the value present must be [−ATR] (see Fresco (1970))—arguably not the marked value for [ATR]. In this section we review the evidence that requires this position.

4.1. For the Noncontrastive Underspecification of [ATR]

We first argue that [ATR] must not be specified in underlying representation on the vowels for which it is not contrastive—that is, neither on high vowels nor on low vowels.

4.1.1. Against Underlying [+ATR] on High Vowels. The first argument that there must be no specification of [ATR] on high vowels when ATR Spread applies has the following form. Since the vowel [i] has no feature specifications at all at the beginning of the postlexical component and ATR Spread (38) is a lexical rule, [i] has no [ATR] value when ATR Spread applies. The choice, then, is to underspecify [i] with respect to [ATR] or to posit an underlying [+ATR] specification on [i] that is deleted prior to the end of the lexical component. Since we have found no evidence for the presence of [+ATR] on the high vowels, and on [i] in particular, we take the former approach that /i/ has no [+ATR] specification in underlying representation.

Consider the evidence that ATR Spread is a lexical rule. First, as shown in section

2.4, ATR Spread must distinguish between prefixation and compounding, a lexical distinction. Second, as shown in section 2.1.2, there are lexical exceptions to the harmony rule. Third, harmony does not apply across word boundaries or clitic boundaries (see Bamgboṣe (1967)), as illustrated in (39) and (40).[32]

(39) Word boundaries

a.	owó Adé	*owọ́ Adé	'Ade's money'
b.	owó ẹmu	*owọ́ ẹmu	'wine money'
c.	àwọ̀ ejò	*àwò ejò	'color of a snake'
d.	ilé Ayọ̀	*ilẹ́ Ayọ̀	'Ayọ's house'

(40) Clitic boundaries

a.	mo lọ	'I went'	mo jó	'I danced'
b.	o fẹ́	'you (sg) want'	o dé	'you (sg) arrived'
c.	ó wá	'he came'	ó kú	'he died'

Finally, ATR Spread cannot create a [+high, −ATR] segment, a lexical constraint in Standard Yoruba.[33]

Evidence that the high vowel [i] has no place specifications at the beginning of the postlexical derivation is found in Pulleyblank (1988), where it is argued (i) that [i] is the only vowel that does not trigger a postlexical rule of regressive assimilation, (ii) that [i] is the only vowel that does not trigger a postlexical rule of denasalization, and (iii) that [i] is the only vowel to interact with a nasal in the postlexical formation of a syllabic nasal. If the underspecified approach to these asymmetries is correct, then the vowel [i] must not be specified for [ATR] postlexically, when these rules take place. From this, we conclude that [i] also has no feature specifications lexically, and in particular has no [ATR] specification.

The two-domain pattern provides a second argument against the underlying specification of [ATR] on high vowels. Recall that if the initial domain of a two-domain form is nonlow, it cannot be [−ATR]. If the high vowel intervening between the two domains

[32] For evidence in favor of analyzing subject pronouns as clitics, see Bamgboṣe (1966) and Pulleyblank (1986c).

[33] Although we have not looked at dialects other than Standard Yoruba in any detail, Bamgboṣe (1967) and Fresco (1970) present evidence from certain dialects with surface nine-vowel systems [i, ị, e, ẹ, a, ọ, o, ụ, u] that appears to provide support of a very interesting type for several basic tenets of the analysis proposed here. The essential difference between Standard Yoruba and such dialects seems to be that in the latter, harmony applies both lexically and postlexically. For example, in Ijeṣa and Ekiti, by not subjecting postlexical derivations to the constraint that high vowels cannot bear [−ATR] specifications, it becomes possible postlexically to derive [ị] and [ụ], as in *ịyọ̀* 'salt' and *ụgbá* 'calabash'. That such vowels are derived postlexically is supported by both distributional facts and overt alternations. In terms of distribution, VCV nouns with two high vowels surface systematically with [+ATR] values. This is accounted for if lexical specifications of [−ATR] cannot link to high vowels. Postlexical alternations include subject clitics and other phrasal sequences. For example, in Ọyọ and Ẹgbado the subject clitics corresponding to those in (40) are the following: *mọ lọ* 'I went'/*mo jó* 'I danced', *ọ fẹ́* 'you (sg) want'/*o dé* 'you (sg) arrived', *ọ́ wá* 'he came'/*ó kú* 'he died'. And in Ijeṣa and Ekiti the final high vowel of a word like *àfi* 'except' is determined by the following word: *àfí owó* 'except money'/*àfị́ ọmọ* 'except children'. Bamgboṣe and Fresco explicitly note that the harmonic values of high vowels are determined by right-to-left application of harmony and that a [−ATR] clitic may be invariant—both facts that the analysis of [ATR] harmony presented here would lead us to expect.

were specified underlyingly as [+ATR], then this distributional fact might be thought to follow from a condition requiring that any free [−ATR] value be located on the rightmost periphery. As such, the [+ATR] specification of the high vowel would prevent [−ATR] from being assigned to a vowel to the left of the high vowel via the prohibition against crossed lines.

But the stipulation that [−ATR] is located at the rightmost periphery is clearly incorrect, given forms such as *ọtí* 'wine', *ẹnu* 'mouth', *ẹ̀gúsí* 'a food made from seeds of melon', *ẹ̀bùrú* 'shortcut'. These and similar forms show that an analysis allowing underlying [+ATR] specifications on high vowels would require the possibility of [−ATR] specifications both preceding [+ATR] specifications (as in *ọtí* 'wine') and following them (as in *ilẹ̀* 'ground'), although the occurrence of [−ATR] preceding [+ATR] would have to be limited to forms in which no mid vowel follows the prelinked high vowel (else the unattested **ẹ̀lùbó* pattern would be an accidental gap).

Proposing that high vowels are underlyingly linked to a [+ATR] value would predict four possible configurations of high vowels with the floating [−ATR] on disyllabic words, as shown in (41).

(41) a. [+ATR] [−ATR]
V C V

b. [+ATR] [−ATR]
V C V

c. [−ATR] [+ATR]
V C V

d. [−ATR] [+ATR]
V C V

Of the four possible configurations, only the types in (41a) and (41c) are attested (cases like *itọ́* 'saliva' and *ọtí* 'wine', respectively). An additional stipulation would be required to exclude the other two types. Evidence for (41b) could be found (although it is not) with verb–object clitic sequences and in compounds (if the second member had no underlying [ATR] specification). And evidence for (41d) could be found (although it is not) with prefixes and in compounds.[34]

It should be noted that the problems raised in (41) are very much an artifact of combining morphemic specifications of a feature (the [−ATR] values) with redundant segment-determined specifications (the [+ATR] values). As a direct consequence of prelinking redundant values, one would be forced to arbitrarily order morphemic specifications with respect to segmental specifications. The type of trapping (Prince (1987))

[34] In the account here, both *ọtí* 'wine' and *itọ́* 'saliva' are represented with a floating [−ATR] underlyingly, as in (i).

(i) [−ATR]
V C V

In *itọ́* the [−ATR] specification links by right-to-left convention to the final vowel, and the initial high vowel receives [+ATR] by redundancy rule; in *ọtí* the [−ATR] specification cannot link to the final high vowel and therefore links by right-to-left convention to the initial mid vowel; the high vowel again receives its [+ATR] specification redundantly.

that the prespecified values create does not arise as a problem within the radically underspecified approach adopted here.

4.1.2. Against Underlying [−ATR] on Low Vowels. The argument against specifying [ATR] on low vowels comes from a consideration of the distribution of low vowels in words with the two-domain pattern. To solidify the argument for the underspecified analysis, consider the effect of specifying low vowels in Yoruba underlyingly for their redundant, noncontrastive [−ATR] value.

Because of words in which a low vowel is followed by a [−ATR] mid vowel (such as *àjẹ̀* 'paddle', *aṣọ* 'cloth'), if [+low] vowels are underlyingly specified as [−ATR], then a free [−ATR] specification must be allowed to cooccur with the specification linked to the low vowel (recall that forms like *àjẹ̀* and *aṣọ* cannot be explained by a left-to-right harmony rule because of forms like *ate* 'hat' and *àwo* 'plate').

(42) In addition to any linked [−ATR] specification, underlying representations may contain a *free* specification of [−ATR].[35]

However, this stipulation is insufficient, given the two-domain pattern: it predicts the existence of the unattested monomorphemic pattern [−ATR, −low] . . . [+high] . . . [−ATR, +low], a pattern like **yọruba*. The stipulation, then, would have to be the following:

(43) Underlying representations may contain at most one *free* specification of [−ATR], which occurs *to the right* of a linked [−ATR] specification (on a low vowel), if any.

Such a stipulation would be unproblematic if it could be derived from independently motivated principles. This is clearly impossible, however. First, although simplicity might be invoked to rule out the nonoccurring floating-linked sequence in disyllabic morphemes like *ẹ̀pà* 'groundnut' (because harmony could provide the [−ATR] specification that surfaces on the mid vowel), the constraint would still be required in trisyllabic morphemes with a medial opaque high vowel. Second, no general condition on sequences of like specifications could be invoked to explain (43): while a floating [−ATR] . . . linked [−ATR] sequence would have to be ruled out, its mirror image, linked [−ATR] . . . floating [−ATR], would be required for a case like *àjẹ̀*. Compare this with the approach taken here where sequences of [−ATR] are invariably ruled out (see (20)), a restriction derivable from the OCP.

In addition, the type of prelinked [−ATR] value underlyingly assigned to a low vowel in a form like *ẹ̀pà* would be required to spread. But if underlyingly linked specifications are allowed to spread in general, then an unprincipled nonphonological diacritic must be added to the nonnativized loans discussed in section 2.1.2 to explain why such words are disharmonic (see Kiparsky (1982)).

[35] Actually, this approach would require a limitation to at most one free specification to prevent the unattested [−low, −ATR] . . . [+high] . . . [−low, −ATR] two-domain violation.

Given that constraints like (43) are ad hoc and undesirable, and that the accounts offered in section 2.1.2 of the disharmonic forms and in section 2.2.2 of harmony involving low vowels are principled, the underlying specification of [−ATR] on low vowels is to be rejected.

To summarize, we have offered several arguments that vowels whose specifications for [ATR] are redundantly assigned—namely, high and low vowels—must not bear such values underlyingly. Hence, on the assumption that features are underspecified in a principled manner, the results here argue that *noncontrastive values in general are unspecified in underlying representation.* But although this rules out any hypothesis whereby [ATR] is assigned to *all* vowels in underlying representation, it would still allow an approach where only mid vowels were specified underlyingly for [ATR]—the vowel height for which there is a surface [ATR] contrast—or where the [ATR] contrast in morphemes with mid vowels results from every such morpheme selecting the appropriate value of [±ATR] as a floating specification. In the next section we present two arguments against these possibilities.

4.2. Against Specification of Contrastive Features Only

If [+ATR] and [−ATR] must be present on mid vowels, where they are contrastive, then in order to be well-formed a (native) morpheme containing any mid vowels would include a (floating) specification for either [−ATR] or [+ATR].[36] Apart from this difference, major aspects of the present analysis would continue to hold. For example, it would still be crucial that no [+ATR] specification spread from a high vowel and that the [−ATR] specification of a low vowel spread onto a preceding mid vowel.[37]

A curious problem arises again with the two-domain pattern. As already established, the first domain in such a pattern, if nonlow, cannot bear [−ATR]. The important point to note in the present context is that such *mid* vowels must be underspecified, a result that follows automatically from the radically underspecified analysis argued for here. But this pattern can only result from stipulation in an account where morphemes with mid vowels are assigned either a [+ATR] or a [−ATR] specification underlyingly: the theory of contrastive specification insists that both values of [ATR] are present for mid vowels in underlying representation, yet because of the two-domain pattern, a rule inserting [+ATR] on mid vowels is also required. But once such a rule is admitted in the grammar, the presence of [+ATR] in underlying representation becomes redundant: as

[36] Versions of contrastive underspecification are presented in works such as Steriade (1987b) and Clements (1987). Our discussion here can be generalized beyond the specific instantiations of contrastive underspecification given there, however. (For a discussion of problems in defining the notion of "contrastive" in a principled fashion, see Archangeli (to appear a)).

[37] Note that in an approach positing "+" and "−" specifications for mid vowels, such spreading from a low vowel would have to be feature-changing to eliminate the possibility of a mid vowel being assigned [+ATR] by a morphemic specification, thereby bleeding spread of [−ATR] from the low vowel. This would, however, introduce a conceptually undesirable redundancy: because the rule is feature-changing, there would never be the need for a [+ATR] specification in a case where a mid vowel precedes a low vowel; because there would be no such need, the rule's feature-changing capacity would never be used.

seen already, the distribution of [ATR] is predicted straightforwardly from [−ATR] specifications alone and considerations of simplicity would select the analysis without [+ATR] specifications.[38]

Clements (1987) has proposed a version of contrastive underspecification for which the above would not constitute a problem, a version of the theory that we will refer to as *prosodic-contrastive underspecification*. The essential suggestion bearing on the discussion here is that when a particular (contrastive) feature functions prosodically, it is not necessary for both values of the feature to be represented—where features that function "prosodically" are features that "commute over a domain larger than the segment, such as the morpheme or word" (Clements (1987, 11)). The morphemic feature [ATR] in Yoruba clearly constitutes just such a prosodic feature and thus can be given the representation argued for here even within a theory that would otherwise assign both + and − values to contrastive features.

Prosodic-contrastive underspecification and radical underspecification resemble each other in significant respects and would provide comparable analyses for a wide range of cases. Let us consider, however, one of the differences between the two approaches.

Much of the discussion in the work on contrastive underspecification focuses on what we might call the *binary reference* problem (see, for example, Steriade (1987b), Clements (1987)). Assuming that some set of rules or conditions refers to both + and − values of some contrastive feature [F], the issue is how to represent this fact within a theory of underspecification. According to contrastive underspecification theory, both values would be present by virtue of the feature's being contrastive. Even if feature [F] were prosodic, hence not normally having both values included, prosodic-contrastive theory provides for the inclusion of both values of a prosodic feature as a marked option. Hence, binary reference is no problem for a contrastive approach.

Consider, however, the effect of imposing a condition that would force the exclusion of one value of a contrastive feature both underlyingly and throughout the derivation—for example, a condition that both (i) prevented the inclusion of redundant information underlyingly and (ii) prevented the insertion of such information during the course of the derivation. Under such a theory, which we might dub *absolute underspecification*, binary reference constitutes a problem serious enough to force the theory's rejection.

But consider binary reference within radical underspecification. As with absolute underspecification, redundant information is excluded from underlying representation. Crucially different from absolute underspecification, however, radical underspecification provides for the insertion of some redundant information even very early in the

[38] This argument is comparable to others given in favor of underspecification, for example Steriade's (1979) analysis of Khalkha Mongolian. Note as well that we are not arguing that a grammar is automatically simplified by (i) the inclusion of a context-free rule inserting [αF], in conjunction with (ii) the corresponding exclusion of [αF] specifications from underlying representations (see, for example, Clements (1987)). But if the rule inserting [αF] (or in this case, [+ATR]) is independently required, then a simpler grammar does result from lexical exclusion of that feature value.

derivation.[39] Within such a theory, cases of binary reference would simply force the application of the appropriate redundancy rules, and no problem of principle would result.

To summarize, the approaches taken to binary reference involving a contrastive feature are as follows:

(44) *Inclusion of both values of a binary feature used contrastively*

Absolute underspecification:	both values *never* included
Radical underspecification:	both values included *if referred to*
Prosodic-contrastive:	both values included *if referred to* or *if the feature does not function prosodically*
Contrastive:	both values *always included*

We present here two arguments in favor of a radical underspecification approach. Consider first the role of *prosodic functioning* within a contrastive theory. It has been well documented within the phonological literature that autosegmental rules may operate within a representation exhibiting a contrast between the presence and absence of a single feature. Since such single-valued use of features is often employed to distinguish between segments or morphemes, contrastive theory must find some way of excluding them from its general requirement that both values of a contrastive feature be present underlyingly—hence the clause that prosodically functioning features can be underlyingly one-valued. The problem is that it seems extremely difficult, perhaps even impossible, to define "prosodic functioning" in a way that characterizes specifically the desired range of cases. Clements (1987) notes explicitly that even cases of assimilatory spreading must be allowed to constitute prosodic functioning. Hence, in a language with homorganic place assimilation, for example, one must presume that the set of place features is prosodic; and in a language with a process like voicing assimilation, spirantization, or nasalization, features like [voiced], [continuant], and [nasal], respectively, would be prosodic. This would mean that a massive number of features must be considered single-valued—resulting in a theory extremely close to radical underspecification. One must ask, however, whether the notion of being *prosodic* is really playing any useful role. The central point seems to be that many features operate in a single-valued way but that for other features binary reference requires specification of both feature values. These are both notions available without invoking some notion of prosodic functioning. Moreover, if for some cases assimilatory spreading and so on is not to be considered sufficient to define a feature as prosodic, then there is a need for some additional (and as yet undefined) concept to make the desired distinction between one- and two-valued underlying specifications.

[39] In accounts such as the one presented here (section 5), as well as in, for example, Archangeli (1984), Pulleyblank (1986a,b), and Archangeli and Pulleyblank (in preparation), this is accomplished via the Redundancy Rule Ordering Constraint.

Apart from such difficulties in defining the appropriate class of prosodic features, a prosodic-contrastive theory does make one prediction that is clearly different from that of radical underspecification—a prediction that appears to be false when one considers evidence from Yoruba. Within contrastive theory, both values of a contrastive nonprosodic feature are present underlyingly—even if not specifically referred to in a language's rule inventory. A radical underspecification approach to the comparable situation, on the other hand, would posit only one underlying value for the feature. Consider in this light features like [high] and [low] in Yoruba, features required to contrast vowels like [i,u] ([+high, −low]), [e,ẹ,o,ọ] ([−high, −low]), and [a] ([−high, +low]). There appears to be no particular evidence for viewing such features as prosodically functioning; hence, in a contrastive theory, both + and − values of [high] and [low] would be included underlyingly.[40] But Pulleyblank (1988) has demonstrated that a wide range of asymmetric vowel behavior in Yoruba can be explained only by not specifying both + and − values for the features [high] and [low] (among others) underlyingly. But if this is the case, then prosodic functioning is superfluous for the establishment of [ATR] as single-valued in Yoruba. That is, viewed as one aspect of the total phonological system, the single-valued behavior of [ATR] cannot be attributed to the feature's *prosodic* nature: nonprosodic features exhibit the same property.

4.3. For Radical Underspecification: Specification of [−ATR] Only

To conclude the arguments in favor of underspecification, we review the evidence that the specified value must be the cross-linguistically unmarked [−ATR] in Yoruba, not the marked [+ATR], thus providing an argument for language-specific underspecification and against underspecification based exclusively on markedness.

On the basis of analyses of [ATR] harmony in languages like Maasai (Levergood (1984)), Kpokolo (Kaye, Lowenstamm, and Vergnaud (1985)), Akan (Pulleyblank (1985)), Okpẹ (Pulleyblank (1986b)), Kinande (Schlindwein (1987)), and Vata (Kaye (1982), Kiparsky (1985)), it appears to be the case that [−ATR] is the unmarked specification for [ATR], inserted by default rule, with [+ATR] specified underlyingly. But we argue here that distributional properties prevent such an analysis of [ATR] in Yoruba. Rather, it is necessary to analyze the harmony system of Yoruba as a marked one, with [−ATR] being specified underlyingly.[41] To demonstrate this point, in this last section we consider the effect of assuming [+ATR] to be the lexically specified value of [ATR]

[40] Pulleyblank (1988) discusses two rules of Yoruba that do affect [high] and [low], one a rule spreading the Place node, the second a rule spreading the Root node. Note, however, that if these rules are considered to derive prosodic status for the features dominated by the relevant class nodes, then in a language with Root node spreading, *all* features would be prosodic—deriving an approach essentially comparable to radical underspecification for any such language.

[41] [−ATR] as the active value has occasionally been proposed—for example, for Pasiego (McCarthy (1984), Vago (to appear)) and Andalusian (Zubizarreta (1979)).

for Yoruba. Under such an approach, the rule of harmony would spread [+ATR], and unspecified vowels would be assigned [−ATR] by default.[42]

4.3.1. Directional Asymmetry with Low Vowels. If [+ATR] is the value present in underlying representation, the explanation of the directional asymmetry with low vowels is lost (that is, [a . . . e], [a . . . o] but *[e . . . a], *[o . . . a]). If [+ATR] links only to nonlow vowels, then it ought to be able to link to mid vowels that either precede or follow a low vowel; but this would produce incorrect results.

Two types of accounts for this low vowel asymmetry might be envisioned. The first would be to assume that low vowels are eligible targets for [ATR] harmony and that a [+low, +ATR] vowel is automatically raised either to [e] (as occurs in a language like Okpẹ; see Hoffmann (1973), Pulleyblank (1986b)) or to [o] (as, for example, in Maasai; see Levergood (1984)). Under this account, underlying sequences like /e . . . a/ or /o . . . a/ would be allowed but would surface as [e . . . e] and [o . . . e] (adopting arbitrarily the Okpẹ-style raising). Such an account is untenable, however, since the required presence of right-to-left spreading (for prefixes) would erroneously rule out the vowel [a] before a [+ATR] vowel as well as after one. That is, words like *ate* 'hat', *àwo* 'plate', and *agétí* 'crop-eared man' (*a* 'agentive prefix' + *gé* 'cut' + *etí* 'ear') would be just as impossible as the unattested words involving the sequences *[e . . . a] and *[o . . . a].[43]

The second solution to this problem concerning low vowels would be to adopt two harmony rules. The first would be a bidirectional rule spreading [+ATR] from mid vowels to mid vowels: right-to-left spread is required for prefixes and left-to-right spread is required morpheme-internally (since if the low vowel trigger is not included, there is no motivation for the right-to-left association of [ATR]). The second would be a right-to-left rule spreading [−ATR] from low vowels to mid vowels, both morpheme-internally and onto prefixes. This analysis is clearly less desirable than the present one since in addition to including a rule essentially identical to ATR Spread (38), it requires a rule of bidirectional spread not required in the analysis positing an underlying [−ATR]. More-

[42] In arguing for language-specific underspecification, we adopt Archangeli's (1984) terminology in referring to redundancy rules determined by markedness theory as *default* rules and redundancy rules determined by language-specific underspecification as *complement* rules. Hence, in the approach that we propose, unless positive evidence to the contrary is encountered, a speaker will assume that "marked" feature values are represented underlyingly, "unmarked" values being assigned via default rule. The two types of rules, default and complement, are proposed to function identically in a grammar and hence are classed together as *redundancy rules*. The terminological distinction is intended to highlight the hypothesis that structurally redundant values may be determined on a language-particular basis: default rules are universal rules, whereas a complement rule is constructed if language-particular evidence requires its existence. For more details, see Archangeli (1984).

[43] One might attempt to block harmony in cases like *ate* and *àwo* by prelinking the [+ATR] specification and then assuming that the Strict Cycle Condition (Mascaró (1978), Kiparsky (1982), Levergood (1984)) would prevent spreading in such a case. Apart from the fact that prelinking in such cases indicates a distributional exceptionality for which evidence is not readily apparent, the Strict Cycle approach would not be able to account for the absence of harmony in polymorphemic cases like *agétí*.

over, either [−ATR] spread must be allowed to change features, overriding a [+ATR] specification, or the stipulation against mid vowel–low vowel words with a floating [+ATR] specification is still necessary in the grammar, to rule out the impermissible sequences *[e . . . a] and *[o . . . a]. Finally, the analysis raises potential problems concerning ternary power since it crucially involves both a rule spreading [+ATR] and a rule spreading [−ATR].[44]

4.3.2. Prefixes before High Vowels. Apart from such problems concerning low vowels, the hypothesis that harmony in Yoruba uses the feature [+ATR] runs into problems concerning high vowels. As illustrated in (4), [i] does not induce [ATR] harmony with tautomorphemic mid vowels. For example, just as *ilé* 'house' and *ebi* 'hunger' (examples with [+ATR] mid vowels) are acceptable, so are *ilẹ̀* 'land' and *ẹ̀bi* 'guilt' (with [−ATR] mid vowels). Hence, the [+ATR] values of high vowels could not be present at the point where a [+ATR] version of harmony takes place.[45] But this conclusion contradicts the evidence in (26) showing that prefixes are [+ATR] before a high vowel. Recall that the pattern in (26) is explained straightforwardly in our analysis, where [−ATR] is the lexically specified value, by assuming that (i) the prefix has no underlying [−ATR] specification and (ii) the high vowel has no [−ATR] value to trigger ATR Spread (38); consequently, both vowels receive a redundant [+ATR] specification.

Such a proposal could not be adopted if [−ATR] were the *redundant* specification (as we are exploring in this section) because an incorrect [−ATR] . . . [high V] pattern would result.[46] Hence, for such polymorphemic cases it would be necessary for [+ATR] to be assigned to high vowels before the application of harmony, in contradiction to the monomorphemic cases. Consequently, in addition to requiring two rules of [ATR] harmony, one for low vowels and one for nonlow vowels, the account positing underlying [+ATR] requires yet another distinction for high vowels, assigning [+ATR] before harmony in polymorphemic cases but after harmony morpheme-internally.

4.3.3. The Two-Domain Pattern. A third problem with assuming [+ATR] to be the underlyingly specified value concerns morphemes with two harmonic domains separated by an opaque high vowel. In cases with two domains four patterns are theoretically possible if the initial vowel is mid.

(45)	Domain 1	Domain 2	
a.	−ATR	+ATR	unattested
b.	−ATR	−ATR	unattested
c.	+ATR	−ATR	attested
d.	+ATR	+ATR	attested

If [−ATR] is the specified value, then (45a) is blocked by the right-to-left application

[44] The issue of ternary power is addressed in Lightner (1963), Stanley (1967), Rińgen (1975), Kiparsky (1982), Dresher (1985), Pulleyblank (1986a), Archangeli (to appear a).

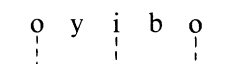
[45] Note that a Strict Cycle style of explanation for the lack of spreading would not be available if the [+ATR] value of high vowels is assigned by rule, thereby constituting a derived environment.

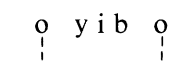
[46] There are some cases where a prefix surfaces as [−ATR] before a high vowel stem (for example, *ẹrù*

of the Association Conventions and (45b) is blocked by the opacity of the high vowel intervening between the two harmonic domains. Pattern (45c) (represented by such words as *èlùbọ́*) has been discussed in section 2.2. The pattern in (45d), exemplified in (46), is unremarkable in our approach, derived by the redundant assignment of [+ATR] to all mid vowels.

(46) a. òyìbó 'any European'
b. orúpò 'mud-bench serving as bed'
c. Òyìngbò 'place in Lagos'
d. èsúró 'Redflanked Duiker'
e. erìko 'midrib of *igi ọ̀gọ̀rọ̀* stripped of its leaves'

The analysis of these cases is not so straightforward if [+ATR] is the underlyingly specified value, however. Since [+ATR] does not spread from a high vowel (recall *ilẹ* 'land' and *ẹ̀bi* 'guilt'), the [+ATR] specification on the final vowels of the examples in (46) cannot derive via spreading from the high vowel. The [+ATR] specification cannot derive via spreading from the initial mid vowel either since apart from problems concerning locality (see Archangeli and Pulleyblank (1987; in preparation)), such an analysis would rule out the possibility of words like *èlùbọ́* 'yam flour' (see (45) and (19)). Hence, the only source for such words would be an underlying representation with multiple floating [+ATR] specifications. Depending on whether floating [+ATR] specifications were allowed to link by convention to high vowels, either three specifications (47a) or two (47b) would be necessary.

(47) a.


b.


([+A] = [+ATR])

Both (47a) and (47b) involve blatant violations of the OCP since underlying representations require underlying sequences of unassociated identical autosegments. Such violations could not even be tempered by prelinking the specifications since prelinking would allow deriving the unattested pattern [−ATR] . . . [+high] . . . [+ATR] (45) by prelinking a final mid vowel to [+ATR].

Permitting the representations in (47) would also introduce indeterminacy into the representation of mid vowel sequences. Words like *epo* 'oil' and *owó* 'money' could be represented either with a single [+ATR] specification that would link and spread or with two [+ATR] specifications that would simply link up. Although conditions of simplicity might be invoked to choose the former analysis over the latter, the analysis introduces the potential for a type of underlying distinction that to the best of our knowledge has no surface reflex.

'load'; *rù* 'to carry a load'). One approach to such cases where [−ATR] is the lexically specified value is to have a floating [−ATR] value included with the stem. See footnote 18. In an approach positing [+ATR] as the lexically specified value, such cases can only be derived by marking the derived forms as exceptions to harmony.

Yet another problem for the approach with lexical [+ATR] specifications arises in accounting for the absence of the pattern in (45) where both harmonic domains are [−ATR]. Accounting for the absence of such forms would require the curious statement to the effect that words of three or more syllables *must* have a [+ATR] specification if they contain a mid vowel followed by a high vowel.

To conclude, in spite of the fact that cross-linguistic evidence appears to support [−ATR] as the default value for [ATR], the distributional facts of [ATR] in Yoruba require that [−ATR] be the *non*redundant value, [+ATR] being assigned by a complement rule. To the extent that the case for any of the languages cited above requiring [−ATR] as the redundant value is strong, the facts from Yoruba come down correspondingly strongly in favor of the proposal in Archangeli (1984) that the theory of underspecification must include the notion of complement rule, with language-specific underspecified entries not solely dependent on considerations of phonological markedness.

5. Conclusion

An optimal analysis of a phonological process ought to make the absolute minimum number of language-specific stipulations. We would argue that the analysis of Yoruba harmony presented here largely achieves this objective. The properties that must be stipulated in the grammar of Yoruba in our account are the following:

(48) a. Morphemes may or may not include the specification [−ATR].
b. [−ATR] associates from right to left.
c. [−ATR] values are spread from right to left by rule.
d. A [−ATR] specification associates only to a nonhigh vowel.

The morphemic nature of [ATR] in Yoruba (48a) is clearly a language-specific fact, since it is not always the case cross-linguistically that [ATR] values for all vowels of a morpheme can be predicted from a single [ATR] specification. The right-to-left association of [ATR] (48b) reflects the (marked) setting of a binary parameter provided by Universal Grammar. The spreading of [ATR] (48c) constitutes the actual expression of harmony in Yoruba (again, a clearly language-specific fact), and in this regard it is noteworthy that the rule required in the proposed account stipulates nothing more than that [ATR] spreads directionally from right to left. Finally, the requirement that [−ATR] associates only to nonhigh vowels (48d) is a condition on the Yoruba vowel inventory that is needed independently of the effects of harmony.

To ensure the adequacy of the minimally stipulative account just summarized, it is necessary that the architecture of phonological theory have certain properties. With respect to phonological features, it is necessary that all feature redundancy be excluded underlyingly, both noncontrastive feature values and redundantly assigned contrastive feature values. Moreover, the specified values determined for structural underspecification are not necessarily those determined by cross-linguistic markedness theory. And

as a point concerning feature structure, it is necessary that features such as tone and [ATR] be structurally distinguished along the lines suggested by recent work in hierarchical feature organization.

We assume further that general conditions govern relevant aspects of the rules and representations that we propose. For example, the OCP prohibits the inclusion of more than one [−ATR] autosegment in a single morpheme's underlying representation, and the division of the phonology into lexical and postlexical components governs the assignment of phonological conditions to domains.

To conclude, we consider certain details of the behavior of the rules assigning redundant [ATR] values that seem to suggest that additional conditions of a very general nature are in force. Recall that the distribution of [−ATR] in morphemes including low vowels requires that [−ATR] specifications not be underlyingly present on low vowels. After the application of the Association Conventions, but prior to the application of ATR Spread (since low vowels trigger harmony), low vowels are assigned [ATR] specifications. The redundant [−ATR] assigned to low vowels and the redundant [+ATR] assigned to high vowels are therefore of a very different nature, the former playing an active role in harmony, the latter behaving in a completely inert fashion throughout the phonology. At issue is whether this difference needs to be stipulated as a language-specific fact of Yoruba.

Several proposals bear on this issue. First, Halle and Mohanan (1985) have proposed that all rules apply in the last component unless there is evidence to the contrary. This principle has the effect of ordering all rules—phonological rules and redundancy rules—as late as possible. Consequently, the rule inserting [−ATR] on low vowels (10) as well as the context-free rule inserting [+ATR] (12) are ordered as late as possible.

Second, if redundancy rules cannot be extrinsically ordered (Pulleyblank (1986a)), then (unlike language-specific phonological rules) they cannot occur earlier unless such ordering is itself principle-driven. We have proposed elsewhere the Redundancy Rule Ordering Constraint as a mechanism for accomplishing just such earlier ordering (Archangeli (1984), Pulleyblank (1986a,b; 1988), Archangeli and Pulleyblank (in preparation)). This principle places a redundancy rule in any component that makes reference to the feature specification inserted by that redundancy rule. With respect to the rule assigning [−ATR] to low vowels, this rule must apply in the same component as the rule of ATR Spread since ATR Spread refers to [−ATR], the value inserted by the rule. The rule inserting [+ATR], on the other hand, can apply late since no rule refers to that value.[47]

Finally, if redundancy rules are classed as universal rules, like the Association Conventions and rules of core syllabification, then they should apply whenever their

[47] Note that if [+ATR] specifications are not present underlyingly, and are assigned (if at all) at a very late stage of the derivation, then they cannot be responsible for the blocking that occurs in cases like *èlùbọ́* 'yam flour' illustrating the two-domain pattern. That is, if the Late Ordering Principle is correct, then opacity of the type observed in Yoruba must be the result of a condition like the Cooccurrence Constraint (as argued here), not the result of a Crossing Condition violation. For discussion, see Archangeli and Pulleyblank (in preparation).

environment is met. (See, for example, Goldsmith (1976) on this property for the Association Conventions and Clements and Keyser (1983) for core syllabification.) Given this Continuous Application Principle, the rule assigning [−ATR] to [+low] vowels applies whenever there is a [+low] vowel without an [ATR] specification, within any component to which the rule is assigned. Since it is assigned to the same component as the rule of ATR Spread by the Redundancy Rule Ordering Constraint, the redundancy rule will apply continuously in that component, therefore applying before the rule of ATR Spread.[48]

Thus, if these general principles are correct, the ordering of these rules is determined completely by principles of Universal Grammar. Hence, there is no need for any statements in the Yoruba grammar beyond those summarized in (48).

Appendix: The Agentive/Instrumental *o/ọ* Prefix (Source: Abraham (1958))

***i* as first vowel of unprefixed base**

òdíwọ̀n	'measuring container'	(dá 'fix' + wọ̀n 'measure')
ofínràn	'contentious person'	(fín + ọ̀ràn 'provoke a quarrel')
òǵbifọ̀	'interpreter'	(gbọ́ 'hear; understand' + ọfọ̀ 'lawsuit')
òjíṣẹ́	'messenger'	(jẹ́ 'reply' + iṣẹ́ 'message')
òjìyà	'victim'	(jẹ 'suffer from' + ìyà 'punishment')
òjiyàn	'disputatious person'	(jà 'fight' + iyàn 'dispute')
òmíràn	'another X'	(míràn 'some')
òpin	'end; termination'	(pin 'come to an end')
òpìtàn	'historian'	(pa 'relate' + ìtàn 'story')
òṣìkà	'cruel person'	(ṣe 'do' + ìkà 'cruelty')
òṣìṣẹ́	'workman'	(ṣe 'do' + iṣẹ́ 'work')

***e* as first vowel of unprefixed base**

òṣèlú	'politician'	(ìṣèlú 'politics' < ṣe 'do' + ìlú 'town; city')
òṣèwé	'publisher'	(ṣèwé 'publish a book' < ṣe 'do' + ìwé 'book')

***ẹ* as first vowel of unprefixed base**

ọdẹ	'hunter'	(dẹ 'hunt')
òfẹ́bìnrin	'man overfond of women'	(fẹ́ 'love' + obìnrin 'woman')
òjẹun	'glutton'	(jẹun 'eat' (intransitive))

[48] For additional evidence in favor of the continuous application of redundancy rules, see Pulleyblank (1986a,b) and Dresher (1985). Note that the Yoruba data are consistent with either continuous application or early application. We assume the Continuous Application Principle because of the facts outside Yoruba.

ọlẹ	'lazy person'	(lẹ 'be lazy')
ọrẹ́	'friend'	(rẹ́ 'be united, be on friendly terms')

***a* as first vowel of unprefixed base**

ọbanijẹ́	'slanderer'	(bà . . . jẹ́ 'spoil' + ẹni 'person')
ọbayéjẹ́	'sower of discord'	(bayéjẹ́ 'be a troublemaker' < bà . . . jẹ́ 'spoil')
ọdájú	'callous person'	(dájú 'be callous' < dá 'be lacking to' + ojú 'presence')
ọdàlẹ	'treacherous person'	(dalẹ 'behave treacherously' < dà 'betray' + ilẹ 'land')
ọdárayá	'cheerful person'	(dá 'cause' + ara 'body' + yá 'happy')
ọdáràn	'criminal'	(dá + ọràn 'commit a crime' < dá 'cause' + ọràn 'trouble')
ọkàwé	'reader'	(kà 'read' + ìwé 'book')
ọlàjà	'conciliator'	(là ìjà 'mediate' < là 'split' + ìjà 'fight') (*see also* òlàjà *below*)
ọlàjú	'civilized person'	(lajú 'open eyes; become civilized' < là 'split' + ojú 'eye')
ọta	'marksman'	(ta 'shoot')
ọta	'bullet'	(ta 'shoot')
ọyájú	'impertinent X'	(yájú 'be impertinent' < yá 'be ready' + ojú 'eye')

***ọ* as first vowel of unprefixed base**

ọdọ́kọ	'nymphomaniac'	(dá 'snap X' + ọkọ 'husband')
ọkọ̀ṣẹ́	'person who refuses to run errands'	(kọ̀ 'refuse' + iṣẹ́ 'message')
ọmọ	'builder'	(mọ 'build')
ọmọ̀lé	'builder'	(mọ 'build' + ilé 'house')
ọmọ́lé	'gecko-lizard'	(mọ́ 'stick to; is resting on' + ilé 'house')
ọmọ̀wé	'educated person'	(mọ̀ 'know' + ìwé 'book')
ọmọ̀wẹ̀	'swimmer'	(mọ̀ 'know' + wẹ̀ 'swim')
ọpọ̀	'abundance'	(pọ̀ 'be abundant')
ọsọ̀rọ̀ sọbótò	'chatterbox'	(sọ̀rọ̀ 'speak' (sọ 'speak' + ọ̀rọ̀ 'word') + sọbótò 'loquaciously')

ọ̀tọ́pinpin	'careful scrutinizer'	(tọ́pinpin 'investigate fully' < tọ̀ 'follow' + pin 'come to an end')
***o* as first vowel of unprefixed base**		
ogbógi	'expert'	(gbógi 'be versed in' < gbó 'become ripe, mature' + igi 'tree')
ògbójú	'brave person'	(gbójú 'be brave' < gbó 'become ripe, mature' + ojú 'eye')
ogbóyà	'brave person'	(gbó 'become ripe, mature' + àyà 'bravery')
òjòwú	'jealous person'	(jowú 'be jealous' < jẹ 'suffer from X' + owú 'jealousy')
òkóbó	'sexually impotent male'	(kú 'die' + obó '?')
òpònú	'fool'	(ponú 'be a fool' < pò 'knead' + inú 'stomach')
òṣòdì	'evildoer'	(ṣòdì 'take the wrong course' < ṣe 'do' + òdì 'wrong side')
òṣónú	'surly person'	(ṣó 'break wind' + inú 'stomach')
òtòṣì	'poor person'	(tòṣì 'afflict with poverty' < ta 'sting' + òṣì 'poverty')
***u* as first vowel of unprefixed base**		
òkú	'corpse of person'	(kú 'die')
òmúlẹ́mófo	'unrealizability'	(múlẹ́ 'be firmly rooted' (< mú 'catch hold of' + ilẹ̀ 'land') + mú 'catch hold of' + òfo 'emptiness')
òmùwẹ̀	'swimmer'	(mù 'dive' + wẹ̀ 'swim')
òpùrọ́	'liar'	(purọ́ 'tell a lie' < pa 'relate' + irọ́ 'falsehood')
òṣùká	'porter's head-pad'	(ṣù 'make into ball' + ká 'encircle')
òṣùnwọ̀n	'measuring container'	(ṣùn '?' + wọ̀n 'measure')
òtuntun	'renewer'	(titun/tuntun 'newness')
exceptions (see also footnote 18)		
odáró	'dyer'	(aró 'indigo' < dáró 'to dye')
òlàjà	'conciliator'	(là ìjà 'mediate' < là 'split' + ìjà 'fight') (*see also* ọ̀làjà *above*)

òrayè	'fool'	(ra + (ní) iyè 'render stupid' < ra 'rub' + iyè 'intelligence'; *also* òùnrayè)
ọ̀mu	'drinker'	(mu 'drink')
ọ̀mùtí	'drunkard'	(mu 'drink' + ọtí 'spirits')
ọ̀tun	'newness'	(titun/tuntun 'newness')

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