

[+ATR] DOMINANCE IN AKAN¹

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Several descriptions of Akan ATR harmony, including Stewart (1967), Schachter & Fromkin (1968), and Dolphyne (1988), have claimed that harmony involves asymmetric assimilation of [-ATR] to [+ATR] vowels. Other scholars, e.g., Clements (1981), Bakovic (2001), have analyzed Akan ATR harmony as involving featurally symmetric assimilation of all affixes to both [+ATR] and [-ATR] roots (i.e., “root-control”). In these analyses, the two [ATR] values pattern symmetrically in the phonology, and dominance of [+ATR] plays no essential role.

This paper argues that root-control analyses of Akan have failed to address all of the evidence of [+ATR] spreading found in Akan. Instrumental evidence is also presented to show that certain forms of [+ATR] spreading that have sometimes been dismissed as gradient phonetic processes are in fact categorical and phonological. In all, there is considerable evidence that Akan ATR harmony is based on assimilation to [+ATR] vowels, as claimed by Stewart and others.

Selon plusieurs descriptions, (Stewart 1967, Dolphyne 1988, Schachter et Fromkin 1968), l’harmonie vocalique [ATR] en akan est basée sur le principe que les voyelles [-ATR] s’assimilent aux voyelles [+ATR]. D’autres chercheurs tels que Clements (1981) et Bakovic (2001) ont maintenu que l’assimilation [ATR] est contrôlée par le radical. Les voyelles des affixes s’assimilent à celles des radicaux sans qu’il faille respecter une valeur particulière du trait [ATR]. De ce point de vue, la domination de [+ATR] ne joue aucun rôle essentiel.

Cet article soutient que les analyses basées sur le principe ‘root-control’ (radical comme élément clé de contrôle), n’ont pas tenu compte des données qui indiquent la propagation du trait [+ATR] en akan. En outre, les résultats d’une investigation acoustique démontrent que certaines formes de propagation [+ATR] qui ont parfois été écartées comme processus purement phonétiques revêtent, en fait, un statut catégorique et phonologique. En définitive, il existe des preuves importantes selon lesquelles l’harmonie vocalique en akan est basée sur l’assimilation au trait [+ATR], tel que proposé par Stewart et d’autres chercheurs.

0. OVERVIEW

A language that has figured very prominently in both the descriptive and theoretical and typological literature on ATR harmony (e.g., Archangeli and Pulleyblank 1994, Bakovic 2001, Clements 1981, 1984, Goad 1993, Hall-Lew 2006, Kiparsky 1985, O’Keefe 2003, Polgárdi 1998, Schachter and Fromkin 1968, Stewart 1983, among others) is Akan, a Tano (Kwa) language of Ghana. In addition to a number of careful and detailed phonological studies that exist (e.g., Berry 1957, Clements 1981, Dolphyne 1988, Stewart 1967), there has been much instrumental phonetic work (e.g., Hess 1992, Lindau 1987, Tiede 1996) on the articulatory and acoustic properties of the feature [ATR] in Akan. Indeed, a good case could be made that Akan has been the single most thoroughly studied ATR harmony language.

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The large body of empirical knowledge that has accumulated concerning the behavior of ATR harmony in Akan has not, however, led to complete consensus concerning all aspects of the harmony system. Two quite different views on the mechanisms responsible for Akan ATR harmony exist. One view, advocated by phonologists such as Bakovic (2001) and Clements (1981), maintains that Akan ATR harmony involves featurally symmetric assimilation of affixes to roots. I will refer to this view as the *root-control* analysis of Akan ATR harmony. Other phonologists (e.g., Dolphyne 1988, Schachter and Fromkin 1968, Stewart 1967) have proposed that Akan ATR harmony is based on asymmetric anticipatory assimilation of [-ATR] to [+ATR] vowels. According to Dolphyne (1988:117), “vowel harmony in Akan is basically a regressive process in which advanced vowels assimilate unadvanced vowels that precede them.”

In fact, Akan manifests a number of patterns that superficially appear to involve right-to-left spreading of [+ATR], for example anticipatory spreading of [+ATR] vowel quality across word boundaries or between root morphemes in compounds. Taken at face value, such evidence seems to support the view that Akan harmony is based on asymmetric dominance of [+ATR] vowels. A full treatment of such *prima facie* evidence of [+ATR] dominance has yet to be given by proponents of the root-control analysis; in particular, [+ATR] spreading in compounds is not explicitly addressed in work such as Clements (1981) and Bakovic (2001) that treats Akan ATR harmony as root-controlled. It is clear, however, that a major reason for discounting at least some superficial instances of [+ATR] spreading is the belief that the processes in question are phonetic (i.e., involve gradient coarticulation) and not phonological in nature.

The goal of this paper is to survey and assess various forms of evidence for dominance of [+ATR] vowels in Akan, with careful attention in particular to several whose phonological (as opposed to phonetic) status has been disputed. It will emerge that while some cases of gradient (and presumably phonetic) coarticulatory assimilation seemingly do exist, other instances of assimilation to [+ATR] vowels show characteristics of a categorical change to [+ATR] in the phonology. I argue that there is considerable evidence that harmonic alternations in Akan are based on (anticipatory) assimilation to [+ATR], as proposed by phonologists such as Dolphyne (1988), Schachter and Fromkin (1968), and Stewart (1967).

Akan data presented in this paper are drawn from a variety of sources, including Berry (1957), Clements (1981), Dolphyne (1988) and Stewart (1967). In addition, I make use at various points of examples elicited from an adult male speaker of the Akuapem dialect during an Advanced Field Methods course I taught at Trinity Western University in the fall 2007 semester. (Where no other source is explicitly cited, examples in this paper are from this last source.)

The remainder of this paper is organized as follows. Section 1 opens the discussion of Akan itself by providing background on the Akan vowel system, while Section 2 briefly describes and illustrates the general behavior of affix harmony in the language. Section 3 discusses in detail the various potential indicators of asymmetric assimilation to [+ATR] vowels found in Akan and their phonetic or phonological status. In Section 4, I briefly reconsider the question of the possible relevance of gradient [+ATR] spreading in languages like Akan to phonology proper. Section 5 summarizes the major conclusions of the paper.

1. THE AKAN VOWEL INVENTORY

Akan shares a number of phonological characteristics with most other Tano languages, including robust ATR harmony and a phonemic inventory of nine oral vowels, shown below. Vowel nasality and length are contrastive as well.

(1)	i	u
	ɪ	ʊ
	e	o
	ɛ	ɔ
	a	

Phonetically, a tenth vowel quality (symbolized in this paper as [æ]) also exists. As noted by Clements (1981:114), it is rather similar to [ɛ] in terms of its impressionistic height and frontness. Interestingly, this vowel quality has been analyzed in at least three different ways: as a phonemic [+ATR] counterpart of /a/ (Stewart 1967), as a predictable [+ATR] allophonic variant of /a/ before a following [+ATR] vowel (Dolphyne 1988), and as a low [-ATR] vowel that undergoes a phonetic rule of “raising” that causes it to become partially assimilated to a following [+ATR] vowel, i.e., the assimilation process is not a categorical feature changing one but simply gradient coarticulation (Clements 1981). The first (phonemic) analysis has rarely, if ever, been proposed in recent years, as it now seems to be generally agreed that [æ] is in complementary distribution with [a]. To a first approximation (see Clements 1981 for more detailed discussion), [æ] occurs before a non-low [+ATR] vowel in the following syllable and before certain palatal(ized) or labio-palatalized consonants that likely derive historically through gliding of a following [+ATR] vowel, while [a] occurs elsewhere. It thus appears clear that [æ] is an assimilated variant of /a/. I will have more to say below on the question of whether such assimilation is phonetic or phonological.

Some examples of [æ] to the left of [+ATR] vowels are shown below.²

(2)	a. à-tʃí?	back
	b. à-dúrí	medicine
	c. à-fú↓ rúm	donkey
	d. kæri	weigh (Dolphyne 1988:2)
	e. pætu	pretend (Dolphyne 1988:2)

According to most descriptions (as well as our own findings) instances of /a/ to the *right* of a [+ATR] vowel (as in [síká] ‘money’) do not surface as [æ].

2. HARMONIZING AFFIXES

With one possible exception, to be discussed below, Akan does not have dominant [+ATR] suffixes. A variety of affixes alternate to agree in their [ATR] value

² Tone is marked on examples where possible. However, this has not been possible in all cases, since some of the descriptive sources consulted do not always mark tone on Akan examples. In examples where tone is indicated, acute accent represents high tone, and grave accent represents low tone. The symbol [↓] indicates downstep of a following high tone.

with that of a preceding or following root vowel; a few examples are shown below. (Useful summaries of the harmonic behavior of Akan affixes are found in Dolphyne 1988 and O'Keefe 2003.)

(3) Some harmonizing verbal prefixes

a. mí-dà	I sleep
b. wú-dà	you (sg.) sleep
c. ɔ́-dà	he/she sleeps
d. ɔ̀-bé-dá	he/she will sleep
e. jè-bé-dá	we will sleep
f. mí-dì?	I eat
g. wú-dì?	you (sg.) eat
h. ɔ́-dì?	he/she eats
i. ɔ̀-bé-dí?	he/she will eat
m. jè-bé-dí?	we will eat

(4) Some harmonizing nominal prefixes

a. ɔ̀-bú	stone
b. ɔ̀-wɔ́	snake
c. ɔ̀-sìsì-↓fú	cheater
d. ɔ̀-wù-dí-↓fú	murderer

(5) Harmonizing nominalizing suffix [ɪ] ~ [i] (adapted from Dolphyne 1988:83)³

a. a-tɔ-ɪ	west (cf. [tɔ] to fall)
b. sum-ii	pillow (cf. [sum] to lean on)

(6) Harmonizing past tense suffix [ɪ] ~ [i]

(adapted from Dolphyne 1988:94, Clements 1981:145)

a. ɔ̀-tɔ̀-ɪ	he/she bought it
b. ɔ̀-ɲ-tú-ɪ	he/she has'nt dug it up
c. o-bisa-ɪ	he/she asked it (Clements 1981:120)

In example (6c), in which the root contains a [+ATR] vowel /i/ followed by the low vowel /a/, the suffix harmonizes with the latter and not with the former, showing that the low vowel /a/ is opaque to rightward spreading of [+ATR].

Akan is frequently described (e.g., Bakovic 2001, Clements 1981, O'Keefe 2003) as a language whose affix harmony is bidirectional. In the sense that the language has both harmonizing prefixes and harmonizing suffixes, such a description is accurate. It is not the whole story, however. In fact, several suffixes, listed below, do not harmonize with a preceding root but are consistently [-ATR].

³ Dolphyne does not discuss the reason for the difference in the length of the suffix vowel in examples in (5a) and (5b).

- (7) a. Agentive suffix [-**fu**]
 b. Diminutive suffix [-**wa**] / [-**ba**]
 c. Plural suffix [-**num**]

It is quite common for ATR harmony languages to have one or more exceptional affixes that fail to undergo harmony (as we shall see, Akan has at least one prefix of this type also), and since we have seen that other suffixes in Akan do harmonize, it might be tempting to regard failure of these suffixes to harmonize as an idiosyncratic fact about these morphemes.

There are two reasons for not doing so. First, the number of suffixes that harmonize may actually be less than the number that do not. In the Akuapem dialect, the two harmonizing suffixes in (5) and (6) are apparently the only harmonizing suffixes that occur (nor is it very clear that the suffix in (5) is synchronically all that productive). An additional harmonizing suffix has been described in the Asante dialect (Dolphyne 1988:83-84), though it is not entirely clear from the examples that the element in question is actually a suffix rather than a vocalic segment whose predictable insertion is phonologically conditioned. A further additional harmonizing suffix may occur in the Fante and Asante dialects (Dolphyne 1988:85), though Dolphyne does not state explicitly whether this suffix harmonizes and the few examples given all involve [-ATR] roots. At any rate, it is far from clear that harmonization of suffixes constitutes a more regular and general pattern than non-harmonization.

More interestingly, there appears to be a significant generalization regarding which suffixes harmonize and which do not. All of the suffixes that do not harmonize are consonant-initial (Dolphyne 1988:22), while all harmonizing suffixes (including both those in (5) and (6) and the additional dialectal possibilities described above) are vowel-initial. This seems unlikely to be accidental. As argued by Pulleyblank (2002), there appears to be a cross-linguistic tendency for harmony to apply more strongly and/or regularly where less phonological material intervenes between target and trigger. Given the syllable and morpheme structure patterns of Akan, harmonizing V suffixes will most commonly occur immediately adjacent to a preceding root-final vowel. Though disharmonic VCV sequences are not uncommon in ATR harmony languages, disharmonic VV sequences seem to occur less frequently. Thus it would be accurate and reasonable to describe Akan suffixes as generally *not* subject to ATR harmony and to explain the harmonizing behavior of V suffixes as due to the fact that disharmony is more strongly dispreferred in cases where less material intervenes between trigger and target. In contrast, prefix harmony is much more consistently observed. There is thus evidence of a directional tendency (of which we shall see several further indicators) for harmony to apply more strongly from right-to-left than from left-to-right in Akan.

3. SPREADING OF [+ATR] IN AKAN

In this section, we will consider in turn the potential indicators of dominance of [+ATR] vowels found in Akan. Four such indicators have been clearly reported in the literature: leftward spreading of [+ATR] across word boundaries, leftward spreading of [+ATR] between roots in compound words, the existence, according to some analyses, of a [+ATR] allophone of /a/ derived by [+ATR] spreading from a [+ATR] vowel in the following syllable, and a possible instance of a dominant [+ATR] suffix. A fifth indicator of [+ATR] dominance has not received much explicit attention, but is at least mentioned briefly in an important early study by Stewart (1967) and is perhaps

hinted at as well in Schachter and Fromkin (1968). This involves the existence of certain patterns, which I designate *inherent [-ATR] effects*, which could be taken to argue that harmonizing affixes in Akan are in fact underlyingly [-ATR] and undergo asymmetric assimilation to [+ATR] roots.

It seems clear that a major reason why at least some phonologists have discounted certain apparent indicators of [+ATR] dominance is that the relevant patterns have sometimes been claimed to be purely coarticulatory effects and not indicative of feature-spreading assimilation in the phonology. This emerges most clearly in a particularly thorough and detailed discussion of Akan ATR harmony by Clements (1981). Clements' assumption that certain cases of assimilation to [+ATR] vowels in Akan are sub-phonological has been explicitly adopted in a number of subsequent discussions of the language (e.g., Archangeli and Pulleyblank 1994, Bakovic 2003, McCarthy 2009).

Because the issue of phonological dominance of [+ATR] vowels is closely connected to the question of whether certain instances of [+ATR] spreading are phonological, rather than co-articulatory in nature, significant attention will be devoted to this latter question at various points below. This discussion will make reference both to previous research on the topic (in particular Hess 1992) and some novel findings.

3.1 LEFTWARD PHRASAL [+ATR] SPREADING

3.1.1 Impressionistic descriptions

Several studies of Akan (Berry 1957, Clements 1981, Dolphyne 1988, Stewart 1967) report the existence of a process in which [+ATR] spreads leftward across a word boundary, causing a word-final [-ATR] vowel to surface in a more [+ATR] form before a word whose first vowel is [+ATR]. Some examples (adapted from Dolphyne 1988:23-24 and Stewart 1967:190) are shown below.

- | | | | | |
|-----|--------------------|---|---------------|--------------------------|
| (8) | a. /ɔ-pe sika/ | → | [ɔpe sika] | he/she likes money |
| | b. /mɛ-kɔ kumasi/ | → | [meko kumasi] | I'll go to Kumasi |
| | c. /frɛ kofi/ | → | [fre kofi] | call Kofi |
| | d. /ɔ-kɔ fie/ | → | [ɔko fie] | he/she is going home |
| | e. /ɔ-bɛ-dʒi siká/ | → | [ɔbédʒi siká] | he/she will accept money |

Although the transcriptions in (8) tend to suggest a categorical feature change from [-ATR] to [+ATR] in the word-final vowel, some descriptions report a kind of cline effect, such that 1) not only the word-final vowel, but vowels in preceding syllables as well, are affected, 2) the affected vowels (including some in the word-final syllables immediately to the left of the triggering [+ATR] vowel) are sometimes intermediate in quality between underlying [-ATR] and [+ATR] vowels (e.g., assimilated /ɔ/ may be intermediate in quality between [ɔ] and [o]), and 3) the degree of change decreases with distance from the trigger. Clements (1981:157) characterizes the process (which he terms "Vowel Raising") as follows:

"As first noted by Berry (1957), Vowel Raising is not local to the syllable immediately preceding the conditioning syllable but influences the articulation of preceding syllables as well, causing them to acquire

increasingly raised variants in a gradual ‘crescendo’ as the conditioning syllable is approached.”

He goes on to argue on this basis that the process is better viewed as a matter of phonetic implementation than phonology. Though Clements’ suggestion is a reasonable one, consistent with the widespread assumption (cf. Keating 1990) that gradient processes are phonetic and not phonological nature, I will argue that this proposal faces some empirical difficulties.

To begin with, it is not fully clear that all instances of leftward spreading of [+ATR] across word boundaries are in fact gradient. There is a certain amount of instrumental evidence bearing on this question, which will be discussed further below. Since this instrumental evidence is limited and not necessarily conclusive in all respects, however, it is also important to consider evidence based on impressionistic reports in the descriptive literature. Here we find a certain amount of variability. Whereas Dolphyne (1988: 24) reports that high [-ATR] vowels /ɪ/ and /ʊ/ (but not mid [-ATR] vowels /ɛ/ and /ɔ/) sometimes undergo only partial assimilation before a following [+ATR] vowel in a word-initial syllable, surfacing as vowels of intermediate [ATR] quality (between high [-ATR] and high [+ATR]), Clements (1981:154) reports essentially the opposite state of affairs: phrasal assimilation affects high [-ATR] vowels categorically (merging them phonetically with high [+ATR] vowels /i/, /u/), while mid [-ATR] vowels undergo only partial assimilation (surfacing as vowels intermediate in quality between [ɛ], [ɔ] and [e], [o]). Notwithstanding the variability and/or uncertainty that exists, however, it seems fair to summarize existing work as in reasonably good agreement on several points:

1. The number of syllables affected is to some extent variable.
2. [+ATR] spreading results in assimilated vowels of intermediate quality in at least some cases (particularly in syllables to the left of the word-final syllable, but probably in some cases the word-final syllable as well).
3. The likelihood nevertheless remains that assimilation of at least some word-final [-ATR] vowels is consistently or at least typically neutralizing.

The first two generalizations do tend to suggest a gradient anticipatory “crescendo” scenario of the type Clements proposes. What are we to make, however, of the fact (if we take such reports at face value) that assimilation of the word-final vowel is frequently neutralizing?

One possibility is that neutralization is just the extreme endpoint of a process that is not inherently neutralizing but is variable in degree. Cases of this type are not uncommon. Such a situation arises with respect to rounding assimilation of a high prefix vowel across a labial consonant in the Tano language Nawuri (Casali 1995). In at least the Nawuri case (and presumably many such cases), however, it is clear (based on both impressionistic observations and formant measurements) that the typical phonetic output is a partially assimilated vowel. It is not very clear, if we take the descriptive reports of Akan phrasal [+ATR] spreading at face value, that this is what we find in Akan. Rather, it seems likely (if not entirely certain) that the *regular* outcome of phrasal [+ATR] spreading is, in at least some predictable circumstances, a fully assimilated [+ATR] vowel. A reasonable possibility that seems difficult to exclude at present is that assimilation of a word-final vowel (or perhaps certain word-final vowels) is due to a categorical, feature changing process, while any effect on vowels further to the left is a matter of gradient co-articulation.

A second potential challenge to the view that leftward phrasal spreading of [+ATR] is purely phonetic derives from the fact that such spreading appears,

according to at least some sources, to be sensitive to lexical and/or morpho-syntactic information. Under many views of phonetic implementation (e.g., Mohanan 1986), a gradient co-articulatory process of leftward [+ATR] spreading in Akan should not require the presence of a word boundary in order to apply, but should also apply in phonetically identical contexts that happen to occur word-internally. Thus, if a case should arise in which a [-ATR] vowel preceded a [+ATR] word-internally in the output of the phonology, we should expect, under such views of phonetic implementation, that this [-ATR] would undergo the same kind of (putatively phonetic) leftward [+ATR] spreading that applies across word boundaries.

Due to the regular application of ATR harmony word-internally, potential test cases of this type do not ordinarily occur in Akan. However, there are some exceptional circumstances in which they do in fact arise. One such case involves the existence of a progressive prefix [rɪ-] which, according to Dolphyne (1988), consistently fails to harmonize (in the Akuapem dialect) with a following [+ATR] verb root but is invariably [-ATR] on the surface. This behavior is illustrated in the examples below (adapted from Dolphyne 1988:92).

- | | | |
|-----|---------------|-------------------------|
| (9) | a. ɔ-rɪ-kɔ | he/she is going |
| | b. ɔ-rɪ-tù | he/she is digging it up |
| | c. ɔ-rɪ-bisá | he/she is going |
| | d. ɔ-rɪ-bɛ-kɔ | he/she is about to go |

If leftward phrasal spreading of [+ATR] is in fact a purely phonetic process, it is not clear how it is to be exempted from applying in such cases, since the relevant segmental conditions are identical to those that give rise to [+ATR] spreading across word boundaries. (Compare (9c) with (8d) for example.)

Muddying the picture somewhat is the fact that Schachter and Fromkin (1968:126) differ from Dolphyne in claiming (citing examples like [ɔ́rɪdɪ] ‘he/she is eating’) that the progressive prefix does in fact harmonize for [ATR] in Akuapem. We will return to this issue, and its potential bearing on the question of the phonological or coarticulatory nature of leftward [+ATR] spreading in Akan, below.

3.1.2 Instrumental evidence

I now turn to a discussion of instrumental evidence bearing on the gradient or categorical status of leftward [+ATR] spreading across word boundaries. The only previous instrumental study to directly investigate the issue, as far as I am aware, is Hess (1992). Hess looked at tokens of the word /àdáká/ ‘box’ in sentences in which they preceded words with [+ATR] vowels (and also, for comparison, words with [-ATR] vowels), measuring the F_1 values of each of the three /a/ vowels in this word. Her findings did not reveal the expected (under Clements’ proposal) crescendo pattern of gradually decreasing F_1 in successively later instances of /a/ in /àdáká/ before [+ATR] words. Rather, the first and second syllables of /àdáká/ show virtually no assimilatory effect due to a following [+ATR] word, surfacing with F_1 values around 600 Hz regardless of whether the following word contains [+ATR] or [-ATR] vowels. Only the word-final vowel /a/ showed any assimilation to a following [+ATR] word, and the magnitude of the effect was quite large, with F_1 values of /a/ typically lowered by more than 150 Hz in such cases. Hess argues that the revealed pattern of F_1 changes is better interpreted as a categorical change that affects only the word-final

/a/, rather than as a gradual co-articulatory increase in the degree of tongue root advancement with increasing proximity to the trigger.

Hess also looked at word-final instances of the mid [-ATR] vowel /ɛ/ in the same phonological context, preceding a following [+ATR] word. In this case, the results obtained were more consistent with gradient assimilation, in that the F₁ values of assimilated word-final /ɛ/ (mean = 395 Hz) in the word /àsɛ/ ‘beans’ preceding various [+ATR] words were found to be intermediate between values of those of /e/ (mean = 367 Hz) and those of /ɛ/ (mean = 488 Hz) in non-assimilatory contexts. However, F₁ measurements for individual tokens of assimilated /ɛ/ showed heavy overlap with those of /e/, but no overlap with those of /ɛ/ in non-assimilatory contexts. Moreover, F₁ bandwidth measurements (highly correlated with [ATR] distinctions in the speech of Hess’ Kwawu dialect Akan speaker) suggested complete assimilation of /ɛ/ with respect to tongue root position. In Hess’ words, “F₁ bandwidth shows a clear difference and suggests that assimilated /ɛ/ before /i,u/ is produced in much the same way as a [+ATR] vowel” Hess (1992:490).

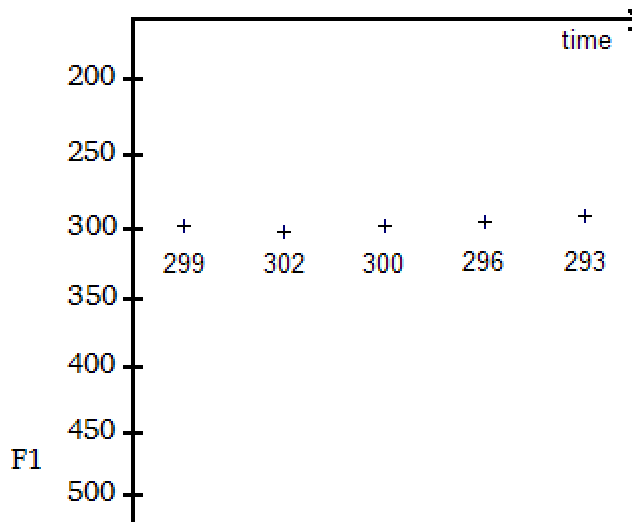
Hess did not investigate instances of word-final *high* [-ATR] vowels before following [+ATR] words. It has been possible, however, to have a preliminary look at this question using an extensive set of sound recordings from a fall semester 2007 Advanced Field Methods course at Trinity Western University in which Akan (Akuapem dialect) was the focus language. These sound recordings contain a number of examples, produced under suitable conditions, of word-final high [-ATR] vowels preceding a following [+ATR] word. Though the examples recorded were not pre-selected to control for all the kinds of factors that might conceivably be relevant to the issue in question, there are a number that seem quite suitable, often pronounced multiple times. I selected two utterances for which multiple recordings are available, shown in (10) below. (The word-final vowel /ɪ/ that is a potential target of leftward [+ATR] spreading is underlined.)

- (10) a. /kòtòdʒɛ́ kɛ̀sɪ́ bí/ a certain big knee (two tokens)
 b. /àwóɔ́ɔ́ bí/ a certain womb (nine tokens).

For each of the eleven tokens (two of (10a), nine of (10b)), F₁ values were measured at five regular intervals throughout the target word-final vowel /ɪ/, using the PRAAT software program (<http://www.fon.hum.uva.nl/praat/>). The mean F₁ values of all measurements at each time point are plotted below.

(11) Mean F_1 values at five evenly-spaced points in word-final /ɪ/ before /bi/

These F_1 values are considerably lower than those typical of /ɪ/ in non-



assimilatory contexts, which average around 415 Hz (see Section 3.2 below). Clearly, the word-final /ɪ/ vowels in these examples have undergone significant degree of anticipatory assimilation to the following [+ATR] vowel. It remains to determine whether this assimilation is categorical and neutralizing (i.e., word-final /ɪ/ has become a fully assimilated [+ATR] vowel), or simply a matter of gradient coarticulation.

Two considerations argue that the assimilatory process is neutralizing. First, the F_1 values attained by these assimilated tokens of word-final /ɪ/ compare quite closely with those typical of /i/. A natural point of comparison here is furnished by the vowel /i/ in the following word /bi/ ‘a certain’ which appears in these examples in (10). Individual tokens of the assimilated word-final /ɪ/’s show heavy overlap with those of the vowel of /bi/, to the extent that the mean values (300 Hz for the eleven word-final /ɪ/’s, 293 Hz for the eleven tokens of /i/ in /bi/) are not statistically distinct based on an unpaired t-test. If on the other hand, each word-final /ɪ/ vowel is compared with the immediately following /bi/ vowel in the same utterance, it turns out that in ten of the eleven tokens the F_1 of the latter is lower than that of the former, a result that a paired t-test shows to be highly significant. This finding, by itself, might seem to argue that phrasal assimilation of word-final /ɪ/ to a following [+ATR] vowel is almost, but not quite, neutralizing. However, the magnitude of the difference (7 Hz) in average F_1 values in this case is so small that its perceptual relevance cannot necessarily be taken for granted.⁴ Moreover, since the surrounding phonetic contexts in which the two vowels (i.e., the word-final [-ATR] vowel and the phrase-final vowel of /bi/) occur are not exactly identical, it is difficult to entirely exclude the possibility that the slightly lower F_1 values in the word-final /ɪ/ of /bi/ are due to contextual influences. The magnitude of the measured F_1 values of the assimilated /ɪ/ vowels thus appears consistent with the conclusion that this anticipatory phrasal assimilation is categorical and neutralizing.

⁴ According to Stevens (1998:225, 228), minimum F_1 differences that can be reliably perceived in synthetic vowel stimuli are in the range of 10 to 30 Hz.

A second, and equally significant, consideration has to do with the temporal profile of the F_1 values in (11). Under standard expectations, coarticulation involves temporal overlap of the gestures involved in the production of neighboring segments. The relevant articulator(s) (in this case, primarily the tongue root) have begun moving toward the target consideration for a following segment before some preceding segment has been completed. Since the articulators are moving increasingly closer to their target values for the second segment during the earlier one, we should expect, under this scenario, to see a gradual change the acoustic correlate(s) of the relevant gesture during the preceding segment. In the particular case we are dealing with here, we would expect, if the articulators have begun moving toward their target values for the /i/ of /bi/ during the preceding word-final /ɪ/, to see this movement reflected in a steady lowering of F_1 over the course of this /ɪ/ vowel. For his kind of gradient, anticipatory build up toward a target articulatory configuration, Clements' term "crescendo" seem entirely appropriate. Below, we shall see a case, in a different assimilatory context in Akan, that plausibly conforms to such a scenario.

This is not, however, what we find in (11). Instead, the F_1 values are consistently low though the entire duration of the word-final /ɪ/, fluctuating by only a few Hertz. Given, moreover, that the actual values of F_1 throughout the entire vowel are (as discussed above) quite close to those that would be expected for [i], the F_1 data are much more in line with a scenario in which the speaker achieves gestures appropriate for [i] at the beginning of the word-final /ɪ/ vowel. But if target gestures appropriate for [i] are aligned with the onset of /ɪ/, this implies, in effect, that the speaker's intended articulatory target for this word-final vowel is [i] and not [ɪ], i.e., /ɪ/ has become fully assimilated to [i] in the output of the phonology. In this case, we are dealing with categorical, feature-changing neutralization and not gradient coarticulation.

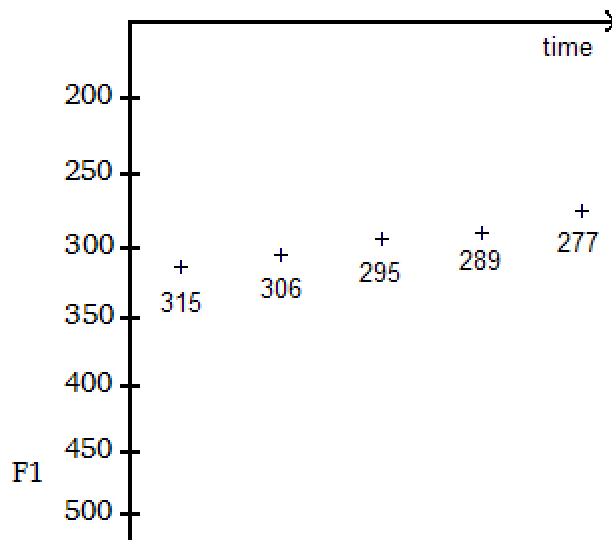
It is interesting to compare the F_1 values in (11) with similar measurements made in a different context, involving instances of the progressive prefix /rɪ-/ before a [+ATR] verb root. As noted above, there has been disagreement in the literature over whether the vowel of this morpheme undergoes assimilation to a following [+ATR] vowel or not; Dolphyne claims that it does not, while Schachter and Fromkin maintain that it does. Of course, in addition to the logical alternatives of categorical assimilation in the phonology, implied by Schachter and Fromkin's description, and a complete absence of any assimilatory effects, we must also consider the possibility, once again, of gradient coarticulation. Though the evidence is not perhaps fully clear cut, there are reasonable indications that this possibility best describes the speech of our own Akuapem language consultant.

To investigate the possibility of assimilation of the vowel of the progressive prefix to a following [+ATR] vowel in a verb root, I made F_1 measurements on recordings of eight tokens of the [+ATR] verb sequence /ɔ-rɪ-dɪdɪ/ 'he/she is eating' and one token of the [+ATR] verb sequence /ɔ-rɪ-dɪ/ (a shorter form with roughly the same meaning). The recordings were not made on a single occasion for the direct purpose of investigating this [+ATR] spreading, but had been supplied by our language consultant at various times during our field methods course, generally in connection with other research topics such as verb tense-aspect morphology.

F_1 measurements made at the approximate center of the vowel /ɪ/ in /rɪ-/ in these nine tokens yielded an average value of 295 Hz. Similar measurements made on the same prefix vowel /ɪ/ in three tokens of /ɔ-rɪ-ɪtɪ/ and four tokens of /ɔ-rɪ-ɪtɪɔ/ (both meaning, roughly, 'he/she is tearing') yielded a much higher average F_1 value of 421 Hz. There is thus clearly a significant degree of assimilation of the vowel of /rɪ-/

to a following [+ATR] vowel. This average value of 295 Hz is, moreover, comparable to the 300 Hz found as the average midpoint value in the word-final /**i**/ vowels in (11) above that result from phrasal assimilation to the following word /**bi**/. By themselves, these facts would tend to suggest that likelihood of neutralizing assimilation to the following [+ATR] root vowel, as reported by Schachter and Fromkin.

There are other facts, however, that call such a conclusion into question. Most significantly, all nine tokens of /**ri**-/ before the [+ATR] verb forms show a pattern in which F_1 declines gradually throughout the vowel /**i**/. This is evident in the plot below, which shows averages over all tokens of F_1 values made at five equally spaced points throughout the vowel.



(12) Mean F_1 values at five evenly-spaced points in the vowel of /**ri**-/ before /**di**/

The average F_1 drop between the first and last measurement points is 38 Hz. In no individual token was the decrease between the first and fifth (i.e., last) measurement points less than 22 Hz. Of the 36 pairs of successive points measured (four pairs of immediately adjacent points per token times nine tokens), only one pair failed to reveal a lower F_1 in the point made later in the vowel than in the point to its immediate left.

Plausibly, this steady decrease in F_1 values over the course of the vowel, which is qualitatively rather different from the picture revealed in the phrasal examples in (11), is indicative of gradient coarticulation rather than categorical assimilation for [+ATR]. Further support for this conclusion comes from the fact that even the rightmost F_1 measurements in these tokens of /**ri**-/ fall short of the value at the center of the following /**i**/ vowel in the verb root /**di**/, which averages 251 Hz.⁵ This is fully

⁵ For reasons that are at this point not fully understood, the F_1 values of the vowel of the word /**di**/ (or /**didí**/) 'eat' which served as the source of [+ATR] assimilation for investigation of /**ri**-/ are consistently lower than those of the same vowel in the word /**bi**/ which is the source of [+ATR] assimilation in the utterances that formed the basis for the investigation of assimilation of word-final /**i**/, the results of which yielded the plot in (11). The average F_1 value of /**i**/ in /**di**/ (or /**didí**/) is 254

consistent with the assumption of an assimilatory cline, with the eventual target located in the vowel of the verb root. Though the F_1 values of the prefix are quite low, suggesting considerable pharyngeal cavity expansion, the fact that they lower progressively toward the value for the following vowel, without in most cases ever quite reaching it,⁶ argues against the assumption that the prefix vowel itself possesses a target [+ATR] specification (i.e., is phonologically a fully assimilated [+ATR] vowel).

There are indications that this coarticulatory assimilation to [+ATR] in the progressive prefix /rɪ-/ also extends leftward into a preceding subject prefix as well. F_1 measurements at the midpoint of the vowel /ɔ/ in the same nine recordings of /ɔ-rɪ-dɪ(dɪ)/ that formed the basis of the plot in (12) yielded an average value of 539 Hz. F_1 measurements near the right edge of this vowel yielded an average of 440 Hz. These values are higher than would be expected for [ɔ], which typically range below 400 Hz (see the vowel space plot in (13) below), nor does the prefix vowel sound qualitatively like [ɔ]; impressionistically, it sounds, to my ears, like a perfectly acceptable [ɔ]. The observed F_1 drop of 99 Hz over the last half of the vowel is however consistent with gradient anticipatory assimilation to the [+ATR] vowel /i/ of the following verb root.

Of course, since /ɔ/ and /i/ also differ in their value of [high], it is also possible that some or all of the F_1 drop in /ɔ/ could be due to gradient assimilation for tongue height, rather than [ATR]. Fortunately, the alternate forms of ‘he/she is tearing’ referred to above, /ɔ-rɪ-tɪtɪ/ and /ɔ-rɪ-tɪtɪʊ/, furnish a useful point of comparison. In these utterances, any lowering of F_1 during the initial /ɔ/ vowel can only be attributed to coarticulatory assimilation for height, since there is no [+ATR] specification that might trigger such lowering. The /ɔ/ vowels in these utterances do indeed show a lowering of F_1 over the last part of the vowel, from an average value (based on three tokens of /ɔ-rɪ-tɪtɪ/ and four of /ɔ-rɪ-tɪtɪʊ/) of 592 Hz at the midpoint to an average value of 562 Hz at the right edge. Importantly, however, the average F_1 values at both points are considerably higher than the corresponding values (539 Hz, 440 Hz) in the same /ɔ-/ prefix in the /ɔ-rɪ-dɪ(dɪ)/ recordings.⁷ Moreover, the magnitude of the

Hz, while the average F_1 value of /i/ in /bi/ is 293 Hz. One possible difference that may be relevant here involves tone. The tone of the following triggering [+ATR] syllable is high (/bɪ/) in the phrasal examples but low (/dɪ/) in the examples used to investigate the assimilatory behavior of /rɪ-. If low tone is accompanied to some degree by lowering of the larynx, this could presumably lead to lower F_1 values as well, due to an increase in pharyngeal cavity volume.

As pointed out by a reviewer, the following consonant is different in the two cases as well. Both [d] and [b] are voiced obstruents, a type of sound whose articulation is known to be accompanied in some languages by pharyngeal cavity expansion (e.g., by larynx lowering) as a means of facilitating voicing. (See for example Bell-Berti 1975, Vaux 1992). If the smaller oral cavity size behind an alveolar than a bilabial closure makes maintenance of voicing potentially more difficult in [d] than in [b], it is conceivable that a greater degree of compensating pharyngeal cavity expansion might accompany the former, potentially resulting (given a sufficiently early anticipatory onset of such a gesture) in a lower F_1 value in the preceding vowel before [d] than before [b].

Finally, one might also speculate that an exceptionally low F_1 value in the [+ATR] vowel of /dɪ/ is a kind of enhancement strategy to keep this vowel perceptually distinct from the preceding [-ATR] vowel, i.e., it is a way of ensuring that the heavy degree of coarticulatory assimilation on the prefix vowel does not lead to complete neutralization of the perceptual difference. Note that this kind of consideration would not apply in the case of the phrasal examples involving /bɪ/, under the assumption that, in this case, the underlying [ATR] distinction between this vowel and the preceding one has been neutralized in the phonology by categorical assimilation (i.e., there is no longer any featural difference to maintain).

⁶ In only three of the nine tokens investigated does the rightmost F_1 measured in /rɪ-/ come within 20 Hz of the F_1 value measured in the middle of the following vowel of /dɪ/, and in only one token does it actually reach this value.

⁷ An unpaired t-test shows the F_1 differences between the two cases to be statistically significant ($p < .05$) at both measurement points.

average F_1 drop (30 Hz) that occurs in these cases in which the verb root vowel is high [-ATR] /ɪ/ is considerably less than the 99 Hz average drop that occurs before the high [+ATR] root vowel /i/ in /di/. Since greater F_1 lowering occurs preceding a vowel that is both high and [+ATR] (i.e., /i/) than before one that is high but not [+ATR] (i.e., /ɪ/), it seems clear that some of the F_1 lowering that occurs in the initial vowel of /ɔ-ri-di(di)/ must be due to coarticulatory assimilation to the [+ATR] specification of /i/. Thus, the extent of anticipatory coarticulation for [+ATR] extends beyond the progressive prefix /ri-/ to a preceding vowel.

Though further research, involving a larger number of speakers, is clearly desirable, the facts available at present seem to suggest different patterns of assimilatory behavior in the two cases we have looked at: that of a word-final high [-ATR] vowel preceding a [+ATR] vowel in the following syllable, as in the examples in (10), and that of the vowel of the progressive prefix /ri-/ before a following [+ATR] verb root. The observed differences are intelligible under the assumption that the former case involves categorical [+ATR] spreading in the phonology while the latter involves gradient coarticulation in the phonetics. If on the other hand we are to assume that the phrasal cases in (10) are also coarticulatory in nature, then it is not clear why the two patterns should exhibit the qualitative differences that they do (compare (11) and (12)), especially under the standard assumption that coarticulatory processes are insensitive to the morphological affiliation of target segments.

To sum up, it is far from clear that all cases of leftward spreading of [+ATR] in phrasal contexts in Akan are coarticulatory in nature. Rather, there are good indications that at least some cases of this type are categorical, and hence phonological. In particular, the earlier instrumental study by Hess, various impressionistic descriptions, and the acoustic measurements contributed by the present study all suggest the strong likelihood that certain word-final [-ATR] vowels undergo categorical assimilation to a [+ATR] vowel in a following word. Conceivably, the assimilatory cline effect described by Berry and others would apply to vowels further to the left of the word-final vowel targeted in the phonology. Under the scenario suggested here, this same coarticulatory spreading is also presumed to apply word-internally to the /ri-/ prefix vowel, which is exceptional with respect to phonological spreading of [+ATR], as claimed by Dolphyne.

3.2 [+ATR] ALLOPHONE OF /a/ BEFORE [+ATR] VOWELS

As noted in Section 1 above, most descriptions of Akan report the existence, phonetically, of a variant realization of /a/ (transcribed in this paper as [æ]) that occurs to the left of [+ATR] vowels. In connection with Hess' research findings discussed in Section 3.1.2 above, we have already looked one context in which this [+ATR] variant of /a/ occurs: to the left of a [+ATR] vowel across a word boundary. The [+ATR] variant of /a/ is not limited to this context, however, but occurs word-internally before [+ATR] vowels as well. In this subsection, we will look at the behavior of [æ] from a more general perspective. In addition to being warranted for the sake of completeness, this fuller examination of the low [+ATR] vowel will strengthen the case for categorical leftward spreading of [+ATR], both by revealing additional contexts in which such spreading applies and by providing additional instrumental evidence which, like Hess' results, strongly suggests that realization of /a/ as [æ] is a categorical change.

Setting aside occasional analyses that have taken [æ] to be a tenth vowel phoneme, there are essentially two competing analyses of this sound: 1) it is a categorically distinct allophone of /a/ derived through phonological spreading of

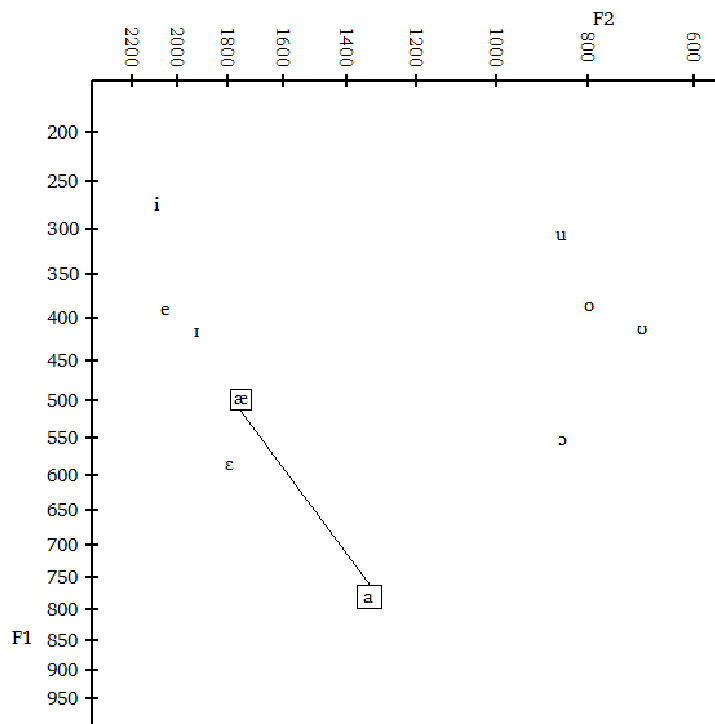
[+ATR] (Dolphyne 1988), or 2) the more [+ATR]-like quality of this vowel is not due to a feature-changing operation in the phonology but is simply the result of gradient coarticulation before a [+ATR] vowel (or before certain palatal(ized) or labio-palatalized consonants) in the following syllable. The latter analysis was first suggested by Clements (1981) and has been assumed in subsequent work such as Archangeli and Pulleyblank (1994, 2007) and McCarthy (2009).

The question of which of the two analyses is correct is of course directly relevant to the larger issue of whether ATR harmony in Akan involves featurally symmetric assimilation of affixes to roots or asymmetric assimilation of [-ATR] to [+ATR] vowels. If [æ] is the result of phonological spreading of [+ATR] from a following [+ATR] vowel onto /a/, the surface distribution of [æ] does not fully follow from the assumption of symmetric bidirectional assimilation of affixes to roots. Such a hypothesis does not account for the complementary distribution of [æ] and [a] root-internally (with the former occurring to the *left* of a [+ATR] vowel or certain palatal(ized) or labio-palatalized consonants and the latter elsewhere), nor does it account for the fact that /a/ in prefixes assimilates to a following [+ATR] root vowel in examples like those in (2a-c) while /a/ in suffixes (in particular, the diminutive suffix [-wa] / [-ba]) does not assimilate to a preceding [+ATR] root vowel. It also has nothing to say about cases where a word-final /a/ surface as [æ] before a [+ATR] vowel in a following word-initial syllable (argued in Section 3.1 above to be categorical, based on the findings of Hess (1992)). If the change from /a/ to [æ] occurs in the phonology, all of the aforementioned examples provide strong evidence of a process of leftward spreading of [+ATR] in the phonology, precisely as proposed by Dolphyne. Thus, in order to maintain the view that ATR harmony in Akan is purely a matter of root-control, it seems necessary to regard the change to /a/ before [+ATR] vowels not as a feature-changing rule of the phonology but as a coarticulatory change that happens in the phonetic component.

There are a number of serious problems with the hypothesis that assimilation of /a/ to a following [+ATR] vowel is a coarticulatory and not a categorical feature changing operation in the phonology. We have in fact already seen one of these in Section 3.1 above: Hess's (1992) study appears to show that assimilation of /a/ before a [+ATR] vowel across word boundaries is categorical and not gradient. A further problem for this hypothesis is the fact that the auditory and acoustic difference between [a] and [æ] is, quite consistently, very large, and of a magnitude that does not seem at all typical of indisputably coarticulatory processes. This is evident in the formant plot below, based on F₁ and F₂ measurements of several (in most cases five) instances of each vowel in sound recordings produced by our Akuapem language consultant.⁸

⁸ For each of the ten vowel qualities with the exception of [e] (for which only three suitable examples were found), five different words in our recorded corpus containing that vowel were selected. Due to the limited number of different words for some vowels, it was not possible to employ a single consistent context in terms of word-position, tone, or manner or place of articulation of adjacent consonants. Word-initial or word-final vowels were used as much as possible to minimize consonantal influence and to promote adequate vowel duration. Adjacent nasal consonants were avoided. Formant measurements were made at a steady-state portion (where such could be identified) near the center of the vowel, using the PRAAT software program.

(13) Formant plot of Akuapem vowels – one adult male speaker



The mean F_1 value (497 Hz) for [æ] is 283 Hz less than the mean F_1 value (780 Hz) for [a]. This seems far too great a difference to attribute the change in vowel quality in this case to coarticulation. That such an F_1 greatly exceeds what would be minimally required to satisfy the demands of a smooth articulatory transition from /a/ to /i/ across an intervening consonant is evident when we compare this result with the results of a study by Przewdziecki (2005) of coarticulatory assimilation of /a/ to following [+ATR] vowels in three dialects of Yoruba. While the degree of mean F_1 lowering in /a/ before a following [+ATR] vowel was found to vary across both speakers and dialects, it did not exceed 32 Hz for any speaker of any dialect (and was typically considerably less) and in most cases did not reach statistical significance. Even allowing that the magnitude of a given coarticulatory effect is to some extent language-specific, it seems unlikely to expect that the coarticulatory effects on F_1 of /a/ due to a following [+ATR] vowel could vary to this degree (almost by a factor of nine) across languages. Thus, if the findings of Przewdziecki's study on Yoruba are indicative of coarticulation, it would appear that the F_1 difference between assimilated and unassimilated /a/ in Akan is a manifestation of something altogether different, i.e., a categorical change from [-ATR] to [+ATR].

Language internal points of comparison exist as well. The difference in mean F_1 values between [a] and [æ] revealed in (13) is actually greater than the F_1 differences between the [-ATR] and [+ATR] vowels found within each of the four contrastive harmonic pairs of vowels, as seen in the following table:

(14)

Harmonic pair	Mean F ₁ for [-ATR] member	Mean F ₁ for [+ATR] member	F ₁ difference
/ɪ/-/i/	415	273	142
/ɛ/-/e/	584	389	195
/ʊ/-/u/	412	305	107
/ɔ/-/o/	552	385	167
/a/- [æ]	780	497	283

If F₁ differences ranging from 142 Hz (in the case of /ɪ/-/i/) to 195 Hz (for /ɛ/-/e/) are indicative of a categorical change in [ATR] value, then there is every reason to believe that the even larger F₁ difference between [a] and [æ] also reflects a categorical difference in [ATR] value. It does not appear that such a difference can reasonably be attributed to phonetic coarticulation.

It is also worth noting that the spacing of the non-low vowels in the F₁ dimension displays a kind of “leapfrog” pattern in which the [+ATR] mid vowels are slightly higher than the high [-ATR] vowels. Such a pattern is understandable if the degree of pharyngeal cavity expansion associated with [+ATR] is sufficiently large (relative to the pharyngeal cavity volume typically associated with [-ATR] vowels) to yield a larger change in F₁ than the change associated with a change in tongue body position from [-high] to [+high].⁹ It is interesting that if the F₁ difference between [a] and [æ] is due to a change in [ATR] value, then low vowels are seen to behave, at least for this particular speaker, in exactly the same way. That is, changing the [ATR] value of a low vowel produces a larger F₁ decrease than changing its value of the feature [low] (as in going from /a/ to /ɛ/ or /ɔ/).

The large F₁ (and F₂) difference between [a] and [æ] suggests the likelihood that the two sounds are auditorily quite different, and this indeed is the case. Prior to discovering its phonological source (/a/), the students in our Trinity Western University field methods course tended to transcribe instances of [æ] as either [ɛ] or [e], and rarely if ever as [a]. They were quite surprised to learn that it is represented as ‘a’ in the Akan orthography, since it seemingly bears little auditory resemblance to the sound [a] as found in [-ATR] contexts. The difference between [a] and [æ] was also clearly perceptible to our Akuapem language consultant, who described [æ] as sounding like the vowel (i.e., /ɛ/) that is written in the orthography as “ɛ,” although he noted that it is written in the Akan orthography as “a”.¹⁰

Other researchers (e.g., Clements 1981, Dolphyne 1988, Stewart 1967) have also noted an auditory similarity of [æ] to [ɛ]. Interestingly, the pronunciation guide in Kotey’s (1998) dictionary of Akuapem Twi describes [æ] as similar to the vowel “e” in the English word ‘they’, and uses the same digraph “ey” to represent both the mid [+ATR] vowel /e/ and the assimilated [æ] variant of /a/. Given the general aims of the dictionary (which is intended in part to aid travelers and other non-native speakers in

⁹ See Casali (2008), Gick et. al. (2006) for relevant discussion. Pattern in which [+ATR] mid vowels are acoustically higher than high [-ATR] vowels for at least some speakers are reported in some other ATR harmony languages as well, e.g., Kinande (Gick et. al. 2006; Starwalt 2008), Lubwisi (Starwalt 2008), Okrika Ijo (Lindau and Ladefoged 1986) and Nawuri (Casali 2002).

¹⁰ Our experience in this regard differs somewhat from that reported by Stewart (1967:86, note 2), who observed that “while Europeans find difficulty in distinguishing [ɜ] [Stewart’s symbol for æ—RC] from [ɛ], speakers of the language find difficulty in distinguishing it from a.”

learning the language), it would likely be a mistake to interpret this transcriptional convention as an implicit claim that the two sounds are, in general, pronounced identically. It does however suggest a rather large and categorical perceptual difference between [a] and [æ], and one that cannot safely be ignored for purposes of language instruction. Even allowing for the fact that coarticulatory process can vary considerably with respect to the perceptual salience of their effects, the consistently large auditory difference between [a] and [æ] in Akan is difficult to reconcile with the notion that we are dealing with a gradient phonetic effect.

A further challenge to the assumption that realization of /a/ as [æ] is phonetic derives from the fact, noted by Clements (1981), that the process is apparently sensitive to morpho-syntactic information. According to Clements (1981:114-116), realization of /a/ as [æ] before high [+ATR] vowels /i/, /u/ occurs in both nouns and verbs in the Asante dialect, whereas realization of /a/ as [æ] before mid [+ATR] vowels /e/, /o/ occurs only in nouns (compare [æ-ko] ‘parrot’, [wa-hodzo mu] ‘he has loosened it’). As discussed in Section 3.1 above, this kind of sensitivity to morpho-syntactic information is not typically expected of purely phonetic coarticulatory processes. Arguably, the fact that it is seemingly necessary to use categorical language in describing the assimilated variant of /a/ as being either present (before mid [+ATR] vowels in nouns) or absent (before the same vowels in verbs) already indicates that something other than gradient coarticulation is at work. That is, there is no indication, in any descriptive source I have come across, that we are talking simply about a *stronger tendency* for /a/ to assimilate a measure of [+ATR] quality from a following [+ATR] vowel in nouns than in verbs. Rather, it appears that we are talking about a change that categorically either does or does not apply, depending on the morpho-syntactic context.

In addition to a consistently large difference in the F₁ dimension, the [a]-[æ] distinction also correlates with a substantial difference (on the order of 400 Hz) in F₂ values. This corresponds, in the perceptual dimension, to reports (cf. Clements 1981:114) that [æ] is auditorily quite fronted with respect to [a]. It does not seem reasonable to attribute this shift in F₂ to coarticulation, both because of the magnitude of the change involved and, perhaps even more interestingly, because the direction of change cannot be consistently understood as induced by anticipatory assimilation to the articulatory configuration required for the following vowel. This is because /a/ is fronted to [æ] not only before front [+ATR] vowels, as in [æ-tʃíʔ] ‘back’, but also before a following back round [+ATR] vowel (a configuration that should entail, all else being equal, a *lowering* rather than a raising of F₂) as well, as in words like [æ-fúrú] ‘donkey’ and [æ-dúrú] ‘medicine’. There is no indication, moreover, of any necessary fronting effect accompanying a change to [+ATR] in underlying /a/ cross-linguistically. With respect to neutralizing assimilation of /a/ to [+ATR] vowels, merger with /e/ (involving concomitant fronting) and merger with /o/ (involving backing and rounding) are both well-attested in nine-vowel languages (see Bakovic 2000, Casali 2008). In the case of non-neutralizing changes (whether allophonic or co-articulatory), several related Tano languages of the Guang subfamily (Casali 1995, Snider 1989, 1990) manifest auditorily raised variants of /a/ before [+ATR] vowels, but without (in contrast to Akan) any perceptible fronting effect.

Though a full account of the fronting effect in the shift from /a/ to [æ] may well pose interesting challenges for any analysis, one reasonable possibility is that it is motivated at least in part by a need to enhance the salience of the perceptual distinction between [a] and its categorically assimilated [+ATR] variant. It seems difficult, in any event, to see how the consistent raising of F₂ associated with [æ] can

be entirely understood apart from some intent on the part of the speaker to produce a large increase in F_2 even in contexts (i.e., before a following back round [+ATR] vowel /**o**/ or /**u**/) where this goes against natural coarticulatory tendencies.

To sum up, the evidence presented above does not support the conclusion that assimilation of /**a**/ to a following [+ATR] vowel in Akan is merely a coarticulatory process affected in the phonetic component, but rather argues very strongly that the process in question involves a categorical change to [+ATR] in the phonology.

3.3 [+ATR] SPREADING IN COMPOUNDS

In addition to leftward spreading of [+ATR] across word boundaries, Akan also has instances of leftward (but not rightward) [+ATR] spreading between adjacent roots in compound words. Some examples, adapted from Dolphyne (1988:24,25) and Berry (1957:128), are shown below.

(15) [+ATR] spreading in compounds

a. / a-bɔ̌-din /	→	[abodin]	(a praise title)
b. / a-sɛm-hunu /	→	[asenhunu]	useless talk
c. / a-hɪnɪ-fie /	→	[ahimfie]	palace
d. / dʒɔ̌n-nini /	→	[dʒɔ̌nenini]	ram
e. / da-du /	→	[dedu]	ten days
f. / a-bɛ-dua /	→	[abedua]	palm tree
g. / a-bu-fuw /	→	[abufuw]	anger

Though such examples have not, as far as I am aware, been explicitly discussed in connection with root-control analyses of Akan vowel harmony, it seems likely that a root-control treatment of ATR harmony in Akan would need to analyze such cases as parallel to the phrasal cases discussed in the preceding section, i.e. as involving gradient coarticulation and not a categorical feature change of [-ATR] to [+ATR]. Optimistically, such cases might turn out to pose no additional problems of principle to those already posed by the phrasal cases.

In fact, however, it is not very clear that [+ATR] assimilation in lexical compounds is actually qualitatively identical to that which occurs in phrasal contexts. The descriptions given by both Berry and Dolphyne suggest that it is not. Both writers are careful to note, in some detail, their belief that leftward spreading of [+ATR] across word boundaries is often partial, while neither provides any indication that assimilation in compounds is anything other than a categorical feature change. This strongly suggests a belief on their part that [+ATR] spreading in compounds is not in fact gradient. The specific wording of Dolphyne's account (1988:24) in particular very naturally suggests that only phrasal assimilation is ever gradient.

It is also interesting to note that Berry specifically claims that the assimilated realization of /**a**/ in compounds such as (15e) is [**e**]¹¹—the same sound that is claimed to result from assimilated /**ɛ**/ in examples like (15f) (also drawn from Berry). (Elsewhere, Berry transcribes the [+ATR] realization of /**a**/ as an underlined vowel [a].)¹¹ This description strongly implies that assimilation of /**a**/ to a following [+ATR] vowel in compounds is not only categorical, but neutralizing. Assuming that the assimilatory

¹¹ Realization of /**a**/ as [**e**] in [+ATR] contexts (a process termed *re-pairing* by Bakovic 2000) is fairly common in nine-vowel [ATR] harmony systems (Casali 2008).

change of /a/ to [e] before [+ATR] vowels in compounds is synchronically productive (the generality of the process is not entirely clear from either Berry's or Dolphyne's description), this provide further potential evidence of systematic assimilation to [+ATR] vowels in Akan.¹²

3.4 INHERENT [-ATR] EFFECTS

Individual descriptions of ATR harmony languages with an [ATR] contrast in high vowels have quite frequently taken [-ATR] (and rarely [+ATR]) to be the underlying value of harmonizing affixes. In some such cases, this decision may well be to some extent arbitrary or motivated primarily by theoretical considerations or precedents set by other work. In a good number of cases however (Casali 2003 and references therein, Casali and Leitch 2002), an intuition that harmonizing affixes are inherently [-ATR] is supported by various (sometimes rather subtle) forms of evidence.

Akan provides an interesting case in point. Several works on Akan have proposed that harmonizing affixes are inherently [-ATR]. Such an analysis is at least implicit in Dolphyne (1988) and weakly explicit in Schachter and Fromkin (1968:56). The claim is expressed most directly however by Stewart (1967:192):

“Whenever, in fact, a prefix is in a harmony span not controlled by the stem, any vowel in that prefix is unraised [i.e., [-ATR]—RC], and this points to the unraised forms of prefixes as the natural base forms, and to the treatment of the raising in terms of assimilation.”

In fact, Akan displays several forms of evidence that potentially supports Stewart's conclusion that harmonizing affixes are underlyingly [-ATR]. These involve cases in which affixes that generally harmonize for [ATR] can also occur in contexts where harmony, for whatever reason, does not apply.

One rather straightforward case of this type involves the fact that subject pronoun prefixes that regularly harmonize when attached to a verb also have corresponding free forms that occur as independent words. These are as shown in the table below, in which the forms cited are drawn from Dolphyne (1988) as well as my own Akuapem data.

(16) Akan pronominal prefixes and independent pronouns

Person & number	Pronominal prefix	Independent pronoun
1 st singular	[mɪ] ~ [mi]	[mɪ]
2 nd singular	[wɔ] ~ [wu]	[wɔ]
3 rd singular	[ɔ] ~ [o]	[ɔnɔ]
1 st plural	[jɛ] ~ [je]	[jɛn]
2 nd plural	[mɔ] ~ [mu]	[mɔ]
3 rd plural	[wɔ] ~ [wo]	[wɔn]

¹² Our own data also contains at least one apparent case of a compound word in which a root-final /a/ has become [e] before a following root with [+ATR] vowels. The word ‘dwarf’, a form composed of the roots /nipa/ ‘person’ and /tia/ ‘short’ is [nɪpɛtiá] in the speech of our Akuapem language consultant.

The independent forms of the pronouns stand in fairly transparent phonological relationships to the corresponding prefixal forms. In three cases, the independent pronoun is exactly identical to one of the allomorphs of the prefix, while in the other cases the pronoun consists of one of the prefix allomorphs plus some additional material. Significantly, each independent pronoun manifests the [-ATR] form of the corresponding vowel in the prefixal form. This fact is highly unlikely to be accidental, especially as very similar patterns are found in a number of other nine-vowel West African languages (e.g., Ahanta; Burmeister 1988, Avatime; Schuh 1995, Chumburung; Hansford 1988, Ebira; Adiva 1989, Ega; Bole-Richard 1981), and is strongly suggestive of the conclusion that the pronominal morphemes in Akan are inherently [-ATR]. If we accept this, then it is possible to state a very simple generalization governing the surface [ATR] values of all the pronominal morphemes, both independent and prefixal: they are [-ATR] except in contexts where their [+ATR] value is plausibly derived via spreading from a [+ATR] vowel to their immediate right.

Such a statement also accounts straightforwardly for the fact that object pronouns in Akan, which always occur to the right of the verb root, are consistently [-ATR]. Under an analysis that views Akan ATR harmony as due simply to bidirectional and word-internal spreading of (either value of) [ATR] from roots to affixes, this fact is not necessarily expected and requires some independent explanation.

Further evidence that harmonizing subject pronoun prefixes are inherently [-ATR] comes from their behavior in hyper-careful pronunciations of utterances. When sentences with [+ATR] forms of harmonized pronouns (i.e., preceding a [+ATR] verb) are said with clear pauses between morphemes, they show up in a [-ATR] form in the speech of our language consultant, as in the example below:

- (17) a. Normal speech: [wú-dí?] you (sg.) eat
 b. Hyper-careful speech: [wó-dí?] " "

Other, similar, examples occur in our sound recordings as well. The relevant generalization in Akan is precisely the one described by Stewart: harmonizing affixes either agree in their [ATR] value with that of the root or else (in contexts where harmony is inapplicable) are phonetically [-ATR].

There is yet one other non-harmonic context in which regularly harmonizing affixes sometimes occur in Akan, illustrated by examples such as [wɔ-bɛ-kæri] (Dolphyne 1988:22) ‘they will weigh it’. In this example, the first morpheme is the third person plural subject pronoun prefix, while the second is the future prefix. In other contexts, both of these morphemes regularly harmonize for [ATR] with a following verb root in Akan (compare [wɔ-bɛ-nóm] ‘they will drink’, [wɔ-bɛ-dí] ‘they will eat’). It appears quite clear that the failure of [+ATR] to spread leftward to these harmonizing prefixes in [wɔ-bɛ-kæri] must be due (cf. Clements 1981) to a blocking effect, which holds quite generally in Akan, of the underlying low vowel /a/ found in the first syllable of the verb /kari/ ‘weigh’. Without exception, the low vowel /a/ blocks leftward spreading of [+ATR] in Akan from a following [+ATR] vowel. That is, whenever /a/ occurs between an underlying non-low [-ATR] vowel to its left and an underlying non-low [+ATR] vowel to its right, the vowel to its left always remains [-ATR] on the surface. Such opacity of low vowels is quite common in nine-vowel ATR harmony languages (Casali 2008 and references therein) and has regularly been analyzed as due to the overriding influence of a very well motivated

constraint against [+ATR] low vowels. What is most unusual about the Akan case, however, is that although the constraint in question is not in fact observed on the surface, since /a/ actually becomes [+ATR], we nevertheless continue to find that the preceding vowel remains [-ATR].

Understanding this pattern is not particularly easy under most theoretical models. In fairly standard OT accounts, for example, we can easily understand prototypical opacity of /a/ to leftward spreading of [+ATR] as due to undominated ranking of a constraint *[+low,+ATR] against low [+ATR] vowels. However, given that this constraint must in any case be violated by the attested surface form [wɔ-bɛ-kæri] in Akan, it is not clear why [+ATR] does not spread all the way to the left edge of the word (which would of course entail no further violations of *[+low,+ATR]), in satisfaction of whatever constraint (e.g., ALIGN(ATR,left)) is responsible for normal harmonization of the same prefixes in examples like [wɔ-bé-díʔ]. That is, given that *[+low,+ATR] is violated by the change from /a/ to [æ], so that a [+ATR] vowel appears to the immediate right of the future prefix [bɛ-] ~ [be-] on the surface, failure to harmonize this prefix (and the regularly harmonizing third person plural subject prefix to its left) appears to lead to gratuitous violations of the harmony constraints.

Of course, if it were the case that the change from /a/ to [æ] occurred in the phonetics and not the phonology, examples like this would pose no great problem. The output of the phonology under this view would be simply [wɔ-bɛ-kari], in which no violation of *[+low,+ATR] occurs. Thus, the coarticulation analysis, if it could be maintained, would potentially simplify the phonological analysis significantly. The failure of [+ATR] to spread left to the prefixes in [wɔ-bɛ-kari] could straightforwardly be attributed to the blocking effect of the (highly ranked) constraint *[+low,+ATR]. As we have seen, however, the view that assimilation of /a/ to [æ] is coarticulatory does not appear to be tenable, and thus we must accept that the output of the phonological component is one in which the normally harmonizing prefixes immediately precede a [+ATR] root vowel [æ] in the surface form, yielding a disharmonic [-ATR] [+ATR] sequence.

It would appear that constructing a fully adequate account of such cases (for which the term *incomplete opacity* might perhaps be appropriate) poses interesting and non-trivial challenges for many current OT frameworks.¹³ What is primarily relevant for our present purposes, however, is the simple fact that, in surface forms of the [wɔ-bɛ-kæri] type, normally harmonizing pronouns surface disharmonically in their [-ATR] allomorphs to the left of a [+ATR] vowel. In such cases, the surface [-ATR] value of these prefixes clearly cannot be straightforwardly attributed to harmony with a following verb root, since no [-ATR] root vowels in fact follow. The pattern conforms straightforwardly however to Stewart's generalization that harmonizing prefixes are consistently [-ATR] outside harmony spans. Under his assumption that such prefixes are inherently [-ATR], it is fully to be expected that their [-ATR] allomorphs will surface in all contexts where [+ATR] spreading should, for whatever reason, fail to affect them. And this is what we find, both in Akan, and in other ATR

¹³ While attempting to provide a full and detailed solution to this challenge is beyond the scope of this paper, I suggest that one reasonable approach to the problem might be to assume that harmony arises in response to a constraint that requires a vowel to be [+ATR] if followed by a *non-low* [+ATR] vowel. Such constraint is fully satisfied by the form [wɔ-bɛ-kæri], since the [-ATR] vowel [ɛ] in the second syllable is followed by a low, rather than a non-low, [+ATR] vowel. An analysis along these lines potentially accounts for the fact that low [+ATR] vowels in Akan are regularly preceded by [-ATR], not [+ATR] vowels (i.e., there is no leftward spreading from low [+ATR] vowels in the language).

harmony languages with an [ATR] contrast in high vowels (Anderson 1980, Casali 2003, Casali and Leitch 2002).¹⁴

If, as the preceding discussion suggests, harmonizing affixes in Akan are inherently [-ATR], then there is good reason to regard regular affix harmony as simply a further instance of the same asymmetric assimilation to [+ATR] vowels seen elsewhere in the language.

3.5 A DOMINANT [+ATR] SUFFIX?

Though Akan is generally described as a root-controlled harmony language, it has at least one potential case of a dominant [+ATR] suffix, a suffix */-ni/* that is seemingly related to a root meaning ‘person’ (Dolphyne 1988:84). Some examples (drawn from Dolphyne 1988:84 and data supplied by our Akuapem language consultant) illustrating the behavior of this suffix are shown below.

(18) Leftward [+ATR] spreading from */-ni/*

- | | | | |
|----------------------------|---|-------------------------|--------------------------------|
| a. <i>/late-ni/</i> | → | [lateni] | citizen of Larteh ([late]) |
| b. <i>/o-sika-ni/</i> | → | [osikaɛni] | rich person (cf. [sika] money) |
| c. <i>/ɔ-tʃɪɛ-tʃɪɛ-ni/</i> | → | [ɔ̃tʃɪɛ̃tʃɪɛ̃ni] | teacher (cf. [tʃɪɛ] show) |

There is no indication in Dolphyne’s description that the assimilation of preceding [-ATR] vowels to the [+ATR] value of */-ni/* is anything other than categorical assimilation to [+ATR]. Though it is not possible, in the absence of relevant instrumental studies, to absolutely exclude the possibility of gradience, it would be equally premature at this point to assume that the process is not feature changing and phonological. If Dolphyne’s description and transcriptions are accepted at face value, then this appears to be yet a further manifestation of anticipatory spreading of [+ATR] in Akan.

A question that is more difficult to answer is whether the morpheme */ni/* is to be analyzed as a root or a suffix synchronically. A possible analysis of the forms in (18) is that they are compounds in which */ni/* occurs as the rightmost root. Since we have already seen instances of leftward [+ATR] spreading in such compounds, the patterns exhibited by the examples in (18) would not, under this analysis, be unexpected. This analysis is rendered all the more plausible by the existence of an independent noun *[oni]* ‘person’ (Dolphyne 1988:84). Tentatively, I follow Dolphyne (see also O’Keefe 2003) in analyzing */ni/* as a suffix.

4. THE PHONOLOGICAL RELEVANCE OF GRADIENT [+ATR] SPREADING

We have seen considerable evidence that, in addition to some [+ATR] spreading that appears to be gradient and coarticulatory (see Section 3.1 above), Akan has clear instances of categorical [+ATR] spreading as well. Thus, even if spreading of the former sort can be treated as a matter of phonetic implementation, not all [+ATR] spreading can be relegated to the phonetic component. Categorical [+ATR] spreading must be phonological.

Interestingly, however, it can be argued that even those instances of [+ATR] spreading which are gradient and coarticulatory (and hence phonetic) are indirectly relevant to the question of whether [+ATR] is the phonologically active or dominant value. As Archangeli (2011) points out, the behavior exhibited by such spreading

¹⁴ In languages in which [ATR] is contrastive only in non-high vowels, as in the common seven-vowel inventory */ieɛaɔou/*, harmonizing affixes more typically show up in a [+ATR] form in contexts where harmony fails to apply (Casali 2003, Casali and Leitch 2002, Leitch 1997).

strongly suggests that only [+ATR], and not [-ATR] values are specified in the output of the categorical phonology that (under fairly standard assumptions) constitutes the input to a phonetic interpretation module. Under the assumption that only [+ATR] is specified in the output of the phonology, the very striking spreading of [+ATR] quality along an assimilatory cline reported by Berry and others (and seemingly found in our own data as well; see Section 3.1.2 above) is a very natural and expected state of affairs. It is widely assumed (e.g., Keating 1990), that specified feature values correspond to articulatory targets that a speaker aims to reach. Segments unspecified for a particular feature lack such an articulatory target; they are not required to possess the gesture corresponding to that feature value, but neither are they prevented from possessing such a gesture or required to manifest its absence or opposite. Because they lack any articulatory target of their own for the relevant feature, they are free to take on whatever articulatory value facilitates efficient achievement of the articulatory targets that are specified on other segments. What this means, in cases in which a [+ATR] vowel is preceded by a span of [ATR]-unspecified (i.e., “[-ATR]”) vowels, is that the featural representations of the non-[ATR] vowels impose no articulatory requirements on tongue root position; consequently, we might expect there to be a relatively smooth articulatory trajectory in which the tongue root approaches its eventual target value, i.e., an advanced position appropriate to a [+ATR] vowel, gradually.¹⁵ Plausibly, such a trajectory is optimal in terms of articulatory effort and planning (since it minimizes abrupt articulatory transitions that might require more effort and/or temporal precision). Nor, in the absence of any articulatory target specifications (i.e., [ATR] feature values) on the preceding “[-ATR]” vowels, are there any representational requirements that might conflict with such an implementation scheme. (Under this view, the phonetic quality that occurs on [-ATR] vowels in the absence of any following [+ATR] vowels would be understood as the manifestation of a neutral or default articulatory setting.)

From this perspective, it is not difficult to make sense of an F_1 temporal pattern like that in (12) above, in which the F_1 contour of the progressive prefix vowel /*r̩*/ in the utterance /*ɔ-r̩-dĩdĩ*/ ‘he/she is eating’ begins at value that is already much lower than those typical of /*ɪ*/ in non-assimilatory contexts and moves closer toward a value appropriate to /*ĩ*/ over the course of the vowel. The only articulatory goal imposed on the speaker is the need to achieve an appropriate target for [ĩ] by the beginning of the first vowel of the verb. If achieving this target with minimal articulatory effort can be facilitated by a very early onset of tongue root advancement, there is nothing to prevent this.

Note however that this picture is coherent only under the assumption that the vowel of the progressive prefix lacks a specified [-ATR] target. If it did have such a target, we would presumably expect, all else equal, that this target would have been achieved, or at least closely approached at some point during the prefix vowel. Even near the beginning of the vowel, however, the F_1 values, though higher than those of the /*ĩ*/ vowel in the following syllable /*dĩ*/, are already far lower than those typical of [ĩ] in non-assimilatory contexts (which commonly exceed 400 Hz). It thus appears that, far from being simply irrelevant to phonological issues, gradient spreading of [+ATR] in Akan is potentially indicative of a significant asymmetry in the status of [ATR] values, as it seems to require the assumption that only [+ATR] specifications are present in the output of the phonology.

¹⁵ Instrumental studies such as Lindau (1987) and Tiede (1996) suggest that other gestures besides tongue root displacement (e.g., larynx lowering) are also implicated in the production of [+ATR] vowels. For expository simplicity, I ignore these additional gestures here.

5. CONCLUSION

Although Akan has frequently been referred to as an example of a language whose ATR vowel harmony is based on a root-control rather than dominance of [+ATR], there are a number of strong indicators to the contrary. We have looked at several forms of evidence of asymmetric assimilation to [+ATR] vowels, including leftward spreading of [+ATR] across word boundaries (not all of which is clearly analyzable as gradient coarticulation), leftward spreading of [+ATR] in compounds, the existence of a categorically distinct [+ATR] allophone of /a/ before [+ATR] vowels, the fact that pronouns, which generally harmonize with a following verb root, are consistently [-ATR] in contexts where harmony is inapplicable (e.g., in their independent forms), and the possible existence of a dominant [+ATR] suffix /-ni/.

At various points, phonological processes or requirements in Akan must refer to the feature value [+ATR], either by spreading its domain or prohibiting it in some context (e.g., in the non-harmonized forms of pronouns). In traditional terms, [+ATR] clearly behaves as the marked value. In contrast, [-ATR] is inert, behaving in various respects as the absence of a [+ATR] specification. It does not spread and, as aptly described by Stewart (1967), can readily be analyzed as the [ATR] value that surfaces by default, e.g., it is the value that surfaces on all pronouns or pronominal affixes that do not precede [+ATR] vowels. As argued in Section 4, the activity of [+ATR] vowels and inertness of [-ATR] vowels is even reflected in gradient, coarticulatory assimilation, which can be simply described in terms of smooth trajectories toward specified [+ATR] targets, with no apparent need to refer to [-ATR] target values. In all, there is very strong evidence that [+ATR] functions as the active, dominant value in Akan.

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