This paper demonstrates that the phonetic vowel sequences of Konni can be analyzed as a diphthongization of long mid vowels. Evidence from phonetics, phonological rules, and tone is cited to support this conclusion. The vowel harmony system of Konni is reviewed and underspecification of features is seen to play a crucial role in explaining vowel harmony. Vowel harmony and underspecification are combined with the coindexing concept of Bruce Hayes to account for diphthongization in Konni. (Author/MDM)
In this paper, I demonstrate that the phonetic vowel sequences of Konni can be analyzed as a diphthongization of long mid vowels. Evidence from phonetics, phonological rules, and tone is cited to support this conclusion. The vowel harmony system of Konni is reviewed and underspecification of features is seen to play a crucial role in explaining vowel harmony, (in particular, that /a/ is unspecified for [low]). Vowel harmony and underspecification are combined with the coindexing concept of Hayes (1990) to account for diphthongization in Konni.

1. Introduction to the Konni vowels

The problems of analyzing vowels of Guran languages are well-known to those who work among them. The bulk of the difficulty in Konni comes in the analysis of the mid vowels, which manifest themselves in diverse and initially confusing ways.

The nine vowel phonemes of Konni divide into two harmony sets based on the Advanced Tongue Root feature:

(1) [+ATR] i u e o
    [-ATR] u e a

With very few exceptions, all vowels in a simple (i.e. non-compound) word come from only one of the two sets:

(2) [+ATR words] suull 'be full' júull 'climb'
    bitièn 'beard' tóbi 'pierce'
    tókórósí 'windows' kúrúba 'cooking pot'.

The vowel harmony extends to all affixes of a word, for example:
### Nouns: articles and plural markers

<table>
<thead>
<tr>
<th>+ATR</th>
<th>-ATR</th>
</tr>
</thead>
<tbody>
<tr>
<td>tīgī-řī</td>
<td>'the house'</td>
</tr>
<tr>
<td>sīlē-řū</td>
<td>'the path'</td>
</tr>
<tr>
<td>dūmō-šō</td>
<td>'the horse'</td>
</tr>
<tr>
<td>dūn-ē-hē</td>
<td>'the knees'</td>
</tr>
<tr>
<td>tōkōrō-sī-sī</td>
<td>'the windows'</td>
</tr>
<tr>
<td>kūn-tī-tī</td>
<td>'the funerals'</td>
</tr>
</tbody>
</table>

### Verbs: aspect markers

<table>
<thead>
<tr>
<th>+ATR</th>
<th>-ATR</th>
</tr>
</thead>
<tbody>
<tr>
<td>kūrī-yē</td>
<td>'has pounded'</td>
</tr>
<tr>
<td>chii-mē</td>
<td>'carry!'</td>
</tr>
<tr>
<td>sūgur-ē</td>
<td>'is washing'</td>
</tr>
<tr>
<td>tū-ō</td>
<td>'is digging'</td>
</tr>
<tr>
<td>dīgī-wō</td>
<td>'cooked'</td>
</tr>
</tbody>
</table>

Note that instead of the expected e/ε and o/ɔ variations, there are several cases of e/a and o/a alternations. This point will be returned to below.

## 2. A problem of interpretation

Though the short vowels present challenges of their own, this paper will focus on the problem presented by long vowels and phonetic vowel sequences.

Long vowels which are low ([aa]) and high ([ii], [uu], [uu]) are unambiguously attested:

(5)

| dāāŋ  | "wood"  |
| hāāqīŋ  | "bush"  |
| kplīlīŋ  | "ancestor"  |
| bōntbūŋ  | "toad"  |

Long mid vowels are rare, with gbēęŋ "a pot" being one of the few clear examples.

More frequent than long mid vowels are various vowel combinations:

(6)

| bitiēŋ  | "beard"  |
| jūŋ  | "room"  |
| li̞-āŋ  | "ax"  |
| chēaŋ  | "waist"  |

The question is, how are these phonetic vowel sequences to be interpreted phonologically? There are three possibilities: as phonemic vowel sequences, as vowel-glide-vowel sequences, and as diphthongs.

The distribution of the vowels within the "sequence" argues against phonemic vowel sequences. There is only a fraction of the possible vowel sequences represented; only 7 out of 32 possibilities for heterogeneous vowel sequences, taking ATR harmony into account, are attested. Furthermore, V2 is never a high vowel, whereas V1 is almost always so.
Interpretation as a glide sequence or diphthong seems more promising, and we turn now to those possibilities.

3. A glide sequence or not?

3.1 Arguments favoring glide presence

Arguments in favor of the presence of a glide center around two factors: the suspect nature of the sequences, and CV patterns of related languages.

First, a pattern that forces us to consider the possibility of a glide between the two vowels is that V1 of the apparent sequence is almost invariably high. As a general principle, it is difficult to hear the difference between [La] and [lya], between [ua] and [uwa]. If in fact a glide were present, that would mean what I have cited as [l'ąn] should rather be [l'tyń], and [dąń] would be [dówń].

Second, related languages where adequate analysis is available indicate that the most common syllable patterns for Gur are CV and CVV, VV indicating a long homogenous vowel. These are also unambiguous syllable patterns in Kònni. Interpreting the "sequences" as disyllabic, with the glide as the consonant of the second syllable, would fit nicely into this pattern.

The above considerations are not language-specific evidence, but comprise fairly strong pressure from phonetic universals and areal features. In the absence of more specific evidence, these would tip the scales toward the glide interpretation. However, there are several pieces of evidence within Kònni which oppose the glide theory.

3.2 Arguments against glide sequence

3.2.1 Evidence from phonetics

There are definitely [lya] sequences in Kònni. /ya/ is the perfective suffix on verbs, as in [gā-yą] 'has gone,' [kpätt-yą] 'has finished.' There is in fact a slight phonetic difference between this [lya] and the sequences under consideration, many of which are monomorphemic. [la] has more of a unitary nature; the [l] is more transitory, being almost an on-glide.

The difference between [la] and [lya] is also supported by instrumental timings, in which eight samples of /lya/ had an average duration of 0.30 seconds, while six samples of /la/ had an average duration of 0.24 seconds. For [+ATR] forms, for which [e] is the counterpart of [a], the average times were 0.33 seconds for five samples of /ie/ and 0.24 seconds for eight samples of /ie/. All test cases involved morpheme boundaries at the end of words, e.g. [kpätt-yą] 'have nailed,' [sitl-yę] 'have poured,' [sî-ą] 'type of fish (pl.),' [bî-ę] 'goats'.

Additional measurements in nouns show that both homogeneous long vowels (aa, ii, u, uu, uu) and putative...
vowel sequences (τa, ie, ua, uo) had the same average duration of 0.19 seconds. These were all in the first syllable of disyllabic words, between stops.

### 3.2.2 Evidence from variability

Pronunciation of the [τya] sequences is constant, but I have heard quite a lot of variation in the [τa]/[ie] sequences, for example:

(7)  
[kpIθaŋ] ~ [kpIθŋ] ~ [kpIθŋ]  "chicken" (pl. [kpIθς]);  
[gBIθŋ] ~ [gBIθŋ]  "pot"  

These variations can be explained in terms of well-motivated rules, as discussed below.

### 3.2.3 Evidence from tone

Tonal evidence also precludes the possibility of the glide solution. Konni allows rising and falling tones only on the last syllable of a word. I assume these glides comprise a tone sequence:

(8)  
L H H H L  H L  Note these are short  
L H H H L  H L  vowels, and bear a  
/tan/  /kuruba/  /kpi/  maximum of 2 tones.  

[tan]  [kuruba]  [kpi]  
'stone' 'pot' 'die'  

Long vowels also bear a maximum of 2 tones:

(9)  
[dαŋ]  'wood'  [yI'Iŋ]  'arrow'  [bʊntʊŋ]  'toad'  

When the definite article is added to a word like those above, the long vowel no longer has two tones:

(10)  
a.  [dαŋ]  "wood"  [dα-a-kʊ]  "the wood"  
   L H  L H  
   L H  /
   daan  daaku  

b.  [yI'Iŋ]  "arrow"  [yI-I'ri]  "the arrow"  
   H L H  H L H  
   /
   yI'Iŋ  yI'Iri
I interpret this as the tones re-associating to maintain the Konni prohibition against contour tones on non-word-final TBU's.

Therefore the unit that bears tone in Konni is the syllable, not just the vowel or mora. A syllable can bear one or at most two tones. Syllables can have either short or long vowels, with or without a nasal coda, but the same restriction holds on all types of syllables.

So the question: do words like [l̂áŋ] 'ax' act tonally like they have two syllables, which means a /y/ could be present, or do they act like one syllable?

Tonally, they behave exactly like the unambiguous long vowels:

1) The "second vowel" never has a rising or falling tone, such as *[blāŋ].
2) When the definite article is added to a mono-syllabic noun, the second tone associates with the article rather than the root:

(11)

a. chíāŋ "waist"  chīā-口腔 "the waist"
   
   1 H                     1 H
   |                     |
   chíāŋ                chíā-口腔

b. l̂áŋ "ax"  l̂ā-口腔 "the ax"

   H LH                        H LH
   |                     |
   l̂āŋ                l̂ā-口腔

This tonal data shows that phonetic vowel sequences act like single syllables. If so, then a glide /y,w/ cannot be present, since that would make such a sequence two syllables.

4. A solution - all sequences from long mid vowels

The above has established that both long vowels and phonetic vowel sequences are single syllables and so the phonetic vowel sequences do not contain a glide. I want to go a step further and claim all phonetic vowel sequences come from underlying long mid vowels, that is:

(12)

/ee/ --> [ie]
/ɛɛ/ --> [ia, e, iɛ]
/oo/ --> [uo]
/ɔɔ/ --> [ua, uɔ]

One of the reasons is, of course, that the variations cited in (7) include long mid vowels. There is no reason to posit an abstract solution in this case. One of the cited forms can be taken as basic and the others derived from it.
Another reason for taking the long mid vowels to be basic rather than the vowel sequences is the comparative evidence from related languages (e.g. Mampruli). In several of these, Naden cites /ɛ,ɔ/ becoming [ya,wa], very close to what I am positing here (Naden 1988:22, 1989:154).

Finally, as noted before, there is a marked scarcity of phonetic long mid vowels, but plenty of the "vowel sequences" in question. The process above (12) explains this distributional gap, showing that long mid vowels generally manifest themselves as diphthongs.

The alternations in the above data can be accounted for by three optional rules. The first two are specific to the long vowels under discussion, while the third is needed independently to account for variation in short vowels. For convenience, I will formulate these in linear terms at this point.

The first rule, Konni diphthongization, may be written informally as:

(13) Diphthongization (informal):

\[
\begin{align*}
\text{ee} &\rightarrow \text{ie} & \text{Note: all vowel sequences are in same ATR harmony set.} \\
\text{ɛɛ} &\rightarrow \text{ta} \\
\text{ʊʊ} &\rightarrow \text{uo} \\
\text{ɔɔ} &\rightarrow \text{va} \\
\end{align*}
\]

It may seem unusual that /ɛɛ,ɔɔ/ would diphthongize to [ya,wa] rather than [Lɛ,Lɔ]. However, as noted in Section 1, the ATR pairs a/e and a/o are well-attested in several suffixes, e.g.:

(14) -ATR +ATR

\[
\begin{align*}
\text{jūbi-kā} &\quad \text{'the knife'} & \text{dēmbi-kē} &\quad \text{'the man'} \\
\text{dārā-hā} &\quad \text{'the days'} & \text{dūnē-hē} &\quad \text{'the knees'} \\
\text{ʊ sī-yā} &\quad \text{'he has bathed'} & \text{ʊ sī-ʋē} &\quad \text{'he has danced'} \\
\text{yī-ʋā} &\quad \text{'give him'} & \text{yīgī-ʋō} &\quad \text{'catch him'} \\
\text{yā-ʋā} &\quad \text{'have-EMPH'} & \text{kēŋ-ʋō} &\quad \text{'come-EMPH'} \\
\text{kō-ā} &\quad \text{'is killing'} & \text{tū-ɔ} &\quad \text{'is digging'} \\
\end{align*}
\]

A more formal account and explanation of the ATR variation and diphthongization rule will be given in Sections 5 and 6, respectively.

The next rule is needed to account for variations such as [kp(āŋ)] - [kpēaŋ] "chicken," where the first vowel lowers:

(15) Lowering: (optional)

\[
\begin{align*}
\text{V} &\rightarrow [\text{-high}]/\underline{\text{V}} \\
&\rightarrow [\text{+low}].
\end{align*}
\]

As far as I know, this process occurs only when vowels are adjacent. The rule as written would give ta --> ɔa as
above, and also \( \text{ua} \rightarrow \text{ja} \), though I have no clear cases of the latter yet.

The third rule involves a fronting of /a/ when followed by /\text{\textasciitilde}l/ in the next syllable:

(16) Fronting of a (optional)

\[
\begin{align*}
\text{V} & \rightarrow [-\text{back}] / \_ \_ \text{C} \_ \_ \text{V} \\
[+\text{low}] & [-\text{back}]
\end{align*}
\]

That is, /a/ \( \rightarrow [\varepsilon] \) before /\text{\textasciitilde}l/, and presumably /\varepsilon\text{/}, though I have no cases of the latter. (The vowel I have transcribed as [\varepsilon] here can sometimes be phonetically lower as well, thus the rule refers to [\text{back}] as the changed feature and not necessarily to height.) This rule is needed independently in the case of short vowels in separate syllables:

(17) \( \text{y\'as\'i} \rightarrow \text{y\'esi} \) 'salt'
\( \text{b\'al\'ik\'a} \rightarrow \text{b\'el\'ik\'a} \) 'language'

It also explains the variations in the vowels under consideration here:

(18) \( \text{p\text{\textasciitilde}as\text{\textasciitilde}} \rightarrow \text{p\text{\textasciitilde}cs\text{\textasciitilde}} \) 'ask'

Here are derivations of the several attested forms of /\text{kpe\'en}/ 'chicken' and /\text{kpe\'esi}/ 'chickens':

(19)

<table>
<thead>
<tr>
<th>Underlying: /\text{kpe'en}/</th>
<th>/\text{kpe'en}/</th>
<th>/\text{kpe'en}/</th>
<th>/\text{kpe'esi}/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diphthong. -</td>
<td>\text{kpe'an}</td>
<td>\text{kpe'an}</td>
<td>\text{kpe'ast}</td>
</tr>
<tr>
<td>Lowering</td>
<td>-</td>
<td>-</td>
<td>\text{kpe'an}</td>
</tr>
<tr>
<td>Fronting</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Surface</td>
<td>[\text{kpe'en}]</td>
<td>[\text{kpe'an}]</td>
<td>[\text{kpe'an}]</td>
</tr>
</tbody>
</table>

5. Underspecification and Vowel Harmony in Konni

To explain the workings of diphthongization in Konni, it is first necessary to review the workings of vowel harmony and the role underspecification plays in it.

Recall that affixes of verbs and nouns harmonize with the root. Besides the usual alternations involving only the [ATR] feature, suffixes with /a/ alternate with /\text{\textasciitilde}e/ and /\text{\textasciitilde}o/:

(20) (reproduced from (4))

\begin{align*}
\text{chil-m\'e} & \ 'carry!' & \text{d\text{\textasciitilde}u-m\'a} & \ 'bite!' \\
\text{s\text{\textasciitilde}ug\text{\textasciitilde}r-\'e} & \ 'is washing' & \text{p\text{\textasciitilde}g\text{\textasciitilde}il-\'a} & \ 'is holding' \\
\text{t\text{\textasciitilde}u-\'o} & \ 'is digging' & \text{k\text{\textasciitilde}b-\'a} & \ 'is killing' \\
\text{d\text{\textasciitilde}ig\text{\textasciitilde}w\text{\textasciitilde}o} & \ 'cooked' & \text{g\text{\textasciitilde}a-\text{\textasciitilde}w\text{\textasciitilde}a} & \ 'went'
\end{align*}
These data are analyzed in Cahill (in preparation), which I summarize here. To explain the alternations present, I invoke the concept of Radical Underspecification, as expounded in Archangeli (1988) and applied in Pulleyblank (1986). The latter’s analysis of Ōkpe is very similar to what is proposed for Konni, and my analysis is indebted to his in large measure.

In Radical Underspecification, all values of features which are predictable are deemed unnecessary in underlying representation. Only one value of any particular feature is allowed to be present underlyingly; the other value is inserted by a redundancy rule. In Konni, the full inventory of features for vowels is:

(21) FEATURE SPECIFICATIONS FOR KONNI VOWELS:

<table>
<thead>
<tr>
<th></th>
<th>i</th>
<th>e</th>
<th>e</th>
<th>a</th>
<th>o</th>
<th>o</th>
<th>u</th>
<th>u</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACK</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>ROUND</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>HIGH</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>LOW</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ATR</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

The values of [back] are derivable from [round] and [low]. They have been omitted below for clarity of presentation. The following redundancy rules are applied (for a justification of these particular rules, see Cahill (in preparation)):

(22) Redundancy rules for Konni vowels:

- lexical: [+round] --> [-low]
- [+ATR] --> [-low]
- post-lexical: [
- ] --> [+high]
- [ ] --> [-ATR]
- [ ] --> [-round]
- [ ] --> [+low]

Once redundancy rules have begun to apply, they are assumed to apply throughout the course of a derivation, whenever they can. Taking these rules into account, the matrix in (21) is reduced to:

(23) UNDERLYING SPECIFICATIONS OF KONNI VOWELS:

<table>
<thead>
<tr>
<th></th>
<th>i</th>
<th>e</th>
<th>e</th>
<th>a</th>
<th>o</th>
<th>o</th>
<th>u</th>
<th>u</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROUND</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIGH</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LOW</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ATR</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

As will be seen, the crucial aspect of the above for vowel harmony is that /a/ is unspecified for [low]. I assume that /a/ is the underlying segment in such cases, and the
interaction of spreading and redundancy rules accounts for its alternation with /e/ and /o/.

To account for the a/o alternation in suffixes, we note that /o/ in such alternations occurs only directly after either a /u/ or /w/. Therefore a rule of Round Spread is also needed:

(24) Round Spread
[+round]
     \ X V
     \ [-low]
     \ X may be either vowel or glide.

The derivation of [tʊ̀] 'is digging' and [kʊ̀] 'is killing' follows. The representations below are intended to be abbreviated forms of a full hierarchical feature tree (see (27)). Nothing crucial hinges on the hierarchy here, so the relevant nodes and also tone are omitted for conciseness and clarity.

(25) Derivation of [tʊ̀] and [kʊ̀]

a. Underlying forms, ATR association:

\[ \begin{array}{c}
+\
\hline
\begin{array}{c}
+\text{A} \\
+\text{rd} \\
t + \text{V}
\end{array}
& \begin{array}{c}
k + \text{V}
\end{array}
\end{array} \]

\[ \begin{array}{c}
+\text{rd} -\text{hi}
\end{array} \]

b. Imperfective /-A/ affixation, with ATR spread:

\[ \begin{array}{c}
+\text{A} \\
\hline
\begin{array}{c}
+\text{rd} -\text{hi} \\
t + \text{V} + \text{V}
\end{array}
& \begin{array}{c}
k + \text{V} + \text{V}
\end{array}
\end{array} \]

\[ \begin{array}{c}
+\text{rd} -\text{hi}
\end{array} \]

c. Lexical redundancy rules:

\[ \begin{array}{c}
+\text{A} \\
\hline
\begin{array}{c}
+\text{rd} -\text{hi} \\
t + \text{V} + \text{V}
\end{array}
& \begin{array}{c}
k + \text{V} + \text{V}
\end{array}
\end{array} \]

\[ \begin{array}{c}
+\text{rd} -\text{hi} \\
-\text{lo} -\text{lo}
\end{array} \]
d. Round Spread:

\[
\begin{array}{c|c}
+A & +A \\
\hline
+rd & -hi \\
-ld & -lo \\
\end{array}
\]

\[
\begin{array}{c|c}
k & +rd \\
\hline
V & +V \\
V & -hi \\
\end{array}
\]

e. Post-lexical redundancy rules:

\[
\begin{array}{c|c}
+A & +A \\
\hline
+rd & -rd \\
-ld & +lo \\
+hi & -hi \\
\end{array}
\]

t \quad \quad t \\
\hline
V & V
\]

[kua]

6. Coindexing

Recall that diphthongization process in Konni is:

\[(26)\]

<table>
<thead>
<tr>
<th>+ATR</th>
<th>set</th>
<th>-ATR</th>
<th>set</th>
</tr>
</thead>
<tbody>
<tr>
<td>front</td>
<td>ee --&gt; ie</td>
<td>ee --&gt; ie</td>
<td></td>
</tr>
<tr>
<td>back</td>
<td>oo --&gt; uu</td>
<td>oo --&gt; uu</td>
<td></td>
</tr>
</tbody>
</table>

The challenge is to represent these changes as a unitary process. The a/e and a/o alternations in vowel harmony above depended on having the vowel /a/ unspecified for most place features, particularly [low]. The diphthongization process likewise depends on removing most place feature specifications from the second V. In addition, diphthongization makes the first V [+high]. To specify this, I will use Hayes' format of coindexing.

A tree model of feature organization was proposed by Clements (1985), and modified by Sagey (1986) and others. The idea is to relate all features autosegmentally to a skeleton position (or CV position, depending on your theoretical preference), while at the same time incorporating the grouping of certain features together. Though the basic idea of grouping features in hierarchical trees is now widely accepted, the exact structure continues to be a matter for further research. One version of this tree, adapted and abbreviated from Archangeli & Pulleyblank (1989), is shown below. Capitals indicate nodes, and features are indicated by the usual brackets.
Hayes (1990) has pointed out that this model (and by implication, its CV phonology predecessor) suffers from a serious defect in dealing with diphthongization processes. In the framework above, long vowels are conceived of as a feature matrix, or tree, linked to two V slots:

(28)  

\[
\begin{array}{c}
V \\
/ \\
ROOT \\
\end{array}
\]

Hayes begins to resolve this paradox by noting that there is an ambiguity in what the lines in phonological representations indicate. Sometimes the lines indicate simultaneity, as in a High tone pronounced simultaneously with the vowel /a/ (below). Other times they indicate category membership, as in
the example where [t a p] all belong to the same syllable
(reproduced from Hayes 1990:40):

(29)

<table>
<thead>
<tr>
<th>a. Association</th>
<th>b. Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lines</td>
<td>Membership</td>
</tr>
<tr>
<td>t a p</td>
<td>/\ = [tap]s</td>
</tr>
</tbody>
</table>

In the representation in (27), the lines serve both functions. On one hand, they indicate category membership in the feature hierarchy, and on the other, they link features to the CV tier to be simultaneously pronounced. Hayes proposes a way to separate the two functions. His formulation involves replacing the partial tree representation in (a) with an outline format as in (b) below:

(30)

<table>
<thead>
<tr>
<th>a. V = b. V</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
</tr>
<tr>
<td>ROOT</td>
</tr>
<tr>
<td>LARYNGEAL</td>
</tr>
<tr>
<td>[voice]</td>
</tr>
<tr>
<td>[spread]</td>
</tr>
<tr>
<td>SUPRALARYNGEAL</td>
</tr>
<tr>
<td>[nasal]</td>
</tr>
<tr>
<td>PLACE</td>
</tr>
<tr>
<td>LABIAL</td>
</tr>
<tr>
<td>DORSAL</td>
</tr>
<tr>
<td>TONGUE-ROOT</td>
</tr>
<tr>
<td>[round]</td>
</tr>
<tr>
<td>[high]</td>
</tr>
<tr>
<td>[back]</td>
</tr>
<tr>
<td>[ATR]</td>
</tr>
</tbody>
</table>

The indentations in the outline format indicate membership, just as lines do in the tree format. Thus the Root node R consists of the Laryngeal and Supralaryngeal nodes L and S, the Supralaryngeal node consists of [nasal] and the Place node P, and so on.

Simultaneity of pronunciation is provided by coindexation; the CV tier is labeled with indices and then the features are "coindexed" to them. For example, the word "secret" is shown below with both association lines and indices. (Here, feature trees are abbreviated by the appropriate phonetic symbols.)

(31) a. | b. |
| C | V | V | C | C | V | C |
| s1 | k | r | e | t |
| C1 | V2 | V3 | C4 | C5 | V6 | C7 |
| s1 | i23 | k4 | r5 | a6 | t7 |
The default case is that if a node is coindexed with a particular C or V, all nodes and features dominated by this node are also indexed to that same C or V. This is more formally stated as a Percolation Convention:

(32) Percolation Convention:
When indices are assigned to or removed from a node N, the assignments and deletions are automatically carried over to all nodes dominated by N. (Hayes 1990:44)

An example of how this works is illustrated below. In Konni, the representation of long /u:/ involves two V positions associated with the features for /u/. The Percolation Convention assigns the indices for V1 and V2 to every node in the feature tree:

(33) V1 V2
R12: L: [+voice] \[+voice\] 12
S12: [-nasal] \[-nasal\] 12
P12: L: [+round] \[+round\] 12
D12: [+high] [+high] 12
[-low] [-low] 12
T12: [+ATR] [+ATR] 12

In formalizing rules using the coindexing notation, the structural description and change is given, including the relevant tiers. Hayes (1990:47) gives the following example of Old French diphthongization (/e: o:/ --> [ei ou]):

(34) Old French Diphthongization:
V_i V_j CV tier
[-low]ij [low] tier
Delete j: [-high]ij [high] tier

The structural description is that [-low] and [-high] are linked to adjacent V positions, that is, we have a long mid vowel. The structural change is that the index j is deleted from the [high] tier, making the second V position unspecified for height. Hayes then assumes a default rule assigning [+high] applies, raising the second V.

Note that the order in which the tiers are listed on the page is not significant. The CV tier could be listed second or third, for example, and it would still be the same rule.

7. Toward formalizing diphthongization

Now we are in a position to formulate the diphthongization rule for Konni:
(35) Diphthongization:

\[ V_i V_j \]
- CV tier
\[-low\]ij
- [low] tier
\[-low\]ij
- [low] tier
\[-high\]ij
- [high] tier
\[-high\]ij
- [high] tier
PLACEij
- Place tier

In words, the structural description is that \([-\text{low}]\) and \([-\text{high}]\) are linked to adjacent V slots, that is, we have a long mid vowel. The structural change is two-fold. First, the \(i\) index is deleted from the [high] tier on the first V, and \([-\text{high}]\) is inserted for the second V. (A [+high] value for \(V_i\) will later be inserted by redundancy rule.) Second, the \(j\) index is deleted on the PLACE node. The result is that all place features are deleted for the second V, except \([-\text{high}]\).

Various spreading and default rules will fill in these features. The net effect of the diphthongization rule makes \(V_i\) a high vowel and gives \(V_j\) the underlying features of \(/a/\).

For conciseness' sake, in the derivations below, only the place node and its daughters are shown after diphthongization has applied. The redundancy rules in (22) and the underlying specifications in (23) are assumed. Once redundancy rules have begun to apply, they are assumed to apply at all stages of a derivation, whenever they can (see Pulleyblank 1986). Below, when \(OF\) is used (where \(F\) stands for any feature, as in \(0\text{Rd}\) or \(0\text{Hi}\)), that implies the absence of that feature and all supporting hierarchical structure. \(OF\) is used here merely as a convenient bookkeeping device, with no theoretical claims made regarding it.

(36) Derivation of [ie] and [ia] from /ee/ and /εε/: 

a. Underlying forms:

\(/ee/\)

\[ V_1 V_2 \]
- \(R_{12}:S:P:T: [+\text{ATR}]\)
- \(L: [0\text{Rd}]\)
- \(D: [-\text{Hi}]\)
- \([0\text{Lo}]\)

\(/εε/\)

\[ V_1 V_2 \]
- \(R_{12}:S:P:T: [0\text{ATR}]\)
- \(L: [0\text{Rd}]\)
- \(D: [-\text{Hi}]\)
- \([-\text{Lo}]\)

b. Percolation:

\[ V_1 V_2 \]
- \(R_{12}:S_{12}:P_{12}:T_{12}: [+\text{ATR}]_{12}\)
- \(L_{12}: [0\text{Rd}]_{12}\)
- \(D_{12}: [-\text{Hi}]_{12}\)
- \([0\text{Lo}]_{12}\)

\[ V_1 V_2 \]
- \(R_{12}:S_{12}:P_{12}:T_{12}: [0\text{ATR}]_{12}\)
- \(L_{12}: [0\text{Rd}]_{12}\)
- \(D_{12}: [-\text{Hi}]_{12}\)
- \([-\text{Lo}]_{12}\)
c. Lexical redundancy rules:

\[ V_{1V2} \]

\[ R_{12}:S_{12}:P_{12}:T_{12}: [+ATR]_{12} \]
\[ L_{12}: [0Rd]_{12} \]
\[ D_{12}: [-Hi]_{12} \]
\[ [-Lo]_{12} \]

\[ V_{1V2} \]

\[ R_{12}:S_{12}:P_{12}:T_{12}: [0ATR]_{12} \]
\[ L_{12}: [0Rd]_{12} \]
\[ D_{12}: [-Hi]_{12} \]
\[ [-Lo]_{12} \]

d. Diphthongization:

\[ V_{1V2} \]

\[ P_{1}:T_{1}: [+ATR]_{1} [0ATR]_{2} \]
\[ L_{1}: [0Rd]_{12} \]
\[ D_{1}: [+Hi]_{1} [-Hi]_{2} \]
\[ [-Lo]_{1} [0Lo]_{2} \]

\[ V_{1V2} \]

\[ P_{1}:T_{1}: [0ATR]_{12} \]
\[ L_{1}: [0Rd]_{12} \]
\[ D_{1}: [+Hi]_{1} [-Hi]_{2} \]
\[ [-Lo]_{1} [0Lo]_{2} \]

e. Reappplication of redundancy rules and ATR spread:

\[ V_{1V2} \]

\[ P_{12}:T_{12}: [+ATR]_{12} \]
\[ L_{12}: [0Rd]_{12} \]
\[ D_{12}: [+Hi]_{1} [-Hi]_{2} \]
\[ [-Lo]_{12} \]

\[ V_{1V2} \]

\[ P_{12}:T_{12}: [0ATR]_{12} \]
\[ L_{12}: [0Rd]_{12} \]
\[ D_{12}: [+Hi]_{1} [-Hi]_{2} \]
\[ [-Lo]_{1} [0Lo]_{2} \]

f. Postlexical redundancy rules:

\[ V_{1V2} \]

\[ P_{12}:T_{12}: [+ATR]_{12} \]
\[ L_{12}: [-Rd]_{12} \]
\[ D_{12}: [+Hi]_{1} [-Hi]_{2} \]
\[ [-Lo]_{12} \]

\[ [ie] \]

\[ V_{1V2} \]

\[ P_{12}:T_{12}: [-ATR]_{12} \]
\[ L_{12}: [-Rd]_{12} \]
\[ D_{12}: [+Hi]_{1} [-Hi]_{2} \]
\[ [-Lo]_{1} [0Lo]_{2} \]

(37) Derivation of [uo] and [ua] from /oo/ and /oo/: 

a. Underlying forms:

\[ V_{1V2} \]

\[ R_{12}:S:P:T: [+ATR] \]
\[ L: [+Rd] \]
\[ D: [-Hi] \]
\[ [0Lo] \]

\[ V_{1V2} \]

\[ R_{12}:S:P:T: [0ATR] \]
\[ L: [+Rd] \]
\[ D: [-Hi] \]
\[ [0Lo] \]

b. Percolation:

\[ V_{1V2} \]

\[ R_{12}:S_{12}:P_{12}:T_{12}: [+ATR]_{12} \]
\[ L_{12}: [+Rd]_{12} \]
\[ D_{12}: [-Hi]_{12} \]
\[ [0Lo]_{12} \]

\[ V_{1V2} \]

\[ R_{12}:S_{12}:P_{12}:T_{12}: [0ATR]_{12} \]
\[ L_{12}: [+Rd]_{12} \]
\[ D_{12}: [-Hi]_{12} \]
\[ [0Lo]_{12} \]
c. Lexical redundancy rules:
\[ V_1V_2 \]
\[ R_{12}:S_{12}:P_{12}:T_{12}:[+ATR]_{12} \]
\[ L_{12}:[+Rd]_{12} \]
\[ D_{12}:[-Hi]_{12} \]
\[ [-Lo]_{12} \]
\[ R_{12}:S_{12}:P_{12}:T_{12}:[0ATR]_{12} \]
\[ L_{12}:[+Rd]_{12} \]
\[ D_{12}:[-Hi]_{12} \]
\[ [-Lo]_{12} \]

\[ \text{d. Diphthongization:} \]
\[ V_1V_2 \]
\[ P_1:T_1:[+ATR]_1[0ATR]_2 \]
\[ L_1:[+Rd]_1[0Rd]_2 \]
\[ D_1:[+Hi]_1[-Hi]_2 \]
\[ [-Lo]_1[0Lo]_2 \]
\[ P_1:T_1:[0ATR]_1[OATR]_2 \]
\[ L_1:[+Rd]_1[0Rd]_2 \]
\[ D_1:[+Hi]_1[-Hi]_2 \]
\[ [-Lo]_1[0Lo]_2 \]

\[ \text{e. Reapplication of redundancy rules and ATR spread:} \]
\[ V_1V_2 \]
\[ P_{12}:T_{12}:[+ATR]_{12} \]
\[ L_{12}:[+Rd]_{12} \]
\[ D_{12}:[+Hi]_1[-Hi]_2 \]
\[ [-Lo]_{12} \]
\[ P_{12}:T_{12}:[0ATR]_{12} \]
\[ L_{12}:[+Rd]_{12} \]
\[ D_{12}:[+Hi]_1[-Hi]_2 \]
\[ [-Lo]_{12} \]

\[ \text{f. Round spreading:} \]
\[ V_1V_2 \]
\[ P_{12}:T_{12}:[+ATR]_{12} \]
\[ L_{12}:[+Rd]_{12} \]
\[ D_{12}:[+Hi]_1[-Hi]_2 \]
\[ [-Lo]_{12} \]
\[ P_{12}:T_{12}:[0ATR]_{12} \]
\[ L_{12}:[+Rd]_{12} \]
\[ D_{12}:[+Hi]_1[-Hi]_2 \]
\[ [-Lo]_{12} \]

\[ \text{g. Postlexical redundancy rules:} \]
\[ V_1V_2 \]
\[ P_{12}:T_{12}:[+ATR]_{12} \]
\[ L_{12}:[+Rd]_{12} \]
\[ D_{12}:[+Hi]_1[-Hi]_2 \]
\[ [-Lo]_{12} \]
\[ [uo] \]
\[ P_{12}:T_{12}:[-ATR]_{12} \]
\[ L_{12}:[+Rd]_{12} \]
\[ D_{12}:[+Hi]_1[-Hi]_2 \]
\[ [-Lo]_{12} \]
\[ [ua] \]

Not only must the rules generate the correct diphthongs, but also must not change the high and low long vowels. It can be readily determined that neither of these are affected by diphthongization.

7. A Psycholinguistic Observation

Of the four rules affecting vowels discussed here, two have been treated as lexical rules: Diphthongization (35) and Round Spread (24). This relates to an interesting
psycholinguistic factor—the spelling of mother-tongue Konni speakers.

At present, there are only three adult literate Komas. These are agreed that the preferred spelling of words discussed above is with the letters {ia, ie, ua, uo}. These correspond, of course, to the sequences [i,a,ie,ua,uo] (The symbols $i$ and $u$ were not part of their knowledge at the time.) For example, even with the extreme variations in phonetic realization of /cc/ (cc $\approx$ ta $\approx$ ea $\approx$ ec $\approx$ see (7)), Konni speakers are adamant in writing it as {ia}.

These preferred spellings correspond to the output of the lexical component of the phonology. To the extent that the output of lexical rules corresponds roughly to the traditional phonemic level and that this level has psychological reality (Mohanan 1986, especially chapter 7), then this reaction of native speakers of Konni supports the assertion that Diphthongization and Round Spread are lexical rules and the others are post-lexical.

9. Conclusion

Starting from the phonetic data, I have demonstrated that apparent vowel sequences in Konni are diphthongs derived from long mid vowels. The critical aspect of the analysis is that /a/ is unspecified for [low] in underlying representation. This not only accounts for the alternation of /a/ with /e/ and /o/ in short vowels of suffixes, but also for the same variation in V$_2$ of the diphthongs: [ie] and [ia], [uo] and [ua]. To formalize a diphthongization rule, Hayes’ coindexation scheme was utilized, thus making it possible to assign heterogeneous features to V$_1$ and V$_2$, an impossibility under the standard hierarchical tree representation of long vowels.

1 Konni is a Gur language (Western Oti-Volta branch) whose closest relative is Buli. The people are Koma, the language Konni. The only published works dealing exclusively with the language are Naden (1987) and Cahill (1992a,b), though a few Konni examples are cited in Naden (1988, 1989). The data in this paper was gathered over several periods since 1986, mostly in the village of Yikpabongo. I wish to extend my thanks to Mr. Abdulai Sikpaari and Mr. Ben Saibu for sharing their mother tongue with me, and Don Burquest and Rod Casali for their remarks on earlier versions of this paper. Any faults that remain are, unfortunately, my responsibility alone.

2 Consonantal phonemes of Konni are (in orthographic symbols): b c h d f g g b h j k k p l m n n m n p s t v w y z. For justification of these and vocalic phonemes, as well as a discussion of various rules that affect vowels, see Cahill (1992b).

3 Unless otherwise noted, transcriptions are given in phonemic form. Though not in focus for most of the paper,
tone is included for completeness' sake. For nouns, tone is taken from the citation form; for finite verb forms, it is taken from the third person singular pronoun subject form.

4 Instrumental analysis was done with SIL's CECIL hardware and software package. The tape recording on which the analysis was done was of one speaker during one session.

5 Alternate positions on underspecification, such as Contrastive Underspecification, are not considered here. The arguments in Pulleyblank (1986) in favor of Radical Underspecification largely apply in the case of Kɔnni.

6 Many analyses using Radical Underspecification posit one vowel as totally unspecified for place in underlying representation, but this is not strictly required by the theory. Unlike most languages where a Radical Underspecification analysis has been applied - õkpɛ (Pulleyblank 1986), Gengbe (Abaglo & Archangeli 1989), and Yoruba (Pulleyblank 1988), for example - Kɔnni has no single vowel which exhibits a convergence of properties that would lead one to wholly underspecify it for place features. In this, it more closely resembles Kasem (Haas 1988) and Esimbi (Hyman 1988).

7 The application of this rule is limited to suffixes, both verbal and nominal. Roots do exist which have /w/ followed by front vowels, e.g. /wɛ/ 'to break,' /wɛli/ 'to sit by fire,' /wɛarɛ/ 'to remain,' /wɛnɛ/ 'problem.' These are not nearly as common as roots with /w/ followed by a back round vowel, but they do not seem to be exceptional forms. A precise delineation of the application of Round Spread will have to await a further investigation of the lexical strata of Kɔnni; for now, it suffices to say that it is a lexical rule applying to suffixes.

8 Odden (1991) proposes a separate node for all vowel place features. While some version of his proposal is probably correct, as far as I can tell the precise hierarchical structure does not affect the issues presented here.

9 Bird (1991) raises the issue of whether a node whose index has been deleted should be considered as floating or as having been deleted. My assumption, following Hayes' suggestion (cited in Bird 1991:140) is that the relevant node is deleted, then later regenerated as daughter. Features are assigned by spreading or redundancy rules. This seems to be more consistent with a scheme which generates nodal structure upon initial assignment of features (Archangeli & Pulleyblank 1989:196). However, nothing crucial in this analysis hinges on this issue.

References:
Cahill, Mike (in preparation). Underspecification and Vowel Harmony in Kɔnni.