Diphthongization and Underspecification in Kɔnni

Mike Cahill

1. Introduction to the Kɔnni vowels*

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

In this paper, I demonstrate that phonetic vowel sequences in Kɔnni can be analyzed as a diphthongization of long mid vowels. Evidence from phonetics, phonological rules, and tone is cited to support this conclusion. In the remainder of Section 1, I present the vowel harmony system of Kɔnni. In Section 2, I introduce the question of how putative vowel sequences are to be interpreted. In Section 3, I propose that these “sequences” are the result of a diphthongization rule. Section 4 considers the place underspecification plays in vowel harmony. In Section 5, Hayes’ (1990) concept of coindexing is reviewed. In Section 6, underspecification is combined with coindexing to provide a formal account for diphthongization in Kɔnni.

The nine vowel phonemes1 of Kɔnni divide into two harmony sets based on the Advanced Tongue Root feature:

\[
\begin{array}{c|c|c}
  \text{Number} & +\text{ATR} & -\text{ATR} \\
  \hline
  i & u & i & o \\
  e & o & \varepsilon & \varnothing \\
  a & & & \\
\end{array}
\]

* Kɔnni belongs to the Gur family (Western Oti-Volta branch) of Niger-Congo (Naden 1988, 1989). The people are Koma, the language Kɔnni. The only published works dealing exclusively with the language are Naden (1987) and Cahill (1992a,b). The data in this paper were gathered over several periods since 1986, mostly in the village of Yikpabongo, in the Northern Region of Ghana. I wish to extend my thanks to Mr. Abdulai Sikpaari and Mr. Ben Saibu for sharing their mother tongue with me, and Don Burquest, Rod Casali, and four anonymous reviewers of UTAWPL for their remarks on earlier versions of this paper. A longer version was presented as Cahill (1993). Any faults that remain are, unfortunately, my responsibility alone.

1 Consonantal phonemes of Kɔnni are (in orthographic symbols): b ch d f g gb h j k kp l m n N Nm ny p s t v w y z. For justification of these and vocalic phonemes, see Cahill (1992b).
With very few exceptions, all vowels in a simple (i.e., non-compound) word come from only one of the two sets:

(2)  

<table>
<thead>
<tr>
<th>+ATR words</th>
<th>–ATR words</th>
</tr>
</thead>
<tbody>
<tr>
<td>súúlí</td>
<td>jólí</td>
</tr>
<tr>
<td>bítíŋ</td>
<td>tóbi</td>
</tr>
<tr>
<td>tókórósí</td>
<td>kóróbà</td>
</tr>
</tbody>
</table>

The vowel harmony extends to all affixes of a word, for example:

(3)  

Nouns: articles and plural markers

<table>
<thead>
<tr>
<th>+ATR</th>
<th>–ATR</th>
</tr>
</thead>
<tbody>
<tr>
<td>tígí-rí</td>
<td>kóó-rí</td>
</tr>
<tr>
<td>sìè-kú</td>
<td>nìì-kú</td>
</tr>
<tr>
<td>tókóró-sí-sí</td>
<td>nánjó-sí-sí</td>
</tr>
<tr>
<td>kùn-tí-tí</td>
<td>són-tí-tí</td>
</tr>
<tr>
<td>dün-é-hé</td>
<td>dà-rá-há</td>
</tr>
</tbody>
</table>

Verbs: aspect markers

<table>
<thead>
<tr>
<th>+ATR</th>
<th>–ATR</th>
</tr>
</thead>
<tbody>
<tr>
<td>kùrì-yé</td>
<td>pàs-yá</td>
</tr>
<tr>
<td>chiì-mé</td>
<td>dó-má</td>
</tr>
<tr>
<td>sùgùr-é</td>
<td>pògíl-á</td>
</tr>
<tr>
<td>tù-ó</td>
<td>kó-á</td>
</tr>
<tr>
<td>dígí-wó</td>
<td>gá-wá</td>
</tr>
</tbody>
</table>

Note that instead of the expected e/e and o/o variations in the suffixes above, 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], [ii], [uu], [uu]) are unambiguously attested:

(5)  

<table>
<thead>
<tr>
<th>ðààŋ</th>
<th>wíŋ</th>
<th>dûójŋ</th>
<th>háá̊</th>
<th>kgíŋ</th>
<th>bûntöŋŋ</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘wood’</td>
<td>‘problem’</td>
<td>‘horse’</td>
<td>‘bush’</td>
<td>‘ancestor’</td>
<td>‘toad’</td>
</tr>
</tbody>
</table>

2 Unless otherwise noted, transcriptions are phonemic. Tone is included for completeness’ sake. For nouns, tone is taken from the citation form; for verbs, from the infinitive form.
Long mid vowels are rare, with gbèéŋ ‘a pot’ being one of the few clear examples in my data.

More frequent than long mid vowels are various vowel combinations:

\[
\begin{align*}
\text{bítéŋ} & \quad \text{‘beard’} & \text{fiáli} & \quad \text{‘be cool’} \\
\text{jùóŋ} & \quad \text{‘room’} & \text{kóò-kó} & \quad \text{‘the farm’} \\
\text{lááŋ} & \quad \text{‘ax’} & \text{duáŋ} & \quad \text{‘bush-pig’} \\
\text{chááŋ} & \quad \text{‘waist’}
\end{align*}
\]

The question is, how are these phonetic vowel sequences to be interpreted phonologically?

The distribution of the vowels within the “sequence” argues against phonemic vowel sequences. Only a fraction of the possible vowel sequences are represented; only 7 out of 32 possibilities for heterogeneous vowel sequences, taking ATR harmony into account, are attested. Furthermore, \( V_2 \) is never a high vowel, whereas \( V_1 \) is almost always so.

A better solution is that these phonetic vowel sequences are actually diphthongs derived from long mid vowels, a position which I will support in the next section.

3. A solution — all sequences from long mid vowels

3.1 A glide is not present

Before moving on, I will consider (and dismiss) another possibility — that of a glide being present in the relevant words, e.g., [íyaŋ] rather than [íáŋ]. As a practical phonetics matter, it can be extremely difficult to distinguish between these two realizations.

There are definitely /íya/ sequences in Kɔnni. /ya/ is the perfective suffix on verbs, as in [gà-yá] ‘has gone’, and [kpáti-yá] ‘has finished’. There is in fact a slight phonetic difference between this [íya] and the sequences under consideration, many of which are monomorphemic. [íá] has more of a unitary nature; the [í] is more transitory, being almost an on-glide.

The difference between [íá] and [íya] is also supported by instrumental timings,\(^3\) in which /íya/ had an average duration of 0.30 seconds, while /íá/ 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 /íye/ and 0.24 seconds for /íel/. All test cases involved morpheme boundaries at the end of words, e.g. [síti-yé] ‘have poured’, [bí-è] ‘goats’.

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\(^3\) Instrumental analysis was done with SIL’s CECIL hardware and software package. The tape recording on which the analysis was done was that of one speaker during one session.
Homogeneous long vowels (aa, ii, uu, uo) and putative vowel sequences (ia, ie, ua, uo) in nouns averaged the same duration of 0.19 seconds between stops.

Finally, pronunciation of the [iya] sequences is constant, but there is quite a lot of variation in the [ia]/[ie] sequences, for example:

(7) [kpíáŋ] ~ [kpééŋ] ~ [kpéáŋ] ‘chicken’ (pl. [kpíésí])
    [gbíéŋ] ~ [gbééŋ] ‘pot’

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

3.2 The long mid vowel solution

The above section presented evidence that the phonetic vowel sequences do not contain a glide. I want to go one step further and claim that all phonetic vowel sequences come from underlying long mid vowels, that is:

(8) /ee/ → [ie]
    /eε/ → [ia, ea, iε]
    /oo/ → [uo]
    /uɔ/ → [oa, 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 /e, œ/ becoming [ya, wa], similar 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 in (8) above explains this distributional gap, showing that long mid vowels generally manifest themselves as diphthongs.

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4 For tonal evidence bearing on the issue, see the fuller version of this paper in Cahill (1993). General tone rules are found in Cahill (1992b).

5 Independent evidence for this claim comes from the spelling of mother-tongue Kɔnni speakers. At the original time of writing, there were only three adult literate Komas. They all agreed that the preferred spelling of words discussed above is with the letters {ia, ie, ua, uo}. These correspond to the sequences [ia, ie, ua, uo] (The speakers did not know the non-Roman symbols i and u.) For example, even with the extreme variations in phonetic realization of /ee/ (eε ~ iα ~ ei ~ iε - see (7)), Kɔnni speakers are adamant in writing it as {ia}. This provides additional evidence for the diphthongization process.
The alternations in the 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, Könni diphthongization, may be written informally as:

(9) Diphthongization (informal):

\[
\begin{align*}
\text{ee} & \rightarrow \text{ie} & \text{oo} & \rightarrow \text{uo} & \text{Note: all vowel sequences are} \\
\text{ee} & \rightarrow \text{ia} & \text{oo} & \rightarrow \text{oa}
\end{align*}
\]

It may seem unusual that /ee, oo/ would diphthongize to [ia, ua] rather than [ie, uo]. However, as noted in Section 1, the ATR pairs a/e and a/o are well-attested in several suffixes, e.g.:

(10) –ATR +ATR

\[
\begin{align*}
\text{jibi-ká} & \quad \text{‘the knife’} & \text{dèmbi-ké} & \quad \text{‘the man’} \\
\text{ù sì-yá} & \quad \text{‘he has bathed’} & \text{ù sì-yé} & \quad \text{‘he has danced’} \\
\text{yá-wá} & \quad \text{‘have-EMPH’} & \text{kéñ-wó} & \quad \text{‘come-EMPH’} \\
\text{kù-á} & \quad \text{‘is killing’} & \text{tù-ó} & \quad \text{‘is digging’}
\end{align*}
\]

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 [kpíán] ~ [kpéáŋ] ‘chicken’, where the first vowel lowers:

(11) Lowering: (optional)

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

As far as I know, this process occurs only when vowels are adjacent. The rule as written would give ia → ea as above, and also oa → a, though I have as yet discovered no clear cases of the latter. The third rule involves fronting of /a/ when followed by /u/ in the next syllable:

(12) Fronting of a (optional)

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

That is, /a/ → [ɛ] before /l/, and presumably /el/, though I have no cases of the latter. (The vowel transcribed as [ɛ] here can be lower as well; thus the rule refers to [back] as the changed feature and not necessarily to height.) This rule is needed independently in the case of short vowels in separate syllables:
(13) yásì ~ yésì ‘salt’
bálìká ~ bélìká ‘language’

It also explains variations in the vowels under consideration here:

(14) píasì ~ pìsì ‘ask’

Here are derivations of the several attested forms of /kpɛɛŋ/ ‘chicken’ and /kpɛɛsɪ/ ‘chickens’:

(15) Underlying: /kpɛɛŋ/ /kpɛɛŋ/ /kpɛɛŋ/ /kpɛɛsɪ/
    Diphthongization — kpɛâŋ kpɛâŋ kpɛâsɪ
    Lowering — — — kpɛâŋ —
    Fronting — — — — kpɛâsɪ
    Surface [kpɛɛŋ] [kpɛâŋ] [kpɛâŋ] [kpɛâsɪ]

4. Underspecification and vowel harmony in Kɔnni

To explain the workings of diphthongization in Kɔnni, 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 /ɛ/ and /o/:

(16) chìì-mé ‘carry!’ dō-má ‘bite!’
sùgùr-é ‘is washing’ pàgìl-á ‘is holding’
tù-ó ‘is digging’ kò-á ‘is killing’
dígí-wó ‘cooked’ gá-łwá ‘went’ (from (4))

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 Okpɛ is very similar to what is proposed for Kɔnni, and my analysis is indebted to his in large measure.

In Radical Underspecification, 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 Kɔnni, the full inventory of vowel features is:
(17) Feature specifications for Kɔnni vowels:

<table>
<thead>
<tr>
<th></th>
<th>i</th>
<th>i</th>
<th>e</th>
<th>ø</th>
<th>ø</th>
<th>o</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>
</tr>
<tr>
<td>ROUND</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>
</tr>
<tr>
<td>LOW</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>
</tr>
</tbody>
</table>

The values of [back] are derivable from [round] and [low]. They are omitted below for clarity of presentation. The following redundancy rules apply:

(18) Redundancy rules for Kɔnni 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 (17) is reduced to:

(19) Underlying specifications of Kɔnni vowels:

<table>
<thead>
<tr>
<th></th>
<th>i</th>
<th>i</th>
<th>e</th>
<th>ø</th>
<th>ø</th>
<th>o</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>
</tr>
<tr>
<td>HIGH</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>
</tr>
<tr>
<td>ATR</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].

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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 — Okpe (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).
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:

(20) \textbf{Round Spread}^7
\[ [+\text{round}] \]
\[ \backslash \quad \text{Note:} \]
\[ X V \quad X \text{ may be either vowel or glide.} \]
\[ \mid \]
\[ [–\text{low}] \]

The derivation of [tùó] ‘is digging’ and [ko’a] ‘is killing’ follows. The representations below are intended to be abbreviated forms of a hierarchical feature tree (23). The relevant nodes and tone are omitted for conciseness and clarity.

(21) \textbf{Derivation of} [tùó] \textbf{and} [koá]

a. Underlying forms, ATR association:

\[ +A \]
\[ \mid \]
\[ t \ V \quad k \ V \]
\[ \mid \mid \]
\[ +\text{round} \quad +\text{round} \]
\[ t \ u \quad k \ o \]

b. Affixation of [–high] vowel imperfective suffix, with ATR spread:

\[ +A \]
\[ / \ \backslash \]
\[ t \ V + V \quad k \ V + V \]
\[ \mid \mid \mid \mid \]
\[ +\text{round} \quad –\text{high} \quad +\text{round} \quad –\text{high} \]

c. Lexical redundancy rules:

\[ +A \]
\[ / \ \backslash \]
\[ t \ V + V \quad k \ V + V \]
\[ \mid \mid \mid \mid \]
\[ +\text{round} \quad –\text{high} \quad +\text{round} \quad –\text{high} \]
\[ –\text{low} \quad –\text{low} \quad –\text{low} \]

^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. /we/ ‘to break,’ /weili/ ‘to sit by fire,’ /wnari/ ‘to remain,’ /wnin/ ‘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. Precise delineation of the application of Round Spread will have to await a further investigation of the lexical strata of \textit{Kann}i; for now, suffice it to say that it is a lexical rule applying to suffixes.
d. Round Spread:

\[
\begin{array}{c|c}
\text{+A} & \text{–A} \\
\hline
\text{t V + V} & \text{k V + V} \\
\text{–low} & \text{–low} \\
\text{+low} & \text{+low} \\
\text{–high} & \text{–high}
\end{array}
\]

5. Coindexing

Recall that the diphthongization process in Kɔnni is:

(22) \[ [+\text{ATR}] \text{ set} \quad [–\text{ATR}] \text{ set} \]

front \[ \text{ee} \rightarrow \text{ie} \quad \text{ee} \rightarrow \text{ia} \]
back \[ \text{oo} \rightarrow \text{uo} \quad \text{oo} \rightarrow \text{ua} \]

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’ (1990) format of coindexing.
Coindexing starts with the tree model of feature organization above, proposed by Clements (1985), and modified by Sagey (1986) and others. Their 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 above as (23). Capitals indicate nodes, and features are indicated by brackets.8

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:

(24)      V  V
          \ /
         ROOT
          | [features]

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.
Most if not all diphthongization processes convert a long segment to a heterogeneous sequence, e.g. /ee/ → [ei]. The difficulty arises because the data demand different features on the two V slots, e.g. [–high] on V₁ and [+high] on V₂, but the model above allows only one value of [high] which must be applied to both V slots. This is Hayes’ “diphthongization paradox”.

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):

(25) a. Association H
    Lines | σ
    b. Category σ
    Membership /\ = [tap]σ
    Lines t a p

In the representation in (25), the lines serve both functions. On the 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 (26a) with an outline format as in (26b) below:

(26) a. = b.

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.)

\[(27)\]  
\[\begin{array}{cccccc}
C & V & V & C & C & V \\
\mid & \mid & \mid & \mid & \mid & \mid \\
\end{array}\]  
\[\begin{array}{cccccc}
\text{s} & \text{i} & \text{k} & \text{r} & \text{o} & \text{t} \\
\text{s}_1 & \text{i}_{23} & \text{k}_4 & \text{r}_5 & \text{o}_6 & \text{t}_7 \\
\end{array}\]

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:

\[(28)\] 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 Kɔnni, the representation of long /u:/ involves two V positions associated with the features for /u/. The Percolation Convention assigns the indices for V\(_1\) and V\(_2\) to every node in the feature tree:

\[(29)\]  
\[\begin{array}{ccccccc}
V_1 & V_2 \\
R_{12;L}:[{+\text{voice}}] & \rightarrow & R_{12;L_{12;}}:[{+\text{voice}}] \_{12} \\
S_{12;}:[-\text{nasal}] & \rightarrow & S_{12;}:[-\text{nasal}] \_{12} \\
P_{12;}:[{+\text{round}}] & \rightarrow & P_{12;L_{12;}}:[{+\text{round}}] \_{12} \\
D_{12;}:[{+\text{high}}] & \rightarrow & D_{12;L_{12;}}:[{+\text{high}}] \_{12} \\
[{-\text{low}}] & \rightarrow & [{-\text{low}}] \_{12} \\
T_{12;}:[{+\text{ATR}}] & \rightarrow & T_{12;L_{12;}}:[{+\text{ATR}}] \_{12} \\
\end{array}\]

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:/ → [ei ou]):

\[(30)\]  
\[\begin{array}{cc}
V_i V_j & \text{CV tier} \\
[{+\text{low}}]_{ij} & \text{[low] tier} \\
\end{array}\]

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 V\(_2\) position unspecified for height. Hayes then assumes that a default rule assigning [+high] applies, raising V\(_2\).
6. Toward formalizing diphthongization

We are now in a position to formulate Kɔnni’s diphthongization rule:

(31) Diphthongization:          V\text{ij} CV tier
        delete i    [–high]ij  [high] tier
        delete j    [–low]ij  [low] tier
        delete j    [round] tier

In words, the structural description is that [–low] and [–high] are linked to adjacent V slots, that is, we have a long mid vowel. The structural change is three-fold. First, the i index is deleted from the [high] tier on the first V. Second, the j index is deleted on the [low] node. Third, the j index is deleted from the [round] tier. The net effect of the diphthongization rule makes V\text{i} a high vowel and gives V\text{j} the underlying features of /a/.

Let us examine the effect of the rule in more detail. For V\text{i}, the value [–high] is deleted. This empty [high] feature is replaced by a [+high] value by the postlexical redundancy rule [ ] → [+high], making V\text{i} a high vowel (u, i).

For V\text{j}, if there is any value of [round] present, (31) deletes it. Practically, this only affects round vowels, since they are the only ones with an underlying specification for [round], namely positive.

Also for V\text{j}, the diphthongization rule above deletes the value [–low]. If the vowel sequence is in a [+ATR] morpheme, the lexical redundancy rule [+ATR] → [–low] immediately reapplies and fills in a [–low] value for V\text{j}. Thus the net result is that V\text{j} for [+ATR] sequences (o, e) remains the same. However if the vowel sequence is in a [–ATR] morpheme, the lexical redundancy rule does not apply, but the postlexical redundancy rule [ ] → [+low] does. So V\text{i} for [+ATR] morphemes in effect remains unchanged, but V\text{j} for [–ATR] morphemes is changed to /a/.

For the sake of conciseness, in the derivation below, only the place node and its daughters are shown after diphthongization has applied. The redundancy rules in (18) and the underlying specifications in (19) 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 0F is used (where F stands for any feature, as in 0round or 0high), that implies the absence of that feature and all supporting hierarchical structure. 0F is used here merely as a convenient bookkeeping device, with no theoretical claims made regarding it.

(32) Derivation of [uo] and [ua] from /oo/ and /œœ/:  
a. Underlying forms:  
\begin{align*}
V_1V_2 & = /oo/ & V_1V_2 & = /œœ/ 
R_{12}:S:P:T:[+ATR] & R_{12}:S:P:T:[0ATR] 
L:[+round] & L:[+round] 
D:[–high] & D:[–high] 
[0low] & [0low]
\end{align*}
b. Percolation:
\[
\begin{align*}
V_1 V_2 \\
R_{12}:S_{12}:P_{12}:T_{12}: [+ATR]_{12} \\
L_{12}: [+round]_{12} \\
D_{12}: [−high]_{12} \\
[0low]_{12}
\end{align*}
\]

\[
\begin{align*}
V_1 V_2 \\
R_{12}:S_{12}:P_{12}:T_{12}: [0ATR]_{12} \\
L_{12}: [+round]_{12} \\
D_{12}: [−high]_{12} \\
[0low]_{12}
\end{align*}
\]

c. Lexical redundancy rules:
\[
\begin{align*}
V_1 V_2 \\
R_{12}:S_{12}:P_{12}:T_{12}: [+ATR]_{12} \\
L_{12}: [+round]_{12} \\
D_{12}: [−high]_{12} \\
[−low]_{12}
\end{align*}
\]

\[
\begin{align*}
V_1 V_2 \\
R_{12}:S_{12}:P_{12}:T_{12}: [0ATR]_{12} \\
L_{12}: [+round]_{12} \\
D_{12}: [−high]_{12} \\
[−low]_{12}
\end{align*}
\]

d. Diphthongization:
\[
\begin{align*}
P_{12}:T_{12}: [+ATR]_{12} \\
L_{12}: [+round]_{12} [0round]_{2} \\
D_{12}: [−high]_{12} [−high]_{2} \\
[−low]_{12} [0low]_{2}
\end{align*}
\]

\[
\begin{align*}
P_{12}:T_{12}: [0ATR]_{12} \\
L_{12}: [+round]_{12} [0round]_{2} \\
D_{12}: [−high]_{12} [−high]_{2} \\
[−low]_{12} [0low]_{2}
\end{align*}
\]

e. Reapplication of redundancy rules and ATR spread:
\[
\begin{align*}
P_{12}:T_{12}: [+ATR]_{12} \\
L_{12}: [+round]_{12} [0round]_{2} \\
D_{12}: [−high]_{12} [−high]_{2} \\
[−low]_{12}
\end{align*}
\]

\[
\begin{align*}
P_{12}:T_{12}: [0ATR]_{12} \\
L_{12}: [+round]_{12} [0round]_{2} \\
D_{12}: [−high]_{12} [−high]_{2} \\
[−low]_{12}
\end{align*}
\]

f. Round spreading:
\[
\begin{align*}
P_{12}:T_{12}: [+ATR]_{12} \\
L_{12}: [+round]_{12} [0round]_{2} \\
D_{12}: [−high]_{12} [−high]_{2} \\
[−low]_{12}
\end{align*}
\]

\[
\begin{align*}
P_{12}:T_{12}: [0ATR]_{12} \\
L_{12}: [+round]_{12} [0round]_{2} \\
D_{12}: [−high]_{12} [−high]_{2} \\
[−low]_{12}
\end{align*}
\]

g. Postlexical redundancy rules:
\[
\begin{align*}
P_{12}:T_{12}: [+ATR]_{12} \\
L_{12}: [+round]_{12} [0round]_{2} \\
D_{12}: [−high]_{12} [−high]_{2} \\
[−low]_{12}
\end{align*}
\]

\[
\begin{align*}
P_{12}:T_{12}: [−ATR]_{12} \\
L_{12}: [+round]_{12} [−round]_{2} \\
D_{12}: [−high]_{12} [−high]_{2} \\
[−low]_{12} [+low]_{2}
\end{align*}
\]

[uo]

[ua]
7. Summary

Starting from the phonetic data, I have demonstrated that apparent vowel sequences in Kɔnni 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 V₂ 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 V₁ and V₂, an impossibility under the standard hierarchical tree representation of long vowels.

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