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*The internal structure of phonological elements : a theory of charm and government**

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0 Introduction

In this article we have two primary objectives: (1) to elaborate in some detail a theory of phonological representations embedded within a parametric framework, and (2) to apply this theory to a particular vowel system which displays some rather interesting properties. This work is a continuation of a collaboration on a programme of research on phonological theory begun in 1982 (cf. Vergnaud 1982; Kaye & Vergnaud 1984; Kaye *et al.* 1984, 1985, in preparation). This programme incorporates the view that phonology is to be regarded as a system of universal principles defining the class of human phonological systems. These principles underdetermine given phonologies in certain specific areas. A complete phonological system consists, then, of these principles along with sets of parameter values. Taken together, the principles and language-specific parameter settings give a complete characterisation of the phonological system under study. In this model, a phonological system contains no rule component. The observed phonological phenomena result from a combination of the general principles governing phonological representations and structures and the parameter values in operation in the particular language. We view this line of research as a continuation of the development of a theory of markedness (cf. Chomsky & Halle 1968 (*SPE*); Kean 1975, 1979). At the moment of writing, this view of phonology remains a long-term objective of our research programme. However, an increasing number of phonological processes which were formerly considered to be manifestations of rules are now successfully derivable from the principles of Universal Phonology (UP) (cf. Kaye & Lowenstamm 1984, to appear).

This article is organised into two major sections: in the first section, we shall present a general introduction to our theory of phonological repre-

sentations. The second section will consist of a detailed application of the theory to the vowel system of Kpokolo, a Kru language spoken in the Ivory Coast.

1 A theory of segmental representations

1.1 Elements

The theory of segmental representations to be presented here differs from other such theories in a number of significant ways. To begin with, the ultimate constituent of this theory is *not* the phonological feature. In fact, phonological features may not be accessed directly or manipulated in any way within this approach. Their role is rather a secondary one serving as an instrument of phonetic interpretation of phonological segments. The primary unit of segment constitution is the ELEMENT, which is a *fully specified matrix*, phonetically interpretable as in *SPE* theory or some equivalent formulation. All phonological segments are either elements themselves or combinations of elements. The elements, along with their definition in terms of features, constitute the primitives of phonological systems. Put another way, the ultimate constituents of phonological segments are themselves autonomous, independently pronounceable units. Following an idea originally proposed by Vergnaud (1982), we may begin by positing the following elements relevant for vowel systems. It will be shown below that this simple system must be augmented to be capable of expressing the variety of extant vowel systems. For the time being we leave aside the question of nasal vowels:

(1) *Some elements*

$$\text{I} = \begin{bmatrix} -\text{ROUND} \\ \underline{-\text{BACK}} \\ +\text{HIGH} \\ -\text{ATR} \\ -\text{low} \end{bmatrix} \qquad \text{U} = \begin{bmatrix} \underline{+\text{ROUND}} \\ +\text{BACK} \\ +\text{HIGH} \\ -\text{ATR} \\ -\text{low} \end{bmatrix} \qquad \text{A} = \begin{bmatrix} -\text{ROUND} \\ +\text{BACK} \\ \underline{-\text{HIGH}} \\ -\text{ATR} \\ +\text{low} \end{bmatrix}$$

By convention all elements are represented in upper case. The underlined features of the system in (1) will be explained below. As can be seen, the three elements shown above are fully specified feature matrices (irrelevant features have not been included). As such they are fully pronounceable, and indeed occur in most if not all of the languages of the world. As we have mentioned above, segments may consist of a single element or combinations of elements. For example, an A element may combine with an I element to form a compound vowel [ɛ]. In like manner A and U combine to form [ɔ]. The exact nature of element combination will be discussed in a later section.

1.2 Lines, features and the cold vowel

Let us now consider the structure of systems incorporating elements such as those in (1) above. An immediate question arises as to what underlies the decision to consider certain vowel segments as primitive (elements) and others as derived (composed). In fact the answer comes from markedness theory (Chomsky & Halle 1968; Kean 1975, 1979).

In the representations of elements shown in (1) above, one of the features in each matrix has been underlined. This is the HOT feature of the element, i.e. the only feature whose value is marked. Thus, for the element I, the hot feature is [BACK]. I is specified as [−BACK], the marked value of this feature. In the case of U, the hot feature is [ROUND] and its marked value is [+ROUND]. A has [HIGH] as its hot feature, with the marked value being [−HIGH]. We will return to the ATR feature below. For completeness we have included specifications for the feature [low]. This feature plays no active role in vowel systems, and we posit no element for which [low] is the hot feature within vowel systems.

It will be noticed that each element has one and only one feature with a marked value, in other words only one hot feature. This is the defining property of an element. I is thus distinguished from, say, [ɛ] in that it contains one marked feature value, [−BACK], whereas the latter segment contains two: [−BACK] and [−HIGH]. *In sum, elements are feature matrices containing precisely one marked feature value.*

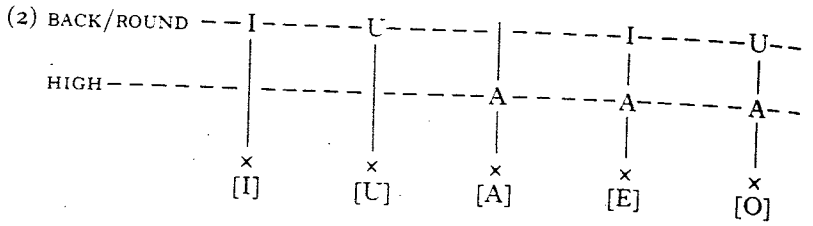
The question of phonological representation now arises. We assume that elements are normally found on separate tiers or LINES. These lines are labelled. A line label is the name of the hot feature of its element. Thus, I is found on the BACK line, U on the ROUND line, etc. Elements on lines display properties of an autosegmental nature. Successive elements on a given line either define separate domains or else trigger OCP (obligatory contour principle) effects (cf. Leben 1973). The presence of a line in a given system indicates that the feature which is the line label is active in the system. The absence of a line labelled, say, GLOTTAL SUCTION, indicates that this feature is inactive in the system in question. For a feature to be active in a system, its marked value must be borne by some element. All elements reposing on a line other than that of the feature in question by definition bear the unmarked value for the feature.

In certain systems lines may be FUSED. In such cases two lines combine to form a single line. This possibility has a number of empirical consequences. A fused line must contain more than one element, since each individual line contains the element whose hot feature is the line label. Fusions of this sort create a situation where two elements reside on the same line. This has implications for possibilities of spreading and for the manner in which OCP effects are triggered. Most importantly, elements on the same line cannot combine to form a compound segment. This is trivially true in the case of non-fused lines, since such a case would imply the association of two identical elements to the same skeletal position. This is always interpreted as a single element attached to a single point. The

results of line fusion partially define impossible element combinations. Fusion of the BACK and ROUND lines, an unmarked option of vowel systems, renders combinations of I and U impossible. This effectively excludes a front rounded vowel series in the systems in question.

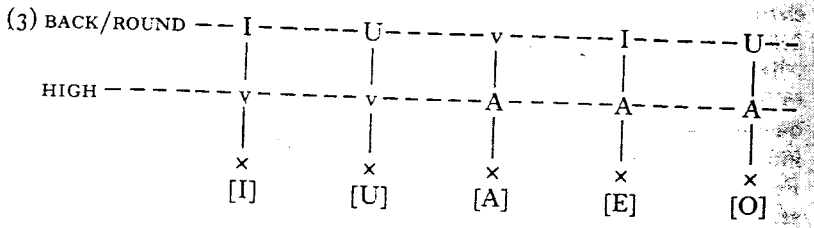
Lines along with positions (cf. Halle & Vergnaud in preparation) form a two-dimensional grid from which phonological representations may be plotted. Lines accordingly play a role in defining the loci of the 'cold vowel' to be discussed below. Consider for example the representations in (2):

(2)



Here we find the representations for a five-vowel system (simplified by eliminating the ATR element from the picture, and hence represented phonetically with capitals). In this system the first three segments are composed of a single element. The final two segments are compounds, consisting of combinations of two elements. This system illustrates a fused BACK/ROUND line. The potential compound segment consisting of I and U is thus excluded from the two-dimensional grid mentioned above. In this representation we have a series of intersections of lines and positions. Each intersection represents, in the simplest cases, a binary choice. The intersection may be identified by a real element of the system or by its absence. *We will claim that the absence of a real element at intersections has a specific interpretation: these 'empty' positions are in fact filled by the cold vowel, i.e. a vowel with no hot features.* This vowel appears at all intersections not filled by a 'real' element – one with a hot feature. Thus, the system in (2) would have the representation shown in (3), where *v* represents the cold vowel:

(3)



Let us consider first the feature definition of the cold vowel as defined for vowel systems. Recall that this vowel has no hot feature. Accordingly, the cold vowel must be a high, back, unrounded, lax vowel: high, since

[−HIGH] is the marked specification for the feature [HIGH] (cf. A); back, since [−BACK] is the marked specification for the feature [BACK] (cf. I); unrounded, since [+ROUND] is the marked specification for the feature [ROUND] (cf. U); and lax, since [+ATR] is the marked specification for this feature. Thus, we derive the definition of the cold vowel given in (4):

(4)
$$v = \begin{bmatrix} -\text{ROUND} \\ +\text{BACK} \\ +\text{HIGH} \\ -\text{ATR} \\ -\text{low} \end{bmatrix}$$

1.3 Matrix calculus and the head operator relation

We now turn to the question of combination of elements and the matrix calculus. We need an operation for taking two fully specified feature matrices and combining them such that the output of this procedure is a single feature matrix. We call this operation FUSION. We can define fusion as involving two elements: a head and an operator (cf. Bach & Wheeler 1980 for a similar notion of operator and head within the framework of Montague Phonology). Fusion consists of substituting the value of the hot feature of the operator for that of the corresponding feature of the head. Otherwise all the remaining feature values are those of the head. The operation is represented in (5), where X, Y and Z are feature matrices and '.' is the fusion operator. By convention the head appears to the right of the fusion operator:

(5) $X . Y \rightarrow Z$

As a concrete example of the fusion operation, consider the fusion of A and I, with I being the head. Recall that these elements have the definitions in (6):

(6)
$$A = \begin{bmatrix} -\text{ROUND} \\ +\text{BACK} \\ \underline{-\text{HIGH}} \\ -\text{ATR} \\ +\text{low} \end{bmatrix} \qquad I = \begin{bmatrix} -\text{ROUND} \\ \underline{-\text{BACK}} \\ +\text{HIGH} \\ -\text{ATR} \\ -\text{low} \end{bmatrix}$$

The fusion operation A . I is then (7):

(7)
$$\underset{\substack{\textit{operator} \\ A}}{\begin{bmatrix} -\text{ROUND} \\ +\text{BACK} \\ \underline{-\text{HIGH}} \\ -\text{ATR} \\ +\text{low} \end{bmatrix}} \cdot \underset{\substack{\textit{head} \\ I}}{\begin{bmatrix} -\text{ROUND} \\ \underline{-\text{BACK}} \\ +\text{HIGH} \\ -\text{ATR} \\ -\text{low} \end{bmatrix}} \rightarrow \begin{bmatrix} -\text{ROUND} \\ -\text{BACK} \\ -\text{HIGH} \\ -\text{ATR} \\ -\text{low} \end{bmatrix}$$

$$A \cdot I \rightarrow [\varepsilon]$$

Notice that the fusion operation is asymmetric. That is, A.I is not equivalent to I.A in our system. In the latter case, A and I have switched roles, A now being the head and I the operator. The resulting fusion is shown in (8):

(8)

−ROUND	−ROUND		−ROUND
−BACK	+BACK		−BACK
+HIGH	−HIGH		−HIGH
−ATR	−ATR		−ATR
−low	+low		+low
operator	*head*		
I	A	→	[æ]

It should be clear from the discussion above that the cold vowel *v* behaves like an identity element when it is an operator. An operator may only change a head by supplying the value of its hot feature; but *v* has no hot feature and so can never have an effect on the outcome when it is an operator. We shall see below that the cold vowel may function as a head in certain marked cases. In such cases its presence will be felt. Thus, v.A is not equivalent to A.v, as is shown below:

(9)

−ROUND	−ROUND		−ROUND
+BACK	+BACK		+BACK
+HIGH	−HIGH		−HIGH
−ATR	−ATR		−ATR
−low	+low		+low
v	A	→	[a]
−ROUND	−ROUND		−ROUND
+BACK	+BACK		+BACK
−HIGH	+HIGH		−HIGH
−ATR	−ATR		−ATR
+low	−low		−low
A	v	→	[ə]

We see then that v.A yields A, while A.v yields a schwa. This will prove an essential point for the discussion of the Kpokolo vowel system below.

To sum up, we have presented part of a theory of phonological representations. The structure of phonological segments is an attempt to encode a theory of markedness into the representation itself. The complexity (markedness) of a segment will be reflected in the number of elements of which it is composed. This 'molecular' approach to segmental structure bears some degree of resemblance to earlier work by Anderson & Jones (1974), which has evolved into 'dependency phonology'. More recently Schane (1984a, b) has proposed a theory of 'particle phonology' which shares some, but by no means all, of the properties of the theory under discussion. It is not our aim to review the differences among these

approaches. We simply note that there are fundamental differences, both formal and substantive, that distinguish them. It should be stressed, however, that our system should not be considered a sort of 'unary feature system'. The ultimate constituents of segments are *not* features, binary, unary or other. They are autonomous pronounceable elements defined as fully specified feature matrices. Phonological processes, we claim, have no direct access to features. Features can be manipulated only indirectly, by combining elements to form compound segments, or by decomposition of compound segments into their constituent parts. *Segmental phonology is composition and decomposition.*

1.4 Charm theory

Up to this point, we have presented the view that phonological representations consist of various elements, alone or in combination. Several of these elements have been defined and discussed in relation to vowel systems. There remains, however, a fundamental question regarding these elements: do they form a homogeneous set? That is, are there natural classes of elements which have an effect on their combinatorial properties? One could imagine a system of elements of equal status in which no prediction could be made as to the combinations in which they were found. Indeed, a set of distinctive features with no accompanying theory of markedness would share many formal properties of such a system. In fact, even a cursory look at segmental structure in the light of the theory that we have been elaborating here shows that there do exist classes of elements sharing a particular property. This property has an impact on the combinations of elements that may exist and on their organisation into segmental systems (vowels or consonants). Let us call this property CHARM. Let us assume that there are charmed elements (indicated as positive [+]) and charmless elements (indicated as negative [−]). We further assume that elements with like charm are repelled and that there is an attraction between elements of unlike charm. The elements may now be grouped according to charm as shown in the following table:

(10)

charmed		*charmless*
A+	(oral)	I−
ɬ+	(pharyngeal)	U−
N+	(nasal)	v−

Intuitively, charm may be related to the property of 'voweliness'. Positively charmed elements have this property, while negatively charmed ones lack it. A vocalic articulation is characterised by the presence of a resonating cavity. There are three principal resonating cavities in the human vocal apparatus and to each is associated a positively charmed element. Thus A+ is related to the oral cavity. The ATR element, ɬ+, is related to the pharyngeal cavity; recall that the interior wall of this cavity is formed by the root of the tongue. Advancing this organ enlarges (activates) this cavity. The special status of this element will be discussed

below. The N+ element is of course related to the nasal cavity. The charmed elements may be thought of as switches which activate the resonating cavity in question. We assume then that the archetypal vowel has a positive charm. Negatively charmed vowels exist, but only in special circumstances. This idea will be developed further below.

The ATR element, ɪ+, plays a special role with respect to charm. It functions as if its hot feature were positive charm. Thus, any expression involving the ATR elements is considered to be positively charmed even if ɪ+ is not the head of the expression. In this sense, ɪ+ acts like a pure charm operator with the property being expressed phonetically as ATR-ness. ATR has other special properties; it does not appear to reside on any line. In normal circumstances it is not the head of a compound segment, and it does not appear as the sole element of a position except in very special circumstances. We do claim however that ATR-ness is pronounceable; the ATR element is a fully specified feature matrix like the other elements of vowel systems. We can derive its feature content theoretically by utilising the idea that an element has one and only one hot feature. The ATR element must be hot for the ATR feature and cold for the rest. This gives us the following definition of the ATR element:

(11)
$$\text{ɪ+} = \begin{bmatrix} -\text{ROUND} \\ +\text{BACK} \\ +\text{HIGH} \\ \underline{\pm\text{ATR}} \\ -\text{low} \end{bmatrix}^{+}$$

In the discussion of the Kpokolo vowel system which will be presented below, we shall see that this theoretical result, the value of the ATR element, is confirmed empirically.

A word must be said regarding the charm of expressions, i.e. compound vowels. In general, the charm of an expression is the charm of its head. In the expression (A+ . I−), the head, I−, has a negative charm. This is then the charm of the entire expression: (A+ . I−)− = [ɛ].

With the presentation of this preliminary discussion of charm and the ATR element, we are now in a position to deal with the question of the ATR paradox. This paradox concerns the status of [+ATR] vowels within a theory of markedness. Are [+ATR] vowels more or less marked than their [−ATR] counterparts? There appear to be contradictory answers to this question. On the one hand, systems with [+ATR] vowels lacking [−ATR] counterparts not only occur, but appear to be the unmarked case. Thus, in five-vowel systems we typically find the vowels /i u e o a/, but not /ɛ ɔ/. In general the appearance of a non-low [−ATR] vowel implies the presence of its [+ATR] counterpart. Systems such as /ɪ ʊ ɛ ɔ a/ do not appear to exist. By these criteria, and following the normal assumptions of markedness theory, [+ATR] would appear to be the unmarked value for this feature at least for non-low vowels. On the other hand, in systems which fully exploit the [±ATR] opposition, i.e. nine- and ten-vowel systems, the

[−ATR] vowels clearly behave as the unmarked members of these pairs (cf. Halle & Vergnaud 1981; Kaye 1982). The paradox arises from the intersection of two independent notions of markedness. In our theory of segments, markedness can be read directly off the phonological representations: the greater the number of elements in a compound segment, the greater its degree of markedness. An ATR vowel involves an additional level of complexity in that it is expressed by an element. Concretely, an ATR vowel has one more element in its composition than its [−ATR] counterpart. This additional complexity at the representational level explains its marked status within a vocalic system. There is, however, a level of systemic markedness, independent of the individual segments, which is related to charm theory and which we shall now discuss. Given the fact that positive charm is simply the expression of the vocalic (resonating) property, it is reasonable to assume that vowels are 'normally' positively charmed. Negatively charmed vowels are in some sense a contradiction and may occur only in specially defined circumstances to be discussed below. Indeed, vowel systems may be defined in terms of the charm requirements imposed on their individual members. We posit that the unmarked vowel system contains only positively charmed segments. The element A+ is positively charmed to begin with, and so it occurs in these systems. I− and U− are negatively charmed and do not occur. They may however combine with the ATR element ɪ+, which has the property of attributing positive charm to the resulting expression. This yields the [+ATR] high vowels [i] and [u] alongside [a]. A+ may of course combine with I− and U− but the resulting expressions (A+ . I−)− and (A+ . U−)− are negatively charmed. In order to meet the requirement that the unmarked vowel system contains only positively charmed segments the ATR element must now combine with these expressions to form a positively charmed segment ((A+ . I−)− . ɪ+)+ = [e], ((A+ . U−)− . ɪ+)+ = [o]. These latter forms exhaust the combinatorial possibilities of the unmarked system, and we derive the familiar five-vowel system /i u e o a/, all of whose segments are positively charmed.

A more marked system would require that each expression of the system be at least partially positive. These are the seven-vowel systems /i u e o ɛ ɔ a/, where an ATR opposition exists for the mid vowels. These vowels all contain the positive element A+ even if they are negatively charmed. Thus, (A+ . I−)− is a possible segment of this system. It is negatively charmed but contains a positively charmed constituent. Pure negative segments such as U− or I− are excluded from these systems. We must further explain, however, the presence of /e o/ in these systems. Systems of the form /i u ɛ ɔ a/, if they exist at all, are quite rare and accordingly highly marked. In general the presence of /ɛ/ and /ɔ/ in a system implies the presence of /e/ and /o/. We can generalise this observation by postulating a principle of charm markedness as in (12):

(12) *Charm markedness*
The presence of a negative segment in a vowel system implies the presence of its positive counterpart

Most highly marked along the charm parameter are systems that permit pure negatively charmed segments, namely I− and U−, the high [−ATR] vowels. These vowels occur in nine- and ten-vowel systems, where they are always accompanied by their [+ATR] counterparts [i] and [u]. The Kpokolo system to be considered below is an extension of these systems. It should be noted that simply setting the charm parameter to the marked case (negatively charmed segments permitted) automatically generates a nine-vowel system: five [−ATR] vowels /ɪ ʊ ɛ ɔ a/ and four [+ATR] vowels /i u e o/, but not a [+ATR] counterpart to /a/. This asymmetry follows directly from charm theory. Both A+ and ɨ+ are positively charmed and one would not expect them to combine easily. There are indeed ten-vowel symmetrical systems with a [+ATR] *a* vowel. Such systems require additional machinery to generate this segment. This result coincides well with the empirical observation that nine-vowel systems are much more frequent than ten-vowel ones.

Vowel systems may consist entirely of positively charmed segments, of segments that are at least partially positive or, in the most marked case, of pure negatively charmed segments with no positive component. In each case the positively charmed counterpart is also present in the system. This explains the unmarked nature of ATR vowels from a systemic point of view.

If positive charm is a property of vowels, or more properly a property of syllable heads, it would be natural to express a number of phonological phenomena in terms of this trait. For example, we could express the force that binds syllable onset and rhyme in terms of charm. We have already noted that in a subsegmental domain opposite charms attract. Suppose we extend this idea to the suprasegmental level. In this sense the rhyme, which can be considered a projection of the nucleus in the familiar sense, contains a positive charm which governs the negatively charmed onset. The fundamental opposition of onset and nucleus is then expressed in terms of charm. The positive and negative units cancel each other, leaving us with a neutral syllable. Neutrality with respect to charm can be viewed as a sort of phonological autonomy. This picture is far from complete. A phonological sequence is not merely a string of autonomous syllables. Numerous phonological processes serve to bind syllables of a given domain (word, clause, sentence) together. Stress, tone, harmony, assimilation, etc., may all be viewed as serving this function in one way or another. What these phenomena have in common is the presence of a dominant unit of some form in relation with one or more subordinate units. We call this relation GOVERNMENT. It is our view that charm is the agent through which government is expressed. This idea will be developed in much more detail in the following section.

2 The vowel system of Kpokolo

Kpokolo is an eastern Kru language spoken in the canton of Kpokolo in the Ivory Coast. It is popularly referred to as Bete, although it is rather different from other dialects bearing this same description. It shares a number of features with Dida, another complex of dialects of the Kru family, and indeed its geographical position places it on the boundary between Dida- and Bete-speaking areas. All information in Kpokolo is based on informant sessions over a period of two years in Montreal.

Kpokolo, like most other Kru languages, has a vowel system making active use of the [±ATR] opposition. Most of these languages contain nine- or ten-vowel systems. Kpokolo displays a richer vowel system. It contains a series of central (i.e. back unrounded) vowels in addition to those found in the smaller systems. Kpokolo is not alone in having this central series of vowels. Similar systems have been reported for other Bete dialects, e.g. Daloa (Zogbo 1981) as well as Godie (Marchese 1979).

Kpokolo has the surface vowels shown in (13). They are organised into seven [−ATR] vowels and six [+ATR] vowels:

(13)

	[−ATR]			[+ATR]		
high	ɪ	ɨ	ʊ	i	ɨ	u
mid	ɛ	ɜ	ɔ	e	ə	o
low		a				

Among the seven lax [−ATR] vowels, there is a high back, unrounded lax vowel [ɨ] and a mid back unrounded lax vowel [ɜ], as well as the five normal lax vowels. In the [+ATR] series there is a tense [+ATR] counterpart to [ɨ], namely [ɨ], and a tense counterpart to [ɜ], namely [ə]. There is no corresponding low [+ATR] vowel. The existence of a series of back unrounded vowels presents a real challenge to the theory of phonological representations that we have presented above. It will be recalled that the theory provides no direct access to features, nor are there any mechanisms for their manipulation. Given the matrix calculus described above it may be seen that deriving a front rounded series is relatively straightforward. In vowel systems where the BACK and ROUND lines are not fused, the respective elements of these lines I− and U− may combine (along with the ATR element in the unmarked cases) to yield a positively charmed segment. Suppose that I− is the head; then the expression (U− . I−)− yields a front rounded vowel, as seen in (14):

(14)

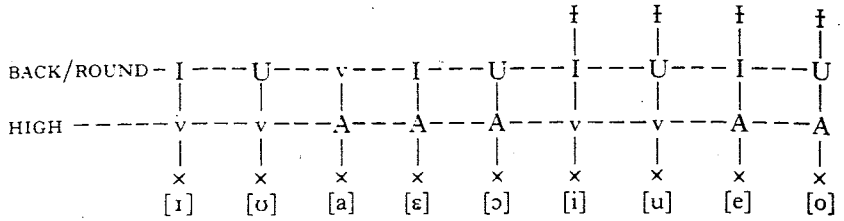
[±ROUND]		[−ROUND]		[+ROUND]
[+BACK]		[−BACK]		[−BACK]
[+HIGH]	.	[+HIGH]	→	[+HIGH]
[−ATR]		[−ATR]		[−ATR]
[−low]		[−low]		[−low]
U		I	→	[y]

It will be noted that in this case the fusion operation is symmetrical, i.e. $(U-\,.\,I-)- = (I-\,.\,U-)-$. Front rounded vowels combine the two hot features which are associated with the elements of which they are composed: [+ROUND] and [−BACK]. Consequently, it is not immediately obvious how we can form the back unrounded series of vowels. Indeed, no combination of the elements I−, U− or A+ results in vowels of this series.

In order to better see the problems posed by the Kpokolo system, let us consider a more standard nine-vowel system, such as that of many Dida dialects:

(15) ɪ ʊ i u
ɛ ɔ e o
a

(BACK–ROUND fused; negatively charmed segments permitted)



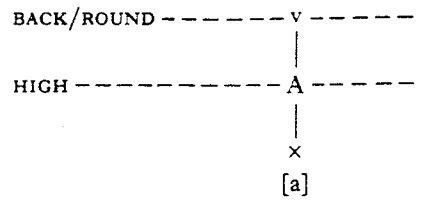
All possible combinations of elements occur except for A+ and ɬ+, whose like charm prevents fusion. The system thus displays the same asymmetry as that of Kpokolo, with no [+ATR] equivalent of /a/. What distinguishes this nine-vowel system from that of Kpokolo is the presence in the latter system of four non-low central vowels. These are the back unrounded vowels, high or mid, [+ATR] or [−ATR]. The challenge is to find representations for each of these vowels as well as a set of parameter settings which will characterise the Kpokolo system.

Let us consider first the mid central [+ATR] vowel [ə]. This vowel in many respects acts like a [+ATR] version of [a]. Kpokolo, like many other Kru languages, has a system of dominant ATR harmony (cf. Kaye 1982). [a] alternates with [ə], with the latter being found in [+ATR] contexts. Kpokolo has a compound form *-ji* which is appended to mass or abstract nouns giving the meaning of 'one of X' or 'piece of X', where X is the noun in question. The non-singular form is either unmarked or uses the morpheme *-ja* to convey a plural meaning. In either case we can set up alternating forms involving ATR-ness. The examples in (16) illustrate the alternation of [a] with [ə] in ATR contexts:

(16) [−ATR]	[+ATR] with *ji*	
glɜ̀mà	glə̀mə̀jì	'bananas'
klɜ̄jà	klə̄jì	'branch'
lɜ̄jà	lə̄jì	'iron'
nɜ̄kàlì	nə̄kə̀jì	'sticks'
bɜ̄bā	bə̄bə̄jì	'white tarots'
glā	glə̄jì	'teeth'

Kpokolo is not unique in this respect. Indeed, in ten-vowel systems, [ə] represents the tenth vowel (Kaye 1980). Given the positive charm of both the A+ element and the ATR element ɬ+, combining them should be impossible. What is needed is a negatively charmed element which can serve as a 'buffer' between the two positively charmed elements. We claim that the cold vowel, v−, is this element. The complete representation of the vowel [a] is shown in (17):

(17)



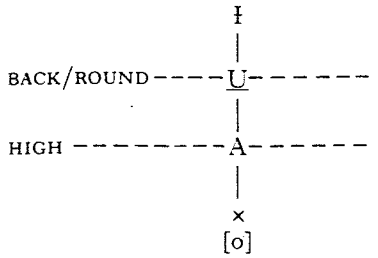
Thus, [a] is in reality the expression $(v-\,.\,A+)+$. The element A is the head of the expression, which is what we would expect given the theory of charm. In situations where the positively charmed ATR element seeks to fuse with [a] there are apparently two possibilities: (1) the positive charm of A+ prevents association; (2) the roles of operator and head are reversed and a negatively charmed expression is formed, to which the positive ATR element can associate. In the case at hand, the second strategy is employed. That is, the expression $(v-\,.\,A+)+$ is replaced by $(A+\,.\,v-)-$, which has a negative charm. The latter expression can then be combined with the ATR element, yielding a positively charmed vowel $((A+\,.\,v-)-\,.\,ɬ+)+$. There is one salient empirical consequence of this analysis: a [+ATR] counterpart of [a] cannot be a low vowel; it must be mid. This follows from the fact that the head of the expression is the cold vowel, v−, which is specified as [−low]. Since operators can only contribute their hot features, and since no vowel element has [low] as its hot feature, the resulting feature matrix must be [−low]. This accords perfectly with the facts: to our knowledge all [+ATR] counterparts to [a] are mid vowels and not low vowels phonetically.

The [ə] vowel shows up in a second context. Kpokolo has alternations which appear to involve the 'unrounding' of non-final rounded vowels. The principal locus of these alternations is in singular–plural noun forms. The plural suffix is -I. It typically causes the deletion of the final stem vowel that immediately precedes it. (See Kaye 1982 for a detailed discussion of a similar case in Vata.) In this unrounding environment, [ə] appears as the unrounded version of [o], as shown in the examples below. The unrounding phenomenon in general will be discussed in a later section:

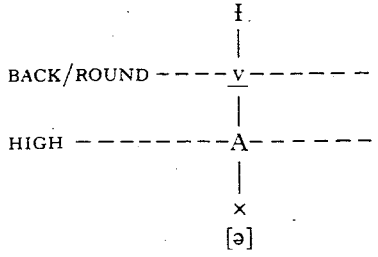
(18) *singular*	*plural*	
tó̩lù	tə̀lì	'groin'
tōlù	tə̄lì	'vein'
gòpú	gèpí	'basket'
kpólū	kpə́lī	'rat'

We see then that [ə] is both the [+ATR] version of [a] and the unrounded counterpart to [o]. The two vowels have the representations in (19):

(19) a.



b.



The head of each segment is underlined in (19). We see that 'unrounding' results from the disassociation of U−.

The high back unrounded vowels [ɤ] and [ɨ] result from the unrounding of [ʊ] and [u] respectively. Consider first the case of [ʊ]. Unrounding occurs in the same contexts as were discussed above. An example of the unrounding of [ʊ] is given below:

(20) *singular*	*plural*	
jʊ̀lʊ̄	jɤ̀lɪ̄	'sun'

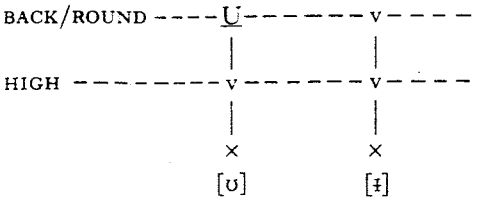
In our account the [−ATR] vowel [ʊ] is composed exclusively of the element U−. Unrounding involves the loss of the U element. Under such circumstances we predict that the cold vowel v− should surface, and this is precisely the case. The vowel [ɤ] is high, back, unrounded and lax. These are exactly the features we have posited for the cold vowel on purely theoretical grounds. Unrounding of [ʊ], then, leads to the surfacing of the completely unmarked vowel v−, namely [ɤ].

By the same logic, Kpokolo should provide us with a unique opportunity to *hear* the ATR element ɪ+ which we have posited to be a high, back, unrounded, tense vowel. Recall that the vowel [u] has the representation (U−, ɪ+)+. Loss of the U− element would mean that only the ATR element is associated with the position in question. We expect the ATR element to surface in such cases and this indeed happens. Examples involving [u]–[ɨ] alternations are given in (21):

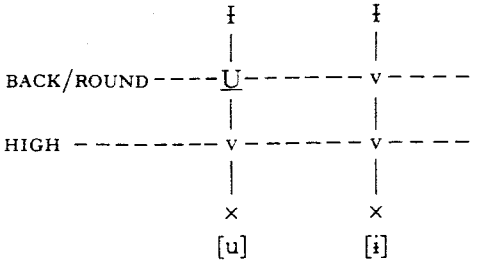
(21) *singular*	*plural*	
sʊ̀sʊ̀	sɨ̀sɨ̀	'charcoal'
lúgbù	lɨ́gbì	'tears'
mùdù	mɨ̀dì	'claw'

The representation of the alternating vowels [ʊ]–[ɤ] and [u]–[ɨ] are given in (22):

(22) a.



b.



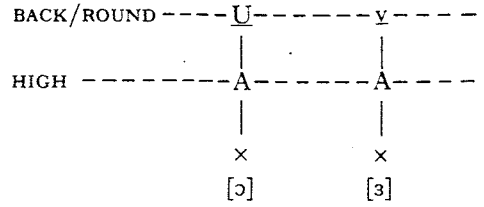
In each case of unrounding, the U− element on the BACK/ROUND line is detached and the cold vowel v− appears in its place.

Up to this point we have discussed three of the central vowels, [ə], [ɤ], and [ɨ]. The remaining vowel, like its tense counterpart [ə], plays a dual role. In unrounding contexts a mid, central, lax vowel [ɜ] appears in place of [ɔ]. In non-governing contexts, i.e. in non-final position in polysyllabic words, or in monosyllables, it appears in place of [a]. Examples of the former sort are given in (23):

(23) *singular*	*plural*	
dɔ́bʊ̀	dɜ́bì	'duck'
pʒlʊ́	pɜ́lí	'market'
gɔ̄lʊ̄	gɜ̄lī	'dugout'
dɔ̀gbʊ́	dɜ̀gbɨ́	'electric fish'
kɔ́lʊ́	kɜ́lɨ́	'bamboo'

In plural forms the initial vowel loses its roundness. Once again the result of unrounding an [ɔ] is not [a] as one might expect, but rather [ɜ]. In fact, as we shall see below, it is impossible to have [a] in this position. A look at the representation of this vowel will give us some indication as to why this is so. The representations of [ɔ] and [ɜ] are as in (24):

(24)



As in the previous cases of unrounding the U element is lost and replaced by the cold vowel v−. This element serves as the head of the segment, yielding [ɜ] rather than [a]. It should be noted that the head/operator distinction is 'line-stable'. That is, the head is found on the same line in both singular and plural forms (the BACK/ROUND line). The head is also constant across syllables; it is on the same line in the initial and in the final syllable.

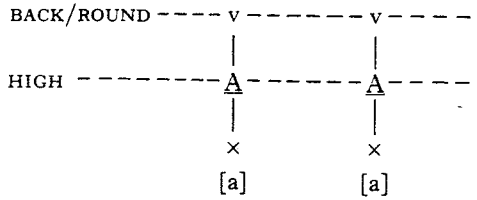
In addition to the [ɔ]–[ɜ] alternations shown above, Kpokolo also displays [à]–[ɜ] alternations:

(25)

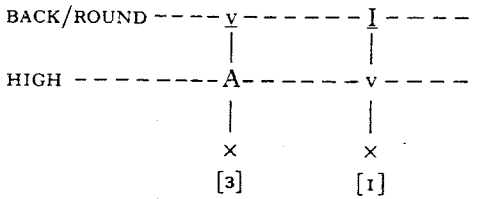
singular	*plural*	
jábā	jɜ́bī	'shorts'
gàgá	gɜ̀gɪ	'hill'
ɓátá	ɓɜ́tɪ́	'pangolin'
kpálā	kpɜ́lī	'bottle'
sākpā	sɜ̄kpī	'toad'
bákà	bɜ́kɪ̀	'stew'
vákà	vɜ́kɪ̀	'ram'
gāfā	gɜ̄fī	'spider (sp.)'
kwálā	kwɜ́lī	'turtle'

Inspection of the forms in (25) shows that non-final [a] occurs when the final vowel is also [a], otherwise [ɜ] appears. Let us consider the two sequences shown in the above forms: [a–a] and [ɜ–ɪ]. Their representations appear in (26):

(26) a.



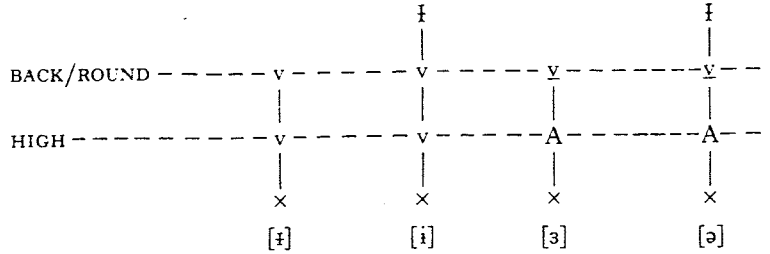
b.



The change of the initial vowel ([a] → [ɜ]) involves no addition or deletion of elements. The only difference is the head/operator relation. This is reversed in the plural form, with the head being found on the BACK/ROUND line, as is that of the final governing vowel. It is then natural to assume that in polysyllabic words the head must be located on the same line. This assumption would explain the singular–plural alternations shown in (25). This hypothesis will be discussed further below.

We have discussed in turn each of the four 'central' (i.e. back unrounded vowels) of Kpokolo. We summarise the results obtained to this point in (27), where the representation of each of these vowels is given:

(27)



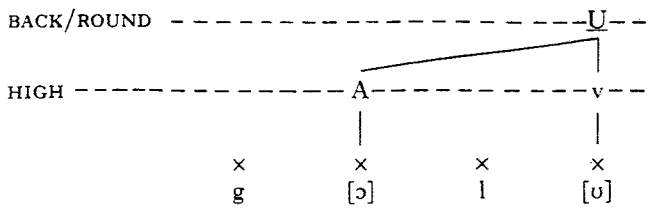
These representations are quite different from those proposed for the front rounded series of vowels. These differences are also reflected in the very particular circumstances in which we find this series of vowels. Part of the story resides in the behaviour of the U− element, which we shall discuss below. We shall also pursue the 'line stability' hypothesis in more detail.

Let us now turn to cases of spreading of the U− element. This is but one of a growing number of U–I asymmetries that we have encountered in various languages. Given the representations that we have proposed in this article, one would expect that the U− and I− elements would manifest similar behaviour in all respects. They have like charm. They are found on the same line, and so on. In fact, U− displays one property that is not at all characteristic of I− in Kpokolo: it spreads to the preceding syllable when conditions are right. Round vowels (those containing the U− element) are found freely in final syllables. In general, they are found in non-final syllables only if the final syllable has a round vowel. In autosegmental terms we can view this phenomenon as a spreading of the U− element along the BACK/ROUND line. It should be remembered that U− but not I− has this property. At our current level of understanding, this must be a stipulation for the phonological system of Kpokolo. Eventually, we would like to derive this fact from more general principles.

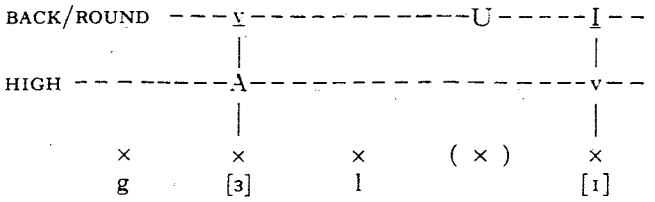
A general property of Kpokolo phonology is that harmonic structures of the sort we are describing are right-headed. Propagation is a right-to-left affair. In this sense the final vowel can be viewed as the governor and any vowels found to its left are considered to be in governed positions. Generally speaking, the U− element is limited to the governor. The appearance of non-final rounded vowels is licensed by the final vowel, which must of

course be rounded itself in such cases. Let us consider an alternation like [gɔ̄lʊ̄]–[gɜ̄lī]. The derivation of the plural form, [gɜ̄lī], is given in (28):

(28) a.

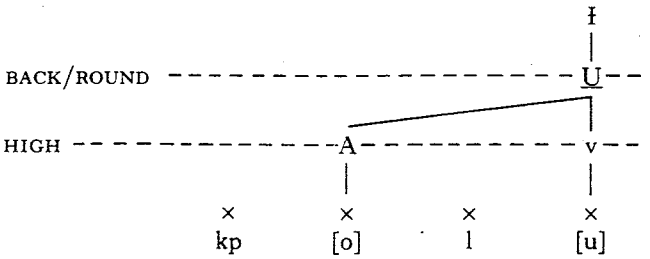


b.

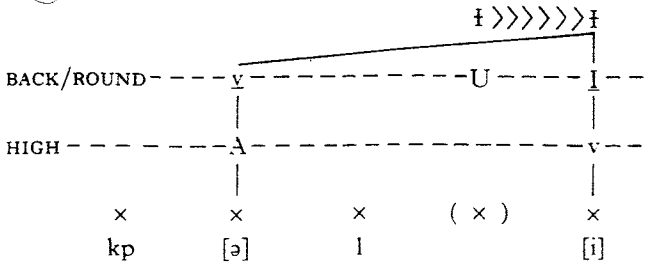


In (28a) the representation of the singular form [gɔlʊ] is given. The final vowel contains the U− element which spreads leftwards to the recessive vowel. In (28b) the plural suffix -I is added. Two successive nuclear positions are illegal within a word, possibly an OCP effect, and accordingly the parenthesised position to the left is deleted. Crucially, the U− element is *not* deleted along with the point but rather remains unassociated on the BACK/ROUND line. It cannot associate to the vowel of the initial syllable since this is a governed position, and a rounded vowel must be licensed in this position by the presence of the U− element in the governing syllable. Since there is now no element represented on the BACK/ROUND line for the vowel of the initial position, the cold vowel, v−, must appear. Furthermore, this element must be the head of the initial vowel because of line stability (the head of the final vowel I being found on the BACK/ROUND line). This gives rise to the expression (A+ . v−)−, i.e. [ɜ]. A parallel derivation exists for the [+ATR] case of the example just discussed, e.g. [kpólū]–[kpə́lī]:

(29) a.



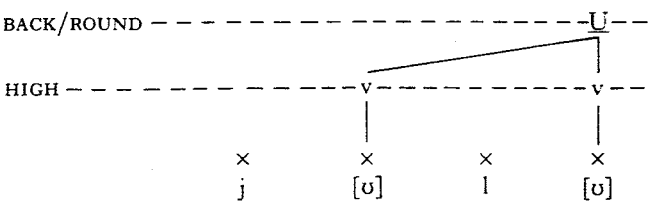
b.



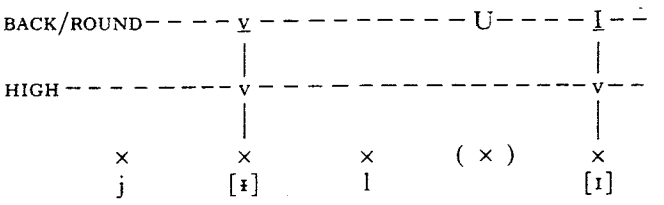
The derivation in (29) is identical to that of (28) save for the presence of the ATR element ɨ+. Kpokolo has a system of dominant ATR harmony, which in our system means that all the relevant positions within the relevant domain (the word) must be within the scope of the ATR operator. We assume that this element 'docks' on the governing (final) vowel of the word and spreads to the other vowels of its domain. This spreading is subject only to the constraints imposed by charm theory: it may not associate to a positively charmed element or expression. This poses no problem in (29a). We may assume that the U− element associates first with the A+ of the initial vowel yielding (A+ . U−)− and that it is to this negatively charmed expression that the ATR element associates, yielding ((A+ . U−)− . ɨ+)+ = [o]. In the plural form (29b) the U− may no longer associate to the first vowel. Line stability yields v− as the head of the resulting segment, which provides a negatively charmed expression (A+ . v−)− with which ɨ+ can combine to yield ((A+ . v−)− . ɨ+)+ = [ə].

Derivations involving the high central vowels proceed in analogous fashion. We illustrate two of these below: [jʊ́lʊ̄]–[jɨlī] and [mùdù]–[mɨ̀dì].

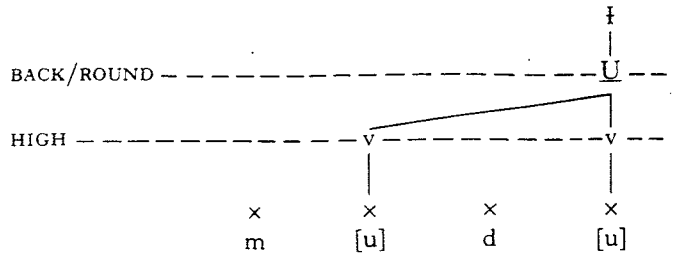
(30) a.



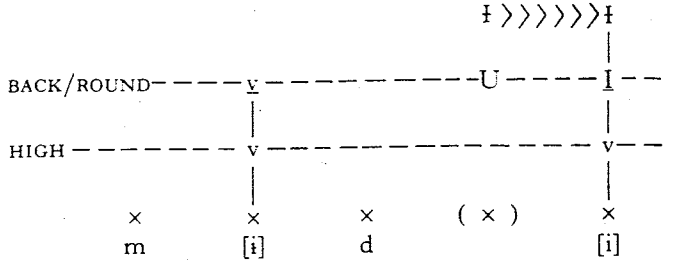
b.



c.



d.

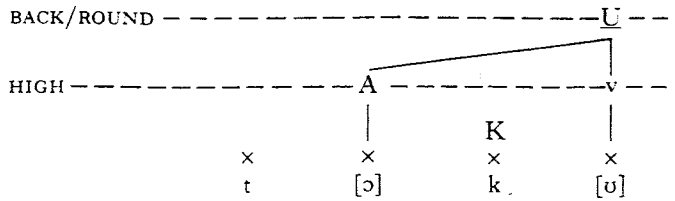


Thus the phenomenon of 'unrounding' can be related to the fact that U— cannot appear in a recessive position within a word unless this is licensed by a rounded governor. Up to this point we have assumed deletion of a skeletal position in plural forms, which leads to a floating U—. While floating, the U— is unable to govern (in this case spread to) the preceding vowel. Hence the latter appears as phonetically unrounded. It is important to realise that this process is not active, i.e. there is no unrounding agent. Rather, it manifests the failure of a rounding element U— to propagate because it is not in a governing position. The reader will recall that we refrained from claiming that the U— element was lost. In the derivations given above it simply floated, not being attached to any skeletal point. This raises an interesting possibility: in Kpokolo, as in many other languages, there exists a labialised velar series of consonants, [kw], [gw] and [ŋw]. It is natural to assume that these consonants are composed in the sense used above. Specifically, they can be considered to consist of a K element, representing velar articulation, and U—, with the former being the head of the segment. It would be interesting to know what happens when in unrounding contexts the consonant intervening between the two nuclei is a velar. Will the floating U— element dock at this segment? If so, will this license the appearance of a rounded vowel in the preceding syllable? The answers are supplied by the following data:

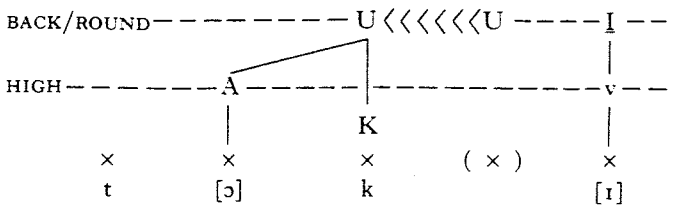
(31) *singular*	*plural*	
tɔ́kō	tɔ́kwī	'shell (turtle)'
nɔ̄nō	nɔ̄nwī	'hunger'
dɔ̀kɔ́	dɔ̀kwi	'pot (small)'
kɔ́nṵ	kɔ́ŋwi	'bird (sp.)'
kōŋù	kōŋwì	'back'

In every case where the onset of the second syllable is a velar, we note that in the plural form the velar becomes labialised, and it is this consonant that licenses the rounded vowel in the initial syllable. A sample derivation is given in (32):

(32) a.



b.



Plural forms are not the only source of consonantal government. Forms with non-derived labialised velars permit the appearance of non-final rounded vowels, as seen in the following examples:

(33) kʊ̀kwɛ̀	'chicken'	kʊ́kwə̀	'madness'
kʊ̀kwà	'gourd'	kʊ́kwə̄	'tarot'
lōkwì	'skirt'	sɔ́kwlɪ̀	'net'

In each of the above examples it is the onset of the final (governing) syllable that provides the skeletal position from which the U— element can be spread to the initial vowel.

Let us now consider the distribution of [ɜ] and [a]. As was noted above, [a] appears in the final syllable of polysyllabic words. It does not appear to the right of just any vowel. This is to be expected if our hypothesis of line stability is correct. In a sample of twenty-eight bisyllabic words ending in [a] we find the following vowels in initial position:

(34) [a] – 13 [ɜ] – 6 [ɨ] – 3 [ʊ] – 3 [i] – 1 [u] – 1 [ɔ] – 1

Both [a] and [ɨ] can be considered as having their heads on the HIGH line and are thus consistent with our line-stability hypothesis. The three cases of [ʊ] precede labialised velar consonants. They are governed by the final onset rather than the final nucleus and involve no violation of line stability. The two cases of high [+ATR] vowels are disharmonic. One, [gbúpà] 'axe' appears to be a compound. The other [sìkà] 'gold' is a loan-word which could also be treated as a compound. The one case of [ɔ] occurs in the number [gbótā] 'eight', which is clearly a compound (cf. [tā] 'three'). The only problematic forms are then the six words involving the nuclear sequence [CɜCa]. Of these six forms, three involve the light diphthong [lɜ].

We shall see below that [ɜ] rather than [a] occurs in these diphthongs. The remaining three forms, [gɜ̄dà] 'tree (sp.)', [ǰɜ̄kà] 'to measure' and [gɜ̄ǰà] 'carp' are the only apparent problems for this analysis. For the moment we have nothing to say about them. The results are nevertheless encouraging enough for us to wish to maintain the line-stability hypothesis.

Considering now cases of [a] in non-final syllables, we have thirty-seven bisyllabic words with [a] in the initial syllable. Of these, thirteen have [a] in the final syllable as well. The overwhelming majority of the remaining cases are obvious compounds. The others may be compounds as well. It is worth looking at verbs in this regard since, unlike the nouns, they are not known to be involved in any compounding process. They should give us a clearer picture concerning the distribution of vowels. There is *no* example of a non-final [a] in verbs.

To sum up, we have seen that [a] occurs as the final syllable of polysyllabic words containing other [a]s or governing consonants. The favoured environment for [a] is then in words composed solely of this vowel. It may also occur preceded by the cold vowel v– in a more limited number of cases. The vowel [ɜ] occurs in non-final syllables followed by most vowels other than [a] or the rounded vowels. It does not occur followed by the labialised consonants. It would be interesting to look at the distribution of these two vowels in monosyllables, and it is to this point that we turn now.

Monosyllabic verbs almost invariably end in [ɜ]. There are thirty-one monosyllabic verbs ending in this vowel. Five monosyllabic verbs end in [a]. Of these five, two have contour tones: [pā̀] 'to run' and [gbà᷄] 'to close'. The remaining three are [wà] 'to like', [gwā] 'to tie up' and [là] 'to call'. What is intriguing about these examples is that the onset of each form contains a segment at least part of which can occur in nuclear position. The element U– is involved in the first two onsets, [w] and [gw], entirely constituting the former and forming part of the latter. As for [l] this segment occurs commonly in light diphthongs of the form [lV] (as in [slō] 'heat', [glō] 'to sow'). One might be tempted to think that these vowel-like elements provoked the appearance of the 'strong' form of the vowel, as if that kind of element in an onset needed the same kind of government as would a preceding nucleus. In other words, a sequence of the form *[CʊCɜ] is impossible. In this case U– is found in the preceding nucleus. In like manner *[wɜ] or *[lɜ] is excluded where a potential nuclear element is found in the preceding onset. Be that as it may, forms like *[wɜ], *[kwɜ] are impossible in Kpokolo. As a final point concerning monosyllabic verbs, it should be noted that [ɜ] rather than [a] is found as the head of a light diphthong regardless of what is in the onset position of the syllable. Thus, alongside [wa] 'to like' we find [wlɜ] 'to break'. Tigrinya, a Semitic language spoken in Ethiopia (Lowenstamm & Prunet in preparation) displays a remarkable similarity with respect to the distribution of [a] and [ɜ]. In this language only [ɜ] is found in closed syllables, e.g. [fɜrɜs] (*[fɜras]) 'horse'. There may be a way of combining these two facts ([ɜ] in closed syllables and [ɜ] as the head of light diphthongs), but a definite conclusion of this question must await further study. Tigrinya, like Kpokolo, also shows [a] unexpectedly in non-final open syllables when preceded by [w] or a labialised consonant. This result is strongly suggestive and would indicate that there is a principled explanation along the lines of the one suggested above.

Monosyllabic nouns may end in [a] but never in [ɜ]. This categorial difference may be due to morphological differences between nouns and verbs. In Kru languages the final vowel of a noun is related to its membership in a nominal class. The pronominal form of each class is simply the [–ATR] version of the final vowel of the stem (cf. Kaye 1981 for details). Thus [pɔ̀lʊ̀] 'market' belongs to the [u] class, [gbà] 'fence' to the [a] class, and so on. Verb stems show no internal morphology at all. The presence of the 'stronger' vowel [a] in noun stems, where it appears to be some form of class marker, may be due to its role in the morphology of nouns. In any event, the complex yet predictable nature of the [a]–[ɜ] distribution, as well as its striking resemblance to a similar phenomenon in Tigrinya, lead us to conclude that this pattern is in no way irregular and should be derivable from general principles following in spirit those that we have posited above.

In this article we have presented a concise description of a theory of government and charm which is designed to explain the nature of phonological representations, the notion of a possible phonological system and the way such representations may give us insights into the diverse phonological phenomena observed in various languages. We have applied this approach to the vowel system of Kpokolo, which has provided us with a reasonably rich array of facts for which any phonological theory should be accountable. We have attempted to explain the observed phenomena with a strict minimum of stipulations, and to derive the bulk of the processes observed from a small number of general principles which we believe make up part of UP.

NOTE

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*The treatment of long vowels in word games**

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1 Introduction

In the current nonlinear model of CV phonology (Clements & Keyser 1983), phonological representations are organised into several levels or tiers, of which the following three are the most significant: the central CV tier (skeleton), whose units, C and V, are autosegmentally associated with the units of the syllable tier on one end and with the units of the segmental tier on the other. The segmental tier itself is organised into subtiers of distinctive features; the internal structure of the syllable tier is subject to considerable debate in the literature. In addition, CV-level units may be linked to melodies on separate autosegmental tiers in the case of supra-segmental phenomena like tone and vowel harmony.

Within the CV phonology framework long segments are represented in terms of two timing units, or slots, on the CV tier. Normally, long vowels are represented as VV, geminate consonants as CC; VC long vowels have been suggested for Turkish and Klamath by Clements & Keyser (1983) and for Hungarian by Vago (to appear), VC geminate consonants for Luganda by Clements (to appear). The two CV-level units are tied either to one segment-level unit or to two identical segment-level units. I will call these configurations respectively the many-to-one and the one-to-one representation of length. The two ways to represent long *a*, for instance, are schematised in (1):

(1) a. many-to-one

b. one-to-one

In the great majority of cases long segments are represented in terms of the many-to-one relation. The one-to-one representation seems to be required in certain cases, however: for some long vowels in Cuna (Sherzer 1970), Gokana (Hyman 1982), and Latin (Steriade & Schein 1984), and