Rule Iteration

GIDABAL[1]

Gidabal presents a typical case of self-bleeding interaction in an iterative rule. In this language, long vowels are shortened after long vowels.

njule-da:ŋ	'he (emphatic)'	nu:n-daŋ	'too hot'
bala-ya:	'is under'	gila:-ya	'that (locative)'
djubunj-dja:	'is night'[2]	ba:m-ba	'is halfway'
gadi-be:	'right here	bur̆u:r̆-be	'only two'
babar̆-a:-daŋ	'straight above'		
djalum-ba:-daŋ-be:	'is certainly right on the fish'		/djalum-ba:-da:ŋ-be:/
gunu:m-ba-da:ŋ-be	'is certainly right on the stump'		/gunu:m-ba:-da:ŋ-be:/

The following rule accounts for these alternations in affinal vowel length.

$$V: \rightarrow V \,/\, V:\, C_0 \_\_\_$$

Vowel shortening makes a long vowel short, which has the consequence that a long vowel which is shortened cannot then condition application of shortening to a following vowel. The rule applies from left to right, which results in an alternating pattern of vowel length. In the derivations below, the arrow indicates which segment is being checked to undergo the rule. Long vowels which will be shortened are underlined in the underlying forms.

/djalum-ba:-da:ŋ-be:/

djalum-ba:-da:ŋ-be: → Not applicable: preceding vowel is short

^

djalum-ba:-da:ŋ-be: → Applies: vowel preceded by long vowel

^

djalum-ba:-daŋ-be: → Not applicable: preceding vowel is now short

^

[djalum-ba:-daŋ-be:]

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[1] Data from Geytenbeek & Geytenbeek (1971), discussed in Kenstowicz & Kisseberth (1977).

[2] This is the same morpheme as *-ya:*, and the glide becomes a stop after a nasal.

/gunu:m-ba:-da:ŋ-be:/

gunu:m-ba:-da:ŋ-be: (^ under 1st a:)	→	Not applicable: preceding vowel is short
gunu:m-ba:-da:ŋ-be: (^ under a: of ba:)	→	Applies: vowel preceded by long vowel
gunu:m-ba-da:ŋ-be: (^ under a: of da:)	→	Not applicable: preceding vowel is now short
gunu:m-ba-da:ŋ-be: (^ under e:)	→	Applies: vowel preceded by long vowel

[gunu:m-ba-da:ŋ-be]

Thus in terms of the input to shortening, a vowel is shortened if it is preceded by a long vowel which is preceded by a short vowel, or no vowel, or separated from a short vowel or word boundary by an even number of long vowels. With the star-parenthesis notation, the rule must be formulated as follows:

$$V{:} \rightarrow V \,/\, \left\{\begin{matrix}\#\\ \breve{V}\end{matrix}\right\} C_0V{:}\ (C_0V{:}C_0V{:})^*\ C_0\,\_\_$$

Inclusion of the word boundary is necessary, so that a long vowel in the first syllable of a word can also trigger shortening, as in /nu:n-da:ŋ/ → [nu:ndaŋ]. A short vowel is not an essential condition on the rule per se, but rather serves as an anchoring point for enumerating the parity of the vowel.

In the case of /djalum-ba:-da:ŋ-be:/, the underlined *a:* satisfies the requirements of the rule, where the specific triggering subcontext that applies is:

$$\breve{V}\,C_0V{:}\ C_0\,\_\_$$

where the material in star-parentheses has a null expansion. The vowel of *be:* does not undergo this sub-rule because it is not preceded by a short vowel then a long vowel. It also cannot undergo the subrule including one instance of the star-parenthetical expression, since that subrule requires:

$$\breve{V}\,C_0V{:}C_0V{:}C_0V{:}C_0\,\_\_$$

i.e. specifically three long vowels in a row — there are only two long vowels before *be*: in this word.

By comparison, in /gunu:m-ba:-da:ŋ-be:/, we find two vowels which undergo shortening. The first one is identified by the same subrule noted above:

$$\breve{V}\,C_0V{:}\ C_0\,\_\_$$

The long vowel of *da:ŋ* is not shortened in this case, because it is preceded by 2 long vowel, not three — but then the vowel of *be:* will be shortened by including one non-null expansion of ther star-parenthesis expression,

$\breve{V}\, C_0V{:}C_0V{:}C_0V{:}C_0$ __

In general, given a sequence /$VC_0V{:}C_0V{:}C_0V{:}C_0V{:}C_0V{:}C_0V{:}C_0V{:}$.../, shortening will affect every odd-numbered long vowel in a sequence of long vowels.

SHONA

There is a tone rule in the Karanga dialect of Shona which lowers a H tone of a prefix to L when it is both preceded and followed by a H tone (a stem H tone does not undergo this lowering: the stem is the final morpheme in the examples below). The following examples motivate the underlying vowels of certain prefixes: *-ká-* "past", *á-* "3s. subject", *-mú-* "3s. object".

ku-tórá	'to take'	ku-mú-tórá	'to take it'
nda-ká-tórá	'I took'	á-ká-ti	'he said'

In the following examples, an underlyingly H toned prefix surfaces with L tone when it is spreceded by a H tone and followed by a L tone (the morpheme which lowers is underlined).

á-<u>ka</u>-tórá	'he took'	nda-ká-<u>mu</u>-tórá	'I took it'
á-<u>ka</u>-mú-tórá	'he took it'		

Additional examples involving the negative prefix *-zá-* are seen in this set of examples.

ha-á-zá-biká	'he didn't just cook'	ha-á-<u>za</u>-tóra	'he didn't just take it'
ha-á-<u>za</u>-mú-tóra	'he didn't just take it'		

Multiple applications of lowering are found in the following examples.

ha-á-<u>za</u>-ká-tóra	'he didn't take'	ha-á-<u>za</u>-ká-mú-bika	'he didn't cook it'
ha-á-<u>za</u>-ká-<u>mu</u>-tóra	'he didn't take it'		

The rule of lowering is formulated as follows:

$$\underset{[+\text{prefix}]}{H} \rightarrow L \,/\, H \_\_\_ H$$
[3]

[3] This feature encodes the fact that the rule only applies to H tones of prefixes, and not a stem internal H — note, however, that a stem H can *condition* the application of lowering.

In order to derive the correct outputs, this rule must iterate from left to right, as the following derivations show.

L-R application	R-L application
/haázámútóra/	/haázámútóra/
a	u
[haázamútóra]	*[haázámutóra]

If this rule were to apply simultaneously to all H tones that satisfy the conditions of this rule, the rule would incorrectly lower every H tone except the first and last in a string of adjacent H tones, this /haázámútóra/ → *[haázamutóra] and /haázákámútóra/ → *[haázakamutóra]. Such an output cannot result from either direction of iterative rule application. What needs to be done in simultaneous application theory is to devise a rule that pre-parses a string of H's in an unbroken string of H's so that the even-numbered H's are identified:

$$\text{H} \rightarrow \text{L} \;/\; \left\{\begin{matrix}\#\\ \text{L}\end{matrix}\right\}\ \text{H (H H)* \_\_ H}$$

As with Gidabal shortening, the disjunction on the left identifies the first H in a string of Hs: it requires the H which is to be lowered to be followed by a H, and because of the star-parenthetic expression, it only allows lowering to affect a H in an even-numbered position in a string of H's.

VATA[4]

Optional rules pose a problem for the simultaneous theory of rule application. The tack which is taken using star-parentheses is to "anticipate" what material will be skipped over, and explicitly allow just those patterns (e.g. even numbers of H tones to be skipped in Shona). The problem is that this won't work in any obvious way if the ability of a rule to apply to some segment depends on whether the rule has *actually* applied to a neighboring segment. ATR harmony in Vata illstrates the problem. [-ATR] (lax) vowels become [+ATR] (tense) before another [+ATR] vowel, where [ʌ] is the [+ATR] correspondent of *a*. This rule is optional, as illustrated by the following data.

ɔ ka za pi	'he will cook food'
ɔ ka zʌ pi	=
ɔ kʌ zʌ pi	=
o kʌ zʌ pi	=

These facts have a simple description in the iterative theory: the following rule applies right-to-left, and is optional:

$$\text{V} \rightarrow [\text{+ATR}] \;/\; \_\_\ \text{C}_0\ [\text{+ATR}]$$

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[4] Data from Kaye (1982).

Each of the surface forms above corresponds to the result of not applying the rule at all, applying the rule once, twice or thrice.

The general form of an iterative ATR harmony rule under the simultaneous theory would be the following.

$$V \rightarrow [+ATR] \;/\; \underline{\quad} \; C_0 \; (VC_0)^* \;\; [+ATR]$$

To derive the output [o kʌ zʌ pi] with the maximal application of harmony, the following substrings must be matched to the underlying form /ɔ ka za pi/.

$$\begin{array}{ll} \text{a.} & \\ \text{b.} & \\ \text{c.} & \end{array} \quad \underline{\quad} \left\{ \begin{array}{l} C_0\varnothing \\ C_0VC_0 \\ C_0VC_0VC_0 \end{array} \right\} [+ATR]$$

Thus /ɔ/ becomes [o] by applying subrule (c), /ka/ becomes [kʌ] by (b) and /za/ becomes [zʌ] by subrule (a).

The problem is describing an output such as [ɔ kʌ zʌ pi], where harmony applies only partially. If harmony is an optional rule, and harmony is the set of subrules a, b, c, ... then we would expect that either {a, b, c} apply, or they do not: if they do, we derive [o kʌ zʌ pi] and if they do not we derive [ɔ ka za pi]. But then there is no means of deriving the equally grammatical output [ɔ kʌ zʌ pi]. We cannot reinterpret optionality as applied to the various subrules abbreviated by star-parentheses as meaning "apply any subrule" — that would allow application of subrule (c) without applying (a) or (b), yielding *[o ka za pi].

The facts of Vata can be described giving a particular interpretation to the algorithm that expands the star-parenthesis notation into specific subrules, namely that the expansion includes any number of repetitions of the parenthetic expression up to *n*, but it must include *all* repetitions from 0 to *n*. Thus a string could be scanned for satisfaction of just subrule (a); or, (a) and (b), or, (a), (b) and (c); but not just (b) and (c), or just (b), or (a) and (c).

FRENCH[5]

Another example which has been discussed, which poses problems for the simultaneous theory, is schwa-deletion in French. Examples of the patterns of deletion are below.

<tu devenais>

tü dəvəne	tü dvəne	tü dəvne

<....voudrais que ce que le bedeau...>

...vudre kə sə kə lə bədo...	...vudre kə s kə lə bədo...
...vudre kə sə k lə bədo...	...vudre kə sə kə l bədo...
...vudre kə sə kə lə bdo...	...vudre k sə k lə bədo...
...vudre k sə kə l bədo...	...vudre k sə kə lə bdo...

5 Data and discussion from Dell 1970, Anderson 1974, Howard 1972.

...vudre kə s kə l bədo... ...vudre kə s kə lə bdo...
...vudre kə sə kə lə bədo... ...vudre kə sə k lə bdo...
...vudre k sə k lə bdo...

An important restriction on the rule is that it cannot apply to two consecutive syllables.

*...vudre k s kə lə bədo... *...vudre kə s k lə bədo...
*...vudre kə sə k l bədo... *...vudre kə sə kə l bdo...
*...vudre k s k lə bədo... *...vudre kə s k l bədo...

The rule can be formalised as:

$$ə \rightarrow \varnothing \ / \ VC \_\_ CV$$

The problem for the simultaneous theory is that any syllable, odd and even alike, can be deleted, so preparsing the string to identify only even numbered (or odd-numbered) syllables does no good — you have to know whether the preceding schwa has *actually* deleted. Stating such a rule is beyond the grasp of the simultaneous theory.

MACUSHI[6]

A similar example is found in Macushi, which reduces every other vowel to schwa, subject to complications — these complications make it impossible to state the rule in the simultaneous theory. Starting at the left, unstressed vowels reduce to schwa unless preceded by a reduced vowel (stress is phase-final).

wanamarɨ́ → wənaməɾɨ́ 'mirror'
u-wanamamri-rɨ́ → əwanəmarərɨ́ 'my mirror'
u-manari-rɨ́ → əmanərirɨ́ 'my cassava grater'

A vowel does not reduce in a closed syllable, thus /šiʔ-miri-ki-pé/ becomes [šiʔmərikəpé] 'little now'. This throws the parity of reducd syllables off: whereas normally reduced vowels appear in the odd numbered syllables, when an odd syllable is also closed, reduced vowels appear in even syllables.

A vowel does not reduce if it is preceded by a cluster of two consonants unless the first is a sonorant. Thus there is no reduction of the second syllable of /pakra-yamínʔ/ → [pakrayəmínʔ] 'bush hogs', and there is no reduction in the initial syllable of /kratu-pé/ → [kratəpé] 'alligator now'. Finally, the vowel of the third syllable does reduce in /karaywa-pé/ → [kəraywəpé] 'Brazilian now' despite the preceding consonant cluster, since the first element of the cluster is a sonorant. In addition, certain vowels lexically fail to reduce; the pattern of vowel reduction procedes from that point. The initial vowel of /paka-piʔpɨ́/ → [pakə-piʔpɨ́] 'cowhide' is an example.

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[6] Data from Hawkins (1950), discussed in Kenstowicz & Kisseberth (1977).

The rule of reduction can thus be formalized as follows (this is the K&K statement of the rule).

$$\underset{[-\text{stress}]}{V} \rightarrow ə \left\{ \begin{array}{c} \# \\ V \\ [-\text{reduced}] \end{array} \right\} ([+\text{son}])\ C \ \_\_\ CV$$

The conclusion to be draw from this example is that it misses a significant generalization if the reduction rule has to repeat these factors, both in the general context of the rule, and in a statement of material that can be skipped. Particularly problematic is the readjustment in the syllable count after lexical exceptions, which do not undergo reduction.

Directionality

On the assumption that rules may apply iteratively, the question of rule directionality arises. It is conceivable that the direction of application has to be stipulated ad hoc for each rule — this was proposed in Johnson (1971) — but that would not only raise questions of generative power (allowing another property to be added to variation between rules of human languages), but more importantly, it would seem to be unnecessary. One proposal advanced in Howard 1972 is that rules apply in the direction of the focus (relative to the determinant or trigger). Thus in (a), the rule applies from left to right because the focus stands to the right of the trigger, and in (b), the rule applies from right to left since the focus is on the left of the trigger.

a. $X \rightarrow Y / Z\_\_\_$
b. $X \rightarrow Y / \_\_\ Z$

Rules of the type (a) correspond to vowel harmony in Turkic and Uralic, *l*-nasalization in various Bantu languages and vowel nasalization in Arabela, which apply from left to right, and rules of the type (b) correspond to vowel raising in Menomini umlaut in Takelma, vowel nasalization in Urhobo and sibilant harmony in Navaho.

Howard observes certain problems for his proposal. One involves rules with triggering material both before and after the focus — an example is a proposed rule turning a vowel into a glide between vowels in Eastern Ojibway. In such cases, it is proposed that rules with "balanced" environments apply rightward. A more significant counterexamples to his proposal, is a voicing dissimilation in Kikuyu where $k \rightarrow \gamma$ / — [-voice], where /nekakaakeroma/ becomes [neγaγaakeroma]. Under Howard's proposed algorithm for predicting the direction of iteration, the rule should apply from right to left. As you can see below, if the rule were to apply starting at the right, an incorrect alternating pattern would result.

Left-to-right application	Right-to-left application
/nekakaakeroma/	/nekakaakeroma/
γ	γ
k	γ
*[nekaγaakeroma]	[neγaγaakeroma]

This pattern can be described in one of two ways, either by reversing the directionality of the rule (as above), or by applying the dissimilation simultaneously. Howard proposes this latter solution for cases of unpredictable direction, based on a theoretical argument regarding disjunction and parentheses. Similar problematic cases involve gradation in Finnish, tone sandhi in Mandarin, and vowel shortening in Slovak, inter alii.

Although Howard observes that there is a functional connection between direction of iteration and feeding / bleeding effect, his principle is stated entirely formally. Jensen & Stong-Jensen (1973) on the other hand focus on function effects of rules. They propose Principle A:

> Propagating rules produce a pattern that is alternating or nonalternating. Segmental and tone rules are nonalternating: they apply to produce maximal effects, in feeding (class I) or nonbleeding (class II) order. Stress, glide and vowel deletion rules are alternating: they apply in bleeding order (class III).

As far as assimilatory rules such as vowel harmony or nasalization are concerned, i.e. rules like (a,b) above, this principle predicts the same outcome as Howard's "towards the focus" algorithm. Their algorithm handles the pattern of Finnish gradation, which is non-alternating (/rokko-tt-utta-tte/ → [rokotutatte] 'you pl. are having (s.o.) innoculated') but which Howard was forced to treat as a simultaneous rule. It also better describes the facts of prosodic rules (glide formation, stress assignment and vowel deletion) which caused problems for Howard's theory, especially Kimatuumbi glide formation (see the section on cyclicity in Kimatuumbi) which should apply from right to left since the focus precedes the trigger, but in fact the rule applies from left to right. Another problematic case for Howard's algorithm is Hidatsa vowel deletion, where /cixi/ → [cix] 'jump!' and /kikua/ → [kiku] 'set a trap!'. Vowel deletion is due to the following rule:

V → ∅ / __ #

By Howard's algorithm, leftward application of this rule would change /kikua/ into *[kik]. The JSJ algorithm correctly predicts bleeding (minimizing) application of rules in such cases.

The JSJ theory is able to handle Kikuyu *k*-dissimilation automatically, whereas Howard was forced to apply that rule simultaneously, and thus the JSJ theory has a distinct advantage. Unfortunately, another process which Howard handles straightforwardly, namely Woleaian *a*-dissimilation, cannot be handled by the JSJ algorithm. In Woleaian, *a* becomes *e* before *a*:

[+low] → [-low] / __ C_0 [+low]

(Word final vowels will also delete). Thus /mata/ → [ma:t] 'eye', /mata-ca/ → [metaš] 'our (incl.) eye' and /mama-mami/ → [matemam] 'our (excl.) eye'. Applying the rule, as predicted by Howard, from right to left gives the observed alternating pattern.

A highly similar rule — *k*-dissimilation in Kikuria, a Bantu language related to Kikuyu — actually applies from right to lft, as predicted by Howard's algorithm. In this language, /g/ becomes [ɣ] when the following consonant is a voiceless obstruent: as in Kikuyu, [ɣ] is phonemically *g*. Prefixes which are dissimilated include the infinitive /ko/, the 2sg object prefix /ko/, the diminutive object prefix /ka/ and the class 7 object prefix /ke/. Prefixes with underlying /g/ include the cl. 3 object prefix /go/ and the class 6 object prefix /ga/.

oko-roma	'to bite'	/oko-roma/
ogo-ko-roma	'to bite you'	/oko-ko-roma/
ogo-ke-roma	'to bite it (7)'	/oko-ke-roma/
oko-go-roma	'to bite it (3)'	/oko-go-roma/
ogo-ko-ga-romera	'to bite it (6) for you'	/oko-ko-ga-romera/
ogo-ko-go-romera	'to bite it (3) for you'	/oko-ko-go-romera/
oko-go-ka-romera	'to bite it (dim) for you'	/oko-ko-ka-romera/
oko-go-ke-romera	'to bite it (7) for you'	/oko-ko-ke-romera/
ogo-tɛrɛka	'to brew'	/oko-tɛrɛka/
oko-ga-tɛrɛka	'to brew it (6)'	/oko-ga-tɛrɛka/
oko-ga-tɛrɛka	'to brew it (dim)'	/oko-ka-tɛrɛka/
oko-go-tɛrɛkɛra	'to brew for you'	/oko-ko-tɛrɛkɛra/
oko-ge-tɛrɛka	'to brew it (7)'	/oko-ke-tɛrɛka/
ogo-ke-go-tɛrɛkɛra	'to brew it (7) for you'	/oko-ke-ko-tɛrɛkɛra/

The alternating pattern is particularly clear in the case of ogo-ke-go-tɛrɛkɛra from /oko-ke-ko-tɛrɛkɛra/.

Examples such as *k*-deletion in Kikuyu and Kikuria — the same rule in two relatively closely related Bantu languages — which differ only in the direction of rule application provide evidence that rule directionality is not ultimately predictable; similarly, syncope in Tonkawa (Phelps 1975) operates from left to right (so /we-yamaxa-oʔ/ → [weymaxoʔ] 'he paints their faces', but syncope in Iraqi Arabic (Odden 1978) applies from right to left so that /yi-libas-úun/ → [yilibsúun] 'they wear'.

One putative example of a contrast in directionality is vowel shortening in Gidabal vs. Slovak. We have seen Gidabal above, and noted that it produces an alternating pattern of. It has been claimed that the same rule in Slovak produces a non-alternating pattern, thus supposedly /či:t-a:v-a:v-a:/ → [či:tavava] 'reads (iterative)', not *[či:tava:va] parallel to Gidabal. However, Vago & Battistella (1982) show that this phenomenon has been misanalysed so that the underlying form of this word is /či:ta-va-va/; indeed, the alternating pattern is seen elsewhere in the langauge, where /kla:t-i:k-a:m/ → [kla:tika:m] 'beehive (dat. pl. dimin)'.

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