

Two Rules or One...or None? [ATR] in Yoruba

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TWO RULES OR ONE...OR NONE? [ATR] IN YORUBA

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1 Introduction

The distribution of [ATR] in Yoruba raises a startling paradox: three crucially ordered rules are necessary, yet the first and third are formally identical. (Schlindwein 1987a makes this observation for Yoruba; see also Schlindwein 1987b). The standard solution for such puzzles is an appeal to cyclicity: in Yoruba such an appeal fails for the rules are all relevant at the earliest lexical level and apply to underived as well as derived forms. We propose that the Identity Paradox is not a morphosyntactic effect, but rather is an artifact of viewing rules as independent statements, sequentially ordered. Abandoning the notion that systematic phonological relations are to be expressed by rules applying in an ordered fashion, we resolve the observed paradox through optimization (aka Harmonic Grammar) (Prince & Smolensky 1991a,b, 1992, 1993, Archangeli & Pulleyblank [henceforth A&P] in press).

The argument is organized along the lines of the preceding paragraph, demonstrating the problem first and then turning to the optimization account.

2 Distribution of [ATR] in Yoruba: Order

Standard Yoruba has seven oral vowels on the surface: [i, e, ɛ [ɛ], a, ɔ [ɔ], o, u]. High vowels do not participate in harmony and cooccur with the full range of vowels (*ide* ‘brass’, *èbi* ‘guilt’, *idè* ‘type of game’, *ebi* ‘hunger’, etc.); the advanced nonhigh vowels [e, ɔ] and the retracted nonhigh vowels [ɛ, a, ɔ] cooccur with members of their own set, but do not cooccur (except as indicated shortly) with members of the opposite set (*ègè* ‘dirge’, *ègé* ‘cassava’, **ege*, **ege*, etc.).

Although the facts as so far described are consistent with either [+ATR] or [-ATR] being active in the phonology of Yoruba, facts concerning low vowels require an active [-ATR] value. Constrasting with the inertness of the advanced value of high vowels, the retracted value of a low vowel causes any preceding mid vowel to similarly retract (*egba* ‘whip’, **egba*). The effect of the [-ATR] value of low vowels is strictly directional: although only [-ATR] mid vowels may *precede* a low vowel, both [-ATR] and [+ATR] vowels may *follow* a low vowel, as lexically appropriate (*agbe* ‘type of bird’, *àgbè* ‘farmer’). Following A&P (1989, in press), the systematically retracted property of low vowels is accounted for by a rule of [-ATR] Insertion; to account for the retracted value of preceding mid vowels, we posit a right-to-left rule of [-ATR] Spread.

The harmonic pattern with mid vowels can be incorporated into this analysis as follows: “retracted” morphemes are distinguished from “advanced” morphemes by the presence of a floating [-ATR] specification as part of their underlying entry. Where present, this free [-ATR] value links from right to left to the first available nonhigh vowel, and then feeds into the directional harmony rule motivated for low vowel cases thereby bringing about harmony between all mid vowels. That the direction of the association process is strictly right-to-left can be seen in morphemes with two mid vowels separated by a high vowel: in such forms, it is only the *rightmost* mid vowel that can be [-ATR] (*èbúté* ‘harbour’, *èlùbó* ‘yam flour’, **elubo*, **elubo*, etc.); see (8a).

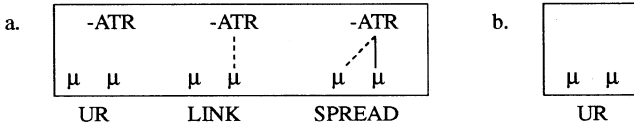
Note that the impossibility of the forms like **elubo* also demonstrates the importance of the Obligatory Contour Principle (OCP) in Yoruba (8a). Since high

vowels cannot be targeted by harmonic spreading, and if all lexical [-ATR] specifications are floating, then two retracted vowels separated by a high vowel (putative **elubo*) could only be derived by two underlyingly floating [-ATR] tokens, a representation that is correctly ruled out by the OCP.

We conclude that the grammar crucial for an account of Yoruba harmony has three components all of which are subject to the OCP: lexical features associate (*Link*), low vowels become systematically retracted (*Insert*), nonhigh vowels preceding retracted vowels become retracted themselves (*Spread*). Because Standard Yoruba [ATR] harmony is presented in detail elsewhere (A&P 1989, in press), our goal here is not to motivate the basic analysis, but to focus on those points crucial to the Identity Paradox. The first point to be demonstrated is the ordering of the three rules, Link, Insert, and Spread.

Consider first the ordering of Link and Spread (1a). Link associates a lexically specified floating token of [-ATR] to the rightmost nonhigh vowel. Spread extends the domain of the linked [-ATR] to nonhigh vowels on the left. (A form with no floating [-ATR] is shown in (1b) for comparison.)

(1)



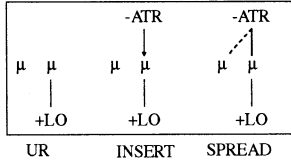
Because Link precedes, and therefore feeds, Spread, strings of mid vowels come to have a single [ATR] value (2). Were Spread to precede, and therefore counterfeed, Link, the unattested **e...e* would be expected.

(2) LINK precedes SPREAD

- | | |
|--|---|
| <p>a. ègé 'cassava'
èké 'forked stick'
èṣe 'row'</p> | <p>b. ègè 'dirge'
èké 'lie'
èṣe 'cat'</p> |
|--|---|

Given standard approaches to phonological analysis, the Insert [-ATR] rule must also precede Spread since, like Link, the rule that inserts [-ATR] feeds the rule that spreads [-ATR].

(3)



The effect of ordering Spread after Insert (the feeding order) is that mid vowels are [-ATR] when to the left of low vowels. Were the ordering reversed, Spread before Insert (counterfeeding), the unattested **e...a* would be predicted.

(4) INSERT precedes SPREAD

- | | |
|--|--|
| <p>egba 'whip'
ègà 'weaver-bird'</p> | <p>èbà 'food made from gàrì'
èràpó 'type of plant'</p> |
|--|--|

The discussion above motivates the partial orders, *Link precedes Spread* and *Insert precedes Spread*. The final step needed to lay out the ordering paradox is to demonstrate that *Link precedes Insert*. The critical case involves a low-mid vowel sequence combined with a floating [-ATR]. As the forms in (5) show, both

[-ATR] and [+ATR] mid vowels may occur to the right of a low vowel, accounted for under our analysis by whether the underlying representation contains a floating [-ATR], (5a), or contains no token of [-ATR], (5b).

(5) LINK precedes INSERT

- | | | | |
|----|----------------|----|------------------------------|
| a. | àjé 'witch' | b. | àfè 'Spotted Grass-mouse' |
| | abéré 'needle' | | àbèrè 'fruit used as a drug' |
| | àgbè 'farmer' | | agbe 'type of bird' |

To derive both patterns without ad hoc conditions, Link must precede Insert. Applying the rules in this order gives wellformed derivations as in (6a). Column A demonstrates the case where a morpheme has a floating [-ATR] specification: first, the [-ATR] value links up from right to left; second, Insert adds [-ATR] to the low vowel, resulting in a single, multiply-linked [-ATR] specification (see A&P in press). This result is consistent with the OCP; to assume that Insert created a sequence of [-ATR] tokens would be to force the rule to violate the OCP, thereby weakening the OCP in general terms in spite of a complete absence of evidence for such a violation and weakening. Column B represents a morpheme without any morpheme-level [ATR] specification. Because the low vowel is initial, the only rule applicable is Insert.

(6)

a. $\left(\begin{array}{l} \text{LINK} \\ \text{INSERT} \end{array} \right.$

	-ATR	
UR	A j E	A f E
LINK	 A j ε	n/a
INSERT	 a j ε	-ATR a f E
OUTPUT:	àjé	àfè
COST:	NONE	NONE

Column A

Column B

b. $\left(\begin{array}{l} \text{INSERT} \\ \text{LINK} \end{array} \right.$

	-ATR			
UR	A j E			A f E
INSERT	 a j E	 a j E	 a j E	 a f E
LINK	 a j ε	n/a	n/a	n/a
OUTPUT:	àjé	*àjé	àjé	àfè
COST:	VIOLATES OCP	BAD & VIOLATES OCP	BAD	NONE

Column C

Column D

Column E

Column F

As shown in (6b), applying Insert *before* Link would be unable to duplicate the correct results just witnessed. The problematic cases are those where a low vowel cooccurs with a morpheme-level [-ATR] value. If Insert were to add a token of [-ATR] to the representation, then whether this added token were to the right or to the left of the existing token of [-ATR] (presumably one or the other by

arbitrary stipulation), an OCP violation would result as seen in columns C and D respectively of (6b). Yet as argued in A&P (1989, in press) and sketched above, [ATR] obeys the OCP in Yoruba. If Insert were to apply in a manner consistent with the OCP, the resulting representation would have a single, “merged” [-ATR] token, as in column E of (6b); such merger would incorrectly bring about the neutralization of the two types of forms in (5), predicting the nonexistence of *a...e* forms.

We conclude that Link must precede Insert, which in turn must precede Spread.

3 Properties of Link and Spread: the Identity Paradox

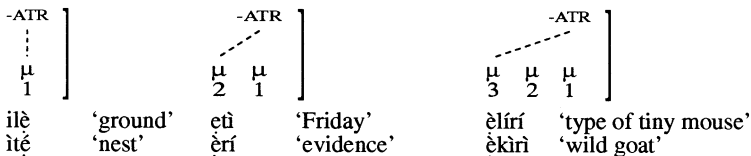
We now turn to the Identity Paradox, demonstrating that Link and Spread are formally identical. Our first observation is that the formal effect of both Link and Spread is to add an association line between [-ATR] and a vowel. In terms of the explicit framework developed in A&P (in press), both rules are characterized by the parameter values “Insert Path”. Each rule has additional properties: (i) featural conditions, (ii) values for two other parameters, Iteration and Direction. As the ensuing discussion shows, the two rules are identical for all such additional factors.

Consider first the Iterativity parameter. Iterative rules can apply to a successive string of targets while noniterative rules can apply only to a single target (see A&P in press). In the case of iterative linking, a rule scans across a string until the first eligible target, if any, is encountered; with noniterative linking, a rule stops after consideration of a single potential target. As shown in (7a), [-ATR] links to whichever mid vowel is the *rightmost*, skipping over a string of high vowels. Such behavior demonstrates that Link must be iterative.

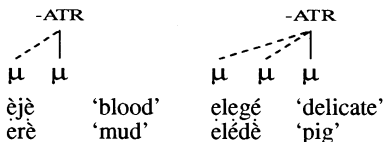
Spread is also iterative, affecting a string of eligible targets, as shown in (7b). All mid vowels in a form undergo Spread: crucially, more than one mid vowel can be affected, cf. *ẹlẹgẹ* ‘delicate’.

(7) ITERATIVITY

a. LINK



b. SPREAD



We turn next to the Direction parameter: both rules apply from right to left. The critical forms showing the direction for Link are those with two mid vowels flanking a high vowel. As shown in (8a) only the rightmost mid vowel may be [-ATR], as expected under right to left linking. Were Link a left to right rule, the unattested **e...i...e* pattern would be predicted.

(8) DIRECTIONALITYa. LINK

μ μ μ MID HI MID	μ μ μ MID HI MID	μ μ μ MID HI MID	μ μ μ MID HI MID
èbúté ‘harbour’ èkúté ‘house-rat’ eriko ‘midrib of igi ògòrò ‘stripped of its leaves’	èlùbó ‘yam flour’ erùpè ‘earth’ ewúré ‘goat’	*[è i e]	*[è i e]

b. SPREAD

<u>RIGHT TO LEFT</u> μ μ MID LO	* μ μ MID LO	* μ μ LO MID	μ μ LO MID
ewà ‘beauty’ erápó ‘type of plant’ épádi ‘area in the vicinity of the rampart’	*[e a]	[a e]: possible, but not by SPREAD	àyè ‘chance’ àtè ‘type of resin’ àkèré ‘type of edible frog’

With respect to Spread, the critical forms involve low and mid vowels. To the right of a low vowel, mid vowels may be either [-ATR], or [+ATR], depending on the presence or absence of an underlying [-ATR] value. Positing spread of [-ATR] from left to right would incorrectly rule out one of these attested classes, namely those with either of the patterns *a...e* or *a...o*. Conversely, to the left of a low vowel, mid vowels may *only* be [-ATR], accounted for by the application of Spread from *right to left*.

In addition to sharing the parametric properties of applying *iteratively* from *right to left*, Link and Spread share identical substantive properties: both rules target uniquely the class of nonhigh vowels. As can be seen in (7a), when Link encounters a high vowel, the association process simply skips over the high vowel; association cannot target a high vowel (*etiri* ‘difficult’, **etiri*, etc.). (We use [i] to represent a retracted high vowel.) Similarly, as seen in (7a) and (8a), Spread cannot target a high vowel either (*ide* ‘brass’, **ide*, etc.). In Standard Yoruba, this restriction holds generally rather than of specific rules: there are no high [-ATR] vowels.

To conclude, the crucial properties of Link and Spread are identical: in terms of parameters, both rules *insert a path from right to left, iteratively*.

The effect of associating [-ATR] on a representation with a free [-ATR] is “linking”; the effect of association on a representation with a linked [-ATR] is “spreading”. The putative differences between the processes of linking and spreading in Yoruba, then, are artifacts of the divergent representations to which the “two” rules apply. That is, the crucial differences are due to properties of input *representations*, not to differences in the formal properties of *rules*. In purely formal terms, *Link is equivalent to Spread*. Yet the ordering arguments of section 2 establish that “Link” *precedes* Insert and “Spread” *follows* Insert, the Identity Paradox.

The Identity Paradox poses a serious challenge to the coherence and restrictiveness of the view that phonologies include a list of (partially) ordered rules. To account for the Yoruba pattern within such a theory, one possibility is to posit two completely identical Link/Spread rules, one preceding Insert and one following Insert (9a). Another possibility is that the same rule may appear in multiple positions within the list of rules (9b). Either of these conclusions about rule lists is possible only within an unrestrictive theory. In addition, it is accidental within both accounts that [-ATR] extends its domain as far as possible regardless of its source (i.e. regardless of whether [-ATR] is present underlyingly or is inserted by rule).

(9) Implications of the Identity Conclusion

- | | | | | | |
|----|--|----|--|----|--|
| a. | { LINK=SPREAD A
INSERT
LINK=SPREAD B | b. | { LINK=SPREAD A
INSERT
LINK=SPREAD A | c. | LINK=SPREAD & INSERT |
| | --A, B are different rules, accidentally identical | | --LINK=SPREAD is one rule, listed twice | | --(LINK=SPREAD applies anywhere and everywhere) |
| | | | | | --LINK=SPREAD behaves like a convention but is language-particular |

This observation is expressed in a third approach (9c): Insert remains a rule, but Link=Spread applies anywhere and everywhere, following Myers (1991). Unfortunately, while a persistent rule solution might at first appear to be a successful alternative, further data from Yoruba demonstrates that it is untenable. We digress briefly to demonstrate that the (9c) approach fails in Standard Yoruba: specifically, it fails to apply after a rule creating long vowels.

Consonants delete in certain environments in Standard Yoruba (Oyelaran 1971, Akinlabi 1993). When this deletion results in a mid-high sequence, the mid vowel spreads rightwards and the high vowel is lost. Strikingly, this spread may result in a sequence of a long [+ATR] mid vowel followed by a [-ATR] vowel. Crucially, the creation of such a potential environment for [-ATR] harmony does not feed the harmonic rule of Link=Spread.

(10) Anywhere and everywhere option is not tenable (cf. Akinlabi 1993)

- | | | | | | |
|----|--------|---|-------|--------|---------------|
| a. | yorùbá | ↔ | yoòbá | *yoòbá | 'Yoruba' |
| b. | odíde | ↔ | oóde | *oóde | 'Grey Parrot' |
| c. | erùpè | ↔ | eèpè | *èèpè | 'earth' |

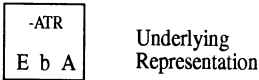
One might entertain the possibility that consonant deletion takes place at a stage in the grammar where [-ATR] harmony has ceased to be applicable. Such a possibility is unlikely, however. Akinlabi (1986) and Folarin (1987) present arguments that consonant deletion, progressive vowel spreading and the [ATR] harmony rules all apply on the same lexical stratum; this removes the possibility of explaining their noninteraction in purely morphosyntactic terms. We are forced to the conclusion that the *anywhere-and-everywhere* option fails to account for the distribution of [ATR] in Yoruba, and hence fails to resolve the Identity Paradox.

4 Optimization

The failure of ordered rules and of everywhere rules forces exploration of different approaches to the characterization of language particular relations. Here we propose a nonderivational approach in which the grammar includes a function that provides a direct mapping between underlying and surface forms. Our proposal follows most closely ideas found in a number of works by Alan Prince and Paul Smolensky (Prince and Smolensky [P&S] 1991a,b, 1992, 1993); see also Goldsmith (to appear) and the papers therein.

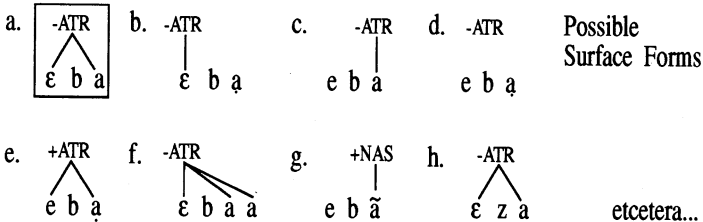
The basic idea is the following. Assume a set of wellformed underlying representations. A Yoruba example would be a morpheme with a floating [-ATR] value.

(11) A nonderivational alternative



Logically, such a representation could be mapped onto an infinite number of surface representations, for example, the forms given in (12). (In the following examples, [a] is used to represent an *advanced* low vowel.)

(12) A nonderivational alternative



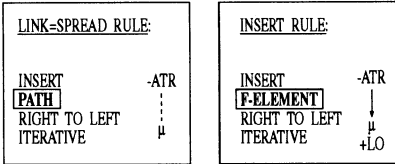
Of the class of such logically possible corresponding surface forms, the phonological grammar must select (12a) as the best, or optimal, surface form for the underlying representation given in (11), choosing between the various candidates that compete for such optimal status. Consider first those in (12e-h). These cases are straightforwardly defined as nonoptimal because in each case, the relation between underlying and surface form cannot be defined in terms of a systematic function involving [-ATR]: (12e) involves [+ATR], (12f) involves lengthening of a vowel, (12g) involves the assignment of nasality, (12h) involves a consonantal change. As regards the cases in (12a-d), (12d) is formally related to the input in (11) by the Identity relation, (12c) is related by linking from right to left without spreading. (Alternatively, (12c) could be related to the input by insertion of [-ATR] to the low vowel with merger of the morpheme-level specification.) (12b) is related by linking (without spreading) from left to right, and (12a) is related by linking and spreading.

The optimization hypothesis claims that a static set of constraints defines one such form as the best for a given input. The challenge is how to accomplish this characterization without resorting to a completely unconstrained set of "constraints" as replacement for the unconstrained sets of rules of the standard approach. We propose a characterization in terms of two interacting scales, each scale derived from independently motivated properties of rules and representations (see A&P in press). The first scale ranks relations between representations in terms of *parametric* factors; the second performs a similar evaluation in terms of *grounding* factors.

Inspection of (13a) reveals that there is a single parametric difference between Link=Spread and Insert. Link=Spread adds a *Path* (association line) while Insert adds an *F-element* (feature). Values for other parameters, Function, Direction, and Iteration, remain constant. (The parameters are motivated in A&P in press.)

(13) Parametric Factors

a. Parameter of variation



b. Ranking: **PATH » F-ELEMENT**

Following A&P (in press), we argue that relations defined by *Path* are less marked, therefore preferred, to relations defined by *F-element*. A Path rule exacts a minimal change in the representation, affecting only relations between existing information. An Insert Path rule enlarges the domain of influence of the Argument, making that feature more salient and so more recognizable/recoverable. Path insertion when applied to a free Argument links it to prosodic structure; without a path to prosodic structure, the free F-element would not surface, a Prosodic Licensing effect (Itô 1986). (The notion is also akin to the PARSE family of constraints found in P&S 1993; thanks to Robert Kirchner for bringing this to our attention.) By contrast, adding/removing an F-element alters the information content of the representation, making the relation between the two representations less recoverable since one contains information lacking in the other. Thus, manipulating a Path is optimal (13b), we claim, in comparison to manipulating an F-element.

Substantive conditions restricting where [-ATR] may associate are also relevant in Yoruba. Insert F-element imposes the substantive condition that the mora affected must be [+low]; the language as a whole imposes the substantive condition that all [-ATR] vowels are nonhigh. These conditions are neither ad hoc nor unusual: under Grounding Theory (A&P in press), feature cooccurrence conditions governing rules and representations are required to be physically motivated. The relation between the tongue body position and tongue root position is such a grounded relation: tongue body lowering and tongue root retraction enhance each other both articulatorily and acoustically. Within the grounding framework, the interaction is formally expressed by the *RTR/LO CONDITION: If [-ATR] then [+low]; if [-ATR] then not [-low]* and the *RTR/HI CONDITION: If [-ATR] then [-high]; if [-ATR] then not [+high]*.

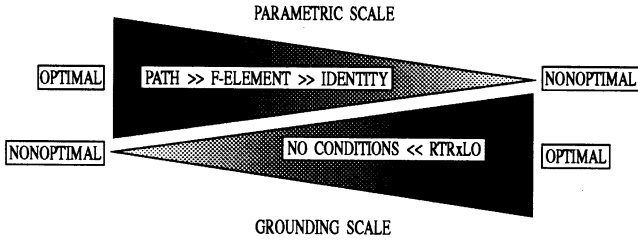
Following Grounding Theory (A&P in press), configurations that respect RTR/LO are evaluated as substantively better than configurations that do not obey the condition. This is motivated by cross-linguistic evidence suggesting a skewing towards rules and representations that respect the condition, and by phonetic evidence for a strong correlation between tongue root retraction and tongue body lowering both articulatorily and acoustically. (See A&P in press for references to the phonetic literature on this topic.)

(14) Grounding factors (A&P in press):

- a. General (governs all representations): RTR/HI: If [-ATR] then [-high]
- Rule-specific (governs F-element rule only): RTR/LO: If [-ATR] then [+low]
- b. Relevant Ranking: **RTRxLO » no conditions**

Given the rankings in (13b) and (14b), what remains is to integrate the two classes of factors. We propose that integration is accomplished via “trade-off”: as the parametrically defined relations degrade, their quality in terms of grounding must be improved.

(15) Trade-off



The Path factor defines the strongest parametric configuration: as such, it can relate underlying and surface forms under optimal conditions with regards to grounding ([-ATR] associates to a *low* vowel), as well as under less optimal conditions ([-ATR] associates to any eligible (i.e. nonhigh) vowel). The F-element factor is weaker in terms of the parametric scale: as such, it can relate underlying and surface forms only under the best conditions as regards grounding ([-ATR] is inserted only onto a *low* vowel). Both combinations of factors are more highly evaluated than Identity, that is, relating underlying and surface representations that are identical with respect to [ATR].

(16) Integrated Yoruba [-ATR] Scale

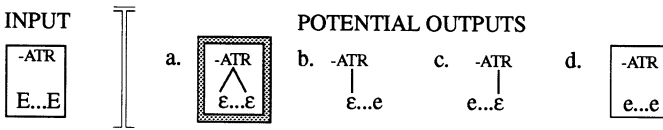


At this juncture, 3 issues remain. First we demonstrate that the [ATR] function in (16) actually does account for the Yoruba patterns. Second, we resolve the Identity Paradox. Finally, we return to the consonant deletion cases to show that the optimization approach to Yoruba succeeds where the *anywhere-and-everywhere* approach fails.

5 Resolving the Identity Paradox

Consider first examples of mid-voweled words with a floating [-ATR] in their underlying representation, cases such as *ese* ‘row’ (2a). Restricting our consideration to surface forms that can be related in terms simply of the feature [-ATR] (since any other alternatives will be valued less highly than Identity), four candidate surface representations need to be considered:

(17) Surface Candidates for [E...E] with a Floating [-ATR]



The representation in (17d) relates input and output representations by the Identity relation — a wellformed relation. The representations in (17b,c) each involve relations that are wellformed in a general sense; that is, in some language, rule parameters could be set to give left-to-right association without spreading (17b) or to give right-to-left association without spreading (17c). In Yoruba, however, such possibilities are illformed: the parameters in (13) define right-to-left iterative relations as superior to the Identity relation; other imaginable relations (such as defined by *left-to-right* or *noniterative*) are evaluated as worse than Identity. (Forms that are as good as or better than *Identity* are boxed; the optimal form is in

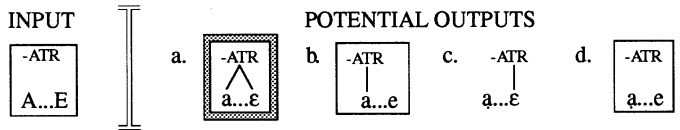
a shaded box.) As such the output in (17d) is ranked as better than those of (17b,c). The final candidate to be considered is (17a). This output is related to the input by the right-to-left iterative *Path* relation; grounding conditions (only the general condition RTR/HI is relevant) are satisfied. Unambiguously, the output in (17a) is the optimal one, correctly deriving forms like *ese* 'row': the relation that relates such a surface form to the underlying representation, *insert path R-L iterative*, is defined as optimal by the scale in (16).

In contrast to the case just seen, consider the optimal output for an underlying form involving two mid vowels *without* a morpheme-level [-ATR] specification, the underlying representation of a word like *èse* 'cat' (2b). In large measure, the logical possibilities are as in (17). The one significant difference is that, unlike (17d), the form defined by Identity would not include a floating [-ATR]; the wellformed output defined by Identity would be [e...e], two mid vowels unspecified for [ATR] and interpreted as advanced by the phonetics. Unlike with *ese*, the surface form [e...e] would be optimal for *èse*: the only way to define a relation between an input without [-ATR] and an output with [-ATR] (cases not involving Identity) would be to invoke the F-element relation; the grammar of Yoruba, however, defines Identity as more highly ranked than the F-element relation except when restricted to low vowels.

At the beginning of this paper, an ordering paradox was demonstrated within a theory adopting ordered rules. The crux of the argument concerned the ordering of Link/Spread both prior to and after Insert. Two further demonstrations show how these putative ordering effects are derived within an optimization framework. Consider first a case like *àjé* 'witch'; underlyingly, this type of case has a low-mid sequence with a floating [-ATR], used in (6) to demonstrate that Link precedes Insert.

As with (17d) above, the Identity relation defines (18d) as a wellformed output. Like (17c) above, (18c) is illformed for Yoruba: the relation is not one of *Identity*, nor is it appropriate for an *iteratively* defined *Path* relation, nor can it be defined by the *F-element* relation since the putative recipient of [-ATR] is not low. With regards to (18b), although the output cannot be related to the input by an iterative, right-to-left *Path* relation, (18b) does constitute a wellformed output as defined by the *F-element* relation: [-ATR] has been assigned to the maximal set of targets satisfying the substantive condition that they be low. (The single [-ATR] in the output would make this form compatible with the OCP). Finally, (18a), like (17a), is well-defined by the *Path* relation.

(18) Surface Candidates for [A..E] with a Floating [-ATR]

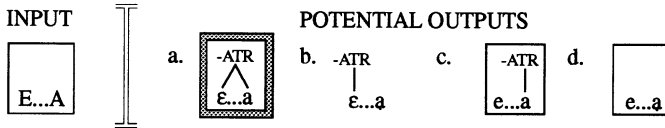


Three output forms therefore compete for the optimal output corresponding to [A...E] with a floating [-ATR]. The winner for such a form is clearly (18a). Comparing (18b) with (18d), we see that the two are equivalent with respect to the second vowel — both vowels are related by *Identity* to the input vowel. As regards the first vowel, the two forms differ with respect to the *F-element* relation. Since *F-element* is more highly ranked than *Identity*, (18b) is the better form. Finally, comparing (18b) with (18a), the two are equivalent as far as the first vowels are concerned. The two outputs differ in that the final vowel of (18b) is

related to the input by *Identity* while the final vowel of (18a) is related to the input by the *Path* relation. Since *Path* is the most highly valued relation in Yoruba, the grammar correctly selects (18a) as the optimal form.

Finally, the “Insert precedes Spread” effect is seen when a mid vowel precedes a low vowel and there is no floating [-ATR], for example, *egba* ‘whip’. The optimal output here, (18a) evaluates the mid vowel by *Path* and the low vowel by F-element. This is better than the other two candidates, for in each of those at least one vowel is evaluated by *Identity*.

(19) Surface Candidates for [E...A] NO Floating [-ATR]



Note that the representation in (18c) corresponds to the surface effect of Spread preceding Insert, ordering of such rules constituting a crucial aspect of a conventional phonological analysis. In optimization terms, (18c) is evaluated as weaker than (18a) without any recourse to notions of derivation or extrinsic rule ordering. In conventional theory, the ordering of “Link then Insert then Spread” results in the wide applicability of “Spread”. Under optimization, this pervasive effect derives from the high ranking of the *Path* relation.

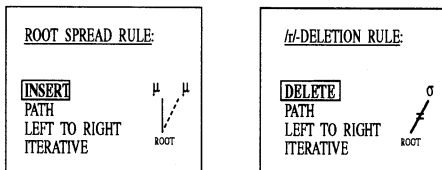
We conclude that the optimization approach characterizes the Yoruba [ATR] patterns correctly without recourse to ordered rules. Since there are no ordered rules, the Identity Paradox does not arise.

6 Interaction with Consonant Deletion

We return briefly to the consonant deletion problem. To review, the optional rule of consonant deletion feeds vowel lengthening; vowel lengthening creates a long mid vowel. Crucially, a following [-ATR] does not spread onto this derived long mid vowel: *yorùbá/yoòbá*, **yoòbá*. We provide a tentative and schematic explanation of this interaction here.

We propose that vowel lengthening spreads a Root node while consonant deletion delinks a Root node: the parametric values for these rules are given in (20) with the difference boxed. (For the purposes of this brief discussion, we ignore numerous issues. On consonant deletion in general, see Oyelaran 1971; for /r/-Deletion, see Akinlabi 1993; on Root Spread, see Pulleyblank 1988, Akinlabi 1993.)

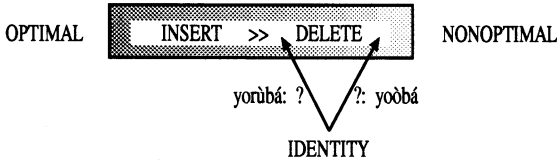
(20) [yorùbá] ↔ [yoòbá] cases



In terms of an optimization scale, Insert is preferred to Delete since deletion removes information from a representation, thereby decreasing recoverability. We suggest that the variability associated with consonant deletion is achieved by two different locations for *Identity*: if *Identity* is stronger than *Delete*, consonant

deletion may not take effect (and neither can vowel lengthening, for its environment is created by the loss of the consonant): *yorùbá* results. On the other hand, if Delete is better than Identity, the consonant deletes and the vowel lengthens: *yoòbá* results.

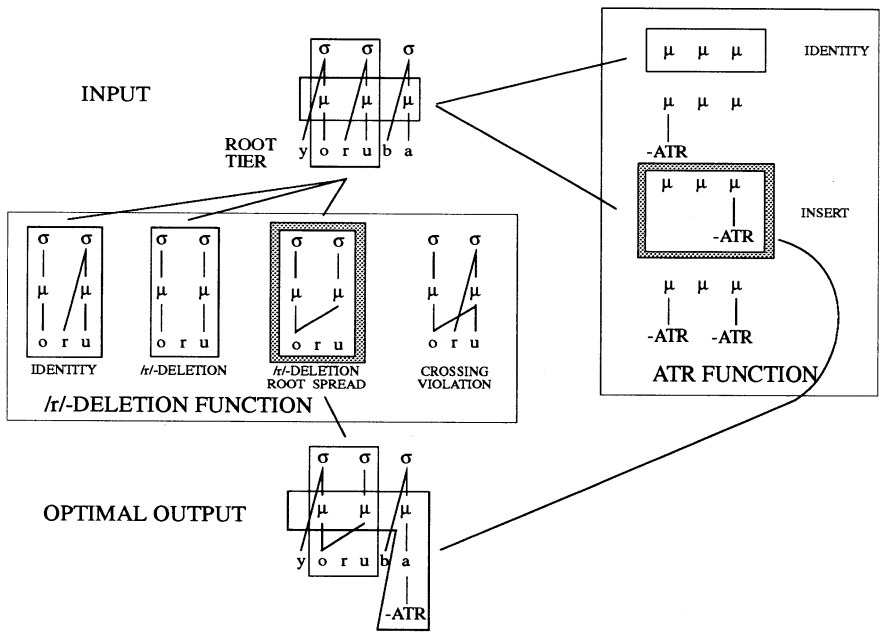
(21)



The question, then, is how to express the counterfeeding relation between the Root node function and the [ATR] function to correctly define relations between Yoruba representations. Our answer is that there is no interaction at all: both functions evaluate relations between representations independently, as depicted for *yoòbá* in (22). Relations between input and a variety of outputs are evaluated in terms of the [ATR] function and in terms of the consonant deletion function in (22). The optimal mapping between underlying and surface forms is the convergence of best mappings from each function.

With respect to the [ATR] function, the best mapping involves [-ATR] linked only to the third mora: the first and second moras are evaluated by *Identity* while the third mora is evaluated by *F-element*. Thus, [-ATR] is associated only to the final vowel, [a]. Of interest is the pairing of the optimal [ATR] output with the optimal output of the consonant deletion function, where consonant deletion and vowel spread create a lengthened mid vowel. In this case, the best mapping is one in which a consonant is lost and a vowel is lengthened. The results of evaluation in terms of these two functions converge in the representation for *yoòbá*, given as the optimal output in (22). (For the consonant function, if Identity were better than Delete, then the two representations would converge on *yorùbá*.)

(22) [yorùbá] ↔ [yoòbá] cases



7 Conclusion

We have argued here that an analysis of the distribution of [ATR] in Yoruba in terms of a list of rules requires an odd type of ordering, the Identity Paradox. Resolving the problems inherent in the “ordered list” approach, we argue for Optimization, a nonderivational theory of phonology. Three properties of Optimization are crucial for the account of Yoruba presented.

(23) Optimization

- a. **Ranking of Factors:** Each class of variable factors which determine the distribution of some F-element are internally ranked. Here, the two classes are parametric and grounding factors.
- b. **Trade-off:** These two rankings are integrated via *trade-off*: as the parametric scale deteriorates, its weakness is offset by improvement in other relevant scales, here the grounding scale, thereby creating a function defining the distribution of the argument in question.
- c. **Independent Optimization Scales:** Internally-ranked sets of parametric factors involving different Arguments may function independently of each other. Built into a single scale, factors feed each other; in separate scales, factors are counterfeeding.

Yoruba illustrates three important results of this approach. First, ordering problems like the Identity Paradox cannot arise because there are no ordered lists of rules. Second, the effects attributed to different kinds of ordering result from whether or not various relations are integrated into a single function. For example, the [ATR] relations defined by Path, F-element, and Identity are all part of a single function, deriving the effect of each feeding the other, and pervasiveness corresponding to a more dominant ranking. By contrast, the Root node function is

completely independent of the [ATR] function, deriving the effect of counterfeeding.

Finally, the approach claims that phonological relations are characterized by the principles in (23). Systems which cannot be expressed in terms of these principles are impossible. For example, trade-off rules out a language in which strong factors are mapped to strong factors and weak factors are mapped to weak ones. Thus, Optimization restricts possible relations, or sets of rules, within a language, allowing us to explore the question of “what is a possible rule inventory?”

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