

## References

- Aoun, J. (1985) *A Grammar of Anaphora*, MIT Press, Cambridge, Massachusetts.
- Aoun, J. and N. Hornstein (1985) "Quantifier Types," *Linguistic Inquiry* 16, 623-637.
- Barwise, J. and J. Perry (1983) *Situations and Attitudes*, MIT Press, Cambridge, Massachusetts.
- Braroe, E. (1974) *The Syntax and Semantics of English Tense Markers*, monograph, Institute of Linguistics, University of Stockholm.
- Chomsky, N. (1976) "Conditions on Rules of Grammar," *Linguistic Analysis* 2, 303-351. [Reprinted in *Essays on Form and Interpretation*, North-Holland, Amsterdam (1977).]
- Evans, G. (1977) "Pronouns, Quantifiers, and Relative Clauses (I)," *Canadian Journal of Philosophy* vii.3. [Reprinted in M. Platts, ed., *Reference, Truth, and Reality*, Routledge and Kegan Paul, London (1980).]
- Haik, J. (1985) *The Syntax of Operators*, Doctoral dissertation, MIT, Cambridge, Massachusetts.
- Hintikka, J. (1976a) "Language Games," reprinted in E. Saarinen, ed., *Game Theoretical Semantics*, Reidel, Dordrecht (1979).
- Hintikka, J. (1976b) "Quantifiers in Logic and Quantifiers in Natural Language," reprinted in E. Saarinen, ed., *Game Theoretical Semantics*, Reidel, Dordrecht (1979).
- Hintikka, J. (1986) "The Semantics of *A Certain*," *Linguistic Inquiry* 17, 331-336.
- Hornstein, N. (1984a) "Interpreting Quantification in Natural Language," *Synthese* 59, 117-150.
- Hornstein, N. (1984b) *Logic as Grammar*, MIT Press, Cambridge, Massachusetts.
- Hornstein, N. (forthcoming) "Levels of Meaning," in J. Garfield, ed., *Modularity in Representation and Natural Language Understanding*, MIT Press, Cambridge, Massachusetts.
- Jackendoff, R. (1972) *Semantic Interpretation in Generative Grammar*, MIT Press, Cambridge, Massachusetts.
- Quine, W. V. O. (1960) *Word and Object*, MIT Press, Cambridge, Massachusetts.

Linguistics Program  
University of Maryland  
College Park, Maryland 20742

## On the Ill-Formedness of Crossing Association Lines

Elizabeth Sagey

In this article I argue that the ill-formedness of crossing association lines, which has been widely attributed to a well-formedness condition in Universal Grammar (UG) that prohibits such crossing, in fact derives from extralinguistic knowledge, given the proper definition of association lines.

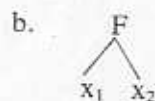
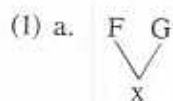
I am grateful to D. Archangeli, M. Halle, M. Hammond, J. Harris, J. Higginbotham, J. Kegl, J. Levin, T. Rapoport, D. Steriade, and four anonymous *Linguistic Inquiry* reviewers for comments on earlier drafts. Preparation of this article was supported in part by the University of California at Irvine Program in Cognitive Sciences, under A. P. Sloan Foundation grant #83-6-15.

An earlier version of this article appeared in N. Fukui, T. Rapoport, and E. Sagey, eds. (1986) *Working Papers in Linguistics* 8, Department of Linguistics and Philosophy, MIT, Cambridge, Massachusetts.

## 1. Simultaneity

Association lines are commonly supposed to represent that the units they link are simultaneous.<sup>1</sup> However, this interpretation of association lines leads to logical contradictions. Included in our knowledge of the world are the following properties of simultaneity and of precedence in time: simultaneity (=) is *transitive*, *symmetric*, and *reflexive*; precedence (<) is *transitive*, *antisymmetric* (if  $A < B$ , then NOT  $B < A$ ), and *irreflexive*; and simultaneity and precedence together have the property of *substitution* (if  $A = B$ , and  $B < C$ , then  $A < C$ ).<sup>2</sup>

Problems arise when these properties are applied to multiple linkings as in contour segments and geminates. If association lines represent simultaneity, then (1a,b) encode the precedence and simultaneity relations in (2a,b), respectively (where F and G are, for instance, [-continuant] and [+continuant]):



(2) a.  $F < G$ ,  $F = x$ ,  $G = x$

b.  $x_1 < x_2$ ,  $F = x_1$ ,  $F = x_2$

From (2), substitution derives the contradictions in (3) that x and F precede themselves; and symmetry and transitivity derive the contradictions in (4):

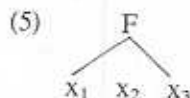
(3) a.  $x < x$

b.  $F < F$

(4) a.  $F = G$

b.  $x_1 = x_2$

Discontinuous multiply-linked structures (of the type that occur in nonconcatenative morphology, vowel harmony, or tone spreading)<sup>3</sup> present another problem. If association lines represent simultaneity, then (5) encodes the precedence and simultaneity relations in (6):



(6)  $x_1 < x_2$ ,  $x_2 < x_3$ ,  $F = x_1$ ,  $F = x_3$

From (6), antisymmetry and substitution derive the contradiction in (7):

(7) a.  $F < x_2$

b. NOT  $F < x_2$  (by antisymmetry on  $x_2 < x_3$  and substitution)

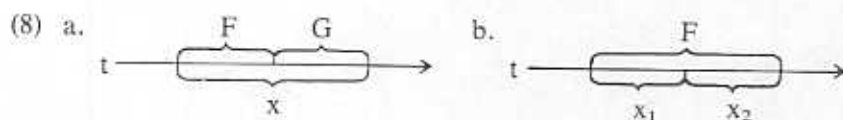
Finally, it is incorrect phonetically to describe the features and x-slots in contour

<sup>1</sup> See, for example, Goldsmith (1976, 41–42), Clements (1985, 228).

<sup>2</sup> These properties hold of simultaneity among units without internal duration. Since features and skeletal slots are temporally unanalyzable units in the phonology, the natural assumption is that simultaneity relations among them treat them the same way. See footnote 4.

<sup>3</sup> See McCarthy (1986), Archangeli (1984), Goldsmith (1976).

and geminate structures as simultaneous. Rather, the timing of features and x-slots in contours and geminates is as illustrated in (8a,b), respectively, where the realizations of F, G, and x are mapped onto a time line:

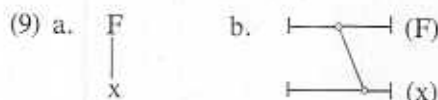


The relation between features and skeletal slots illustrated in (8) is one of partial simultaneity, or overlap in time. I propose, therefore, that overlap in time, not simultaneity, is the relation that association lines represent.<sup>4</sup>

## 2. Overlap

Overlap is *intransitive, symmetric, and reflexive*.<sup>5</sup>

For a feature and an x-slot to overlap means that some part of the feature and some part of the x-slot are simultaneous. However, which parts are simultaneous, and how large those parts are, are left undetermined: overlap requires only that at least one instant of time be shared between the feature and the x-slot. So when F overlaps x, at least one point P(F) in F and one point P(x) in x are simultaneous. Thus, the overlap between F and x that is represented by the association line in (9a) entails simultaneity between P(F) and P(x), as illustrated in (9b):

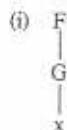


I use the diagram in (9b) only to illustrate the simultaneity between points of time that

<sup>4</sup> I am grateful to J. Higginbotham for suggesting I reexamine overlap and for his suggestions regarding its formal implementation.

A reviewer suggests that "simultaneity" may be used to mean "overlap," so that earlier proposals that association lines represent simultaneity may in fact have been intended as proposals that they represent overlap. Nevertheless, the argument against simultaneity is necessary both because it is not clear whether overlap was intended and because it is unlikely that overlap was intended since overlap requires that features and x-slots have internal duration, as discussed below, which has not been generally assumed.

<sup>5</sup> As pointed out by Hammond (1986), the intransitivity of overlap may cause a problem in hierarchical structures such as (i), in which some features are linked to the skeleton indirectly (see Clements (1985), Sagey (1986b) on feature hierarchies). In (i), F overlaps G, and G overlaps x, but that does not entail that F overlaps x because overlap is not transitive:



Hammond's solution is to define association lines as transitive (and asymmetric), but he is then forced to stipulate the well-formedness condition. I prefer to explain the ill-formedness of crossing association lines (see section 4) and to find another solution to (i).

is entailed by overlap. The line linking the points of time in (9b) is not an association line.<sup>6</sup>

Interpreting association lines as overlap requires that features and *x*-slots have internal duration.<sup>7</sup> Thus, at some level they are like sections of a time line, as in (9b). Viewing features and *x*-slots in this way captures the fact that they are not instantaneous, but occupy some amount of time. For *x*-slots, this fact follows from their role as timing units. However, even features, which might seem to be independent of timing, are inherently noninstantaneous, requiring certain minimal durations for their pronunciation. (See Klatt (1976) on inherent durations and "incompressibility" of articulations.) This internal duration of features and *x*-slots is relevant at the level of phonetic interpretation for subsegmental timing relations (see section 3). I assume that it is accessible only at that late level, and that for the purposes of the phonology only whole *x*-slots and features may be manipulated.

Viewing association lines as overlap avoids the contradictions engendered by simultaneity. The contour and geminate structures in (1a,b) now encode the relations in (10a,b), which in turn entail the statements in (11a,b) (where  $P(x)'$  and  $P(F)'$  need not be the same points as  $P(x)$  and  $P(F)$ , respectively):

- |         |                                                                                                      |    |                                                                                                              |
|---------|------------------------------------------------------------------------------------------------------|----|--------------------------------------------------------------------------------------------------------------|
| (10) a. | $F < G$<br>F overlaps <i>x</i><br>G overlaps <i>x</i>                                                | b. | $x_1 < x_2$<br>F overlaps $x_1$<br>F overlaps $x_2$                                                          |
| (11) a. | All $P(F) < \text{all } P(G)$<br>Some $P(F) = \text{some } P(x)$<br>Some $P(G) = \text{some } P(x)'$ | b. | All $P(x_1) < \text{all } P(x_2)$<br>Some $P(F) = \text{some } P(x_1)$<br>Some $P(F)' = \text{some } P(x_2)$ |

Thus, the overlap in (1a) entails that points within *F* and *G* are both simultaneous with points within *x*, but they need not be simultaneous with the same point, so there is no contradiction. The same holds for (1b). Rather than the contradictory statements " $x < x$ " and " $F < F$ ," substitution derives (12a,b):

- (12) a.  $P(x) < P(x)'$   
b.  $P(F) < P(F)'$

Similarly, the false statements " $F = G$ " and " $x_1 = x_2$ " are not derived because overlap is not transitive. ( $P(F) = P(x)$  but  $P(x)' = P(G)$ .)

Also solved is the problem with discontinuous multiple linkings. The structure in

<sup>6</sup> A reviewer questions the predictions of the illustration in (9b) regarding floating features (that is, whether the points in *F* that are not specified as simultaneous with points in *x* are equivalent to floating features that may trigger downstep or harmony). However, being linked or unlinked (floating) is a property of whole features and *x*-slots, not of points within them. A floating feature is one that is not linked to any *x*-slot (in other words, does not overlap any *x*-slot). Thus, the feature *F* in (9), which is linked to the *x*-slot, will be treated by phonological processes as linked, not floating. ((9b) merely illustrates what is entailed by *F* and *x* being linked, or overlapping. The internal detail of (9b) is not accessible to or manipulable by phonological processes.)

<sup>7</sup> Both *x*-slots and features have duration, but only *x*-slots are relevant for syllabification. Thus, if length is realized through syllabification, then a sequence of two features linked to an *x*-slot will not be interpreted as a geminate, even if features have duration. (Hammond (1986, 6-7) points this out as a potential problem.)

(5) nov  
stitutic

(1

(1

(1

Since 1

### 3. App

This vi  
non the  
timing  
lated) :  
nounce  
ample,  
be pror  
there π  
[mŋ] in  
Co  
on a se  
(16

If assoc  
G, and t  
if assoc  
overlap  
between  
tinctive  
unorder  
Howeve  
segment  
I as  
(see Libe  
interpret  
coding si

\* See

(5) now encodes the relations in (13). (13) entails the relations in (14), from which substitution yields (15).

- (13)  $x_1 < x_2$ ,  $x_2 < x_3$ , F overlaps  $x_1$ , F overlaps  $x_3$   
 (14) All  $P(x_1) < \text{all } P(x_2)$ , all  $P(x_2) < \text{all } P(x_3)$   
       Some  $P(F) = \text{some } P(x_1)$ , some  $P(F)' = \text{some } P(x_3)$   
 (15)  $P(F) < \text{all } P(x_2)$ , all  $P(x_2) < P(F)'$

Since  $P(F)$  need not be the same point as  $P(F)'$ , there is no contradiction.

### 3. Applications

This view of features,  $x$ -slots, and association lines allows us to account for a phenomenon that is unexplained if association lines represent simultaneity: the somewhat random timing behavior across languages of the articulations within complex (multiply-articulated) segments. In some languages the articulations in a complex segment are pronounced simultaneously, or as near to simultaneously as physically possible (for example, [tkw] in Kinyarwanda [tkwaŋga] 'we hate'). But in other languages they may be pronounced always in a particular order (for example, [pt] in Margi [ptəl] 'chief') or there may be free variation in the ordering of the articulations (for example, [ŋw] vs. [mŋ] in Venda [luŋwa] ~ [lumŋa] 'be bitten').

Complex segments are represented as in (16), with the features for each articulation on a separate tier (where F and G are, for example, [+labial] and [+coronal]):<sup>8</sup>

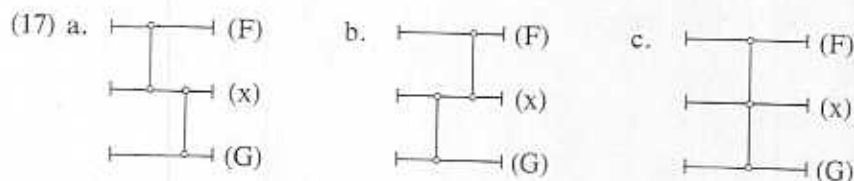
- (16) F  
       |  
       x  
       |  
       G

If association lines represent simultaneity, then (16) entails that F is simultaneous with G, and the complex segments in Margi and Venda are predicted not to occur. However, if association lines represent overlap, then (16) specifies only that each feature will overlap with the  $x$ -slot, and there is no specification regarding precedence or simultaneity between the two features. (Order of articulations within a complex segment is not distinctive in any language.) Phonologically, the features for the two articulations are simply unordered, and the variation seen among Kinyarwanda, Margi, and Venda is predicted. However, we still must account for the different phonetic realizations of the complex segments in these languages.

I assume that this interlanguage variation is at the level of phonetic interpretation (see Liberman and Pierrehumbert (1984)). It appears that some languages impose regular interpretations on the linkings in (16) (for instance, Kinyarwanda interpreting it as encoding simultaneity, and Margi as encoding a sequence) and that other languages impose

<sup>8</sup> See Sagey (1986a,b) on the properties and representation of complex segments, and for further examples.

no regular interpretation, allowing free variation such that the articulations occur in either order or simultaneously (as in Venda). I represent these interpretations at the phonetic level as in (17):



That is, at the phonetic level the internal durations of features and x-slots become available for manipulation by rules of phonetic interpretation. As interpretations of (16), Kinyarwanda's phonetic rules produce (17c), Margi's produce one of (17a) or (17b), and Venda's produce all of (17a,b,c) in free variation.

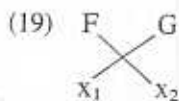
#### 4. Eliminating the Well-Formedness Condition

It is assumed in most current work (for example, Archangeli (1984), Clements (1985), Pulleyblank (1986)) that UG includes the well-formedness condition (WFC) on association lines proposed by Goldsmith (1976, 48):<sup>9</sup>

(18) Association lines do not cross.

I show in this section that (18) is unnecessary because its effects follow from and are explained by the interaction between precedence and overlap in nonlinear representations.

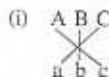
Consider (19), in which the association lines cross. (19) encodes the precedence and overlap relations in (20), which entail (21a-d):



(20)  $F < G$ ,  $x_1 < x_2$ , F overlaps  $x_2$ , G overlaps  $x_1$

- (21) a. All  $P(F) < \text{all } P(G)$   
 b. All  $P(x_1) < \text{all } P(x_2)$   
 c. Some  $P(F) = \text{some } P(x_2)$   
 d. Some  $P(G) = \text{some } P(x_1)$

<sup>9</sup> I argue against (18), rather than Goldsmith's formal version of the WFC (1976, 50-53), because (18) is more widely adopted. Note, however, that even Goldsmith's formal version requires a WFC in UG. Instead of stating that association lines do not cross, it stipulates that the sequence of association lines is totally ordered, and it introduces a projection function  $\pi$ , and an inverse projection  $\pi^{-1}$ , with a WFC in UG that " $\pi$  and  $\pi^{-1}$  preserve connectedness" (p. 51). Moreover, the formal version has a loophole that allows association lines to cross in a structure like (i), because (i) has the "ordered sequence of pairs" (A,c) (B,b) (C,a), the "projections" of which are "connected":



By subst  
(22)

But (22) since sub relations which en dictory."

The lines, but plication. associatio where cr cases ar in (23a) i

(23)

Although applicatio are avoid on tier co Althc lines are i is explain blockage Consider ciatio lin a disconti

(24) a

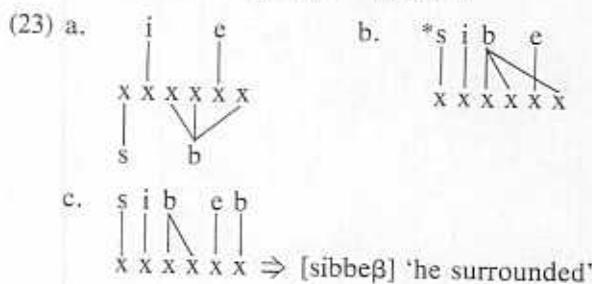
<sup>10</sup> Becat crossing met domains.

By substitution of (21c,d) into (21b) we may derive (22):

(22) Some P(G) < some P(F)

But (22) contradicts (21a), which states that every P(F) precedes every P(G). Therefore, since substitution preserves truth conditions, the original set of precedence and overlap relations in (20) must contain internal contradictions. Thus, the representation in (19), which encodes them, is ill-formed—simply because the relations it encodes are contradictory.<sup>10</sup>

The WFC in (18) is usually interpreted not only as disallowing crossed association lines, but also as actively preventing them by the specific means of blocking rule application. A reviewer objects that the derivation just given does not specify how crossed association lines are avoided. This flexibility is necessary, however, for there are cases where crossing lines are avoided by means other than blockage of rule application. Such cases arise when tier conflation applies to a structure with a discontinuous geminate, as in (23a) in Hebrew (McCarthy (1986, 226)):



Although tier conflation in (23a) would create crossing association lines as in (23b), its application is not blocked. Rather, tier conflation applies and crossed association lines are avoided by fission of the discontinuous linking, yielding (23c). (See McCarthy (1986) on tier conflation and fission.)

Although crossed lines are avoided by fission in a case like (23), it is true that crossed lines are usually avoided by the rule that would create them failing to apply. This fact is explained by a restricted theory of phonology, in which it turns out that in most cases blockage of rule application is the only means available for preventing crossed lines. Consider other logically possible means of resolving the contradiction of crossed association lines. One might delink one of the lines (24a); reorder the features (24b); or split a discontinuous linking and then reorder one of the cloned features (24c):



<sup>10</sup> Because the "lines" in metrical structure encode dominance rather than overlap, the ill-formedness of crossing metrical lines must be derived separately, possibly from a prohibition against improperly nested domains.

c. *Split, then reorder*

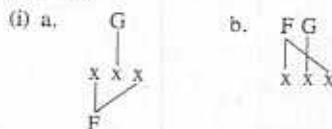
Assuming the restricted theory in Archangeli and Pulleyblank (1986), none of the operations in (24) is available for eliminating crossing lines.

The delinking in (24a) violates Archangeli and Pulleyblank's principle of Specification Preservation, which "preserves intact any specifications [that is, linkings] not directly being affected by the function of the rule in question" (p. 136). Thus, Specification Preservation prevents delinking as a means of resolving crossing lines, as Archangeli and Pulleyblank note (p. 139).

The reordering in (24b) is essentially metathesis, a transformation, which is not among the processes and functions, either automatic or rule-governed, allowed by the restricted theory of rule types in Archangeli and Pulleyblank: rules may only insert or delete features or structure, and the only automatic processes are conflation, merger, and fission.

Finally, (24c) combines fission and metathesis (of the cloned feature) and is ruled out because of the metathesis. Metathesis is required in (24c) because there is an order between F and G prior to fission. The clones of the feature have the same precedence relations as the original because the process of fission is restricted to splitting apart features. It may not change precedence relations. (Metathesis is not involved in the fission accompanying tier conflation in (23) because /b/ and /c/ are on separate (unordered) tiers prior to tier conflation and fission.)<sup>11</sup>

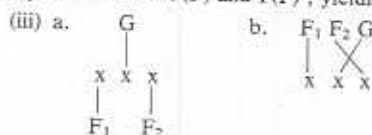
<sup>11</sup> The exact definitions of fission and tier conflation are as follows. Consider a discontinuous linking such as (ia) or (ib):



Through substitution, (ia) or (ib) encodes (ii):

- (ii) Some  $P(F) < \text{some } P(G) < \text{some } P(F)'$

Following a reviewer's suggestion, I define an ordering such as (ii), where a point in G falls between two points in F, as the condition under which fission takes place. I propose that under this condition, fission splits F at some point between  $P(F)$  and  $P(F)'$ , yielding (iii,a,b):



Through substitution, (iii,a,b) encode (iv) (where  $P(F_1)$  equals  $P(F)$  and  $P(F_2)$  equals  $P(F)'$ ):

- (iv)  $P(F_1) < P(G) < P(F_2)$

In (iii,a) tier conflation will place  $F_1$  and  $F_2$  on the same tier as G in locations consistent with the ordering in (iv). To be consistent with " $P(F_1) < P(G)$ ,"  $F_1$  will precede G on the tier (that is, all  $P(F_1) < \text{all } P(G)$ ); to

The  
avoided

It is  
to deriv  
in UG.

property  
cross, o  
at will.

the state  
associat

to allow  
cross. F  
a contra  
represen

## Referenc

Archange  
dis

Archange  
tio

Clements  
252

Goldsmitt  
cht

Hammonc  
cor

Higginbot  
(Al

in l  
sett

Klatt, D. l  
Evi

Liberman,  
and

Can  
McCarthy,  
264.

Pulleyblan

be consist  
 $F_2$  end up o

In (iii,b),  
" $F_2 < G$ " c

precedence  
G, or all  $P(F$   
or changing

Thus, because independent aspects of the phonology restrict how crossing lines are avoided, it is sufficient to derive that crossing association lines are ill-formed.

It is a more explanatory account of the ill-formedness of crossing association lines to derive it from extralinguistic knowledge than to state it as a well-formedness condition in UG. With a WFC in UG, the ill-formedness of crossing lines is essentially an arbitrary property of language: UG could just as easily have contained a WFC requiring lines to cross, or it could have contained no WFC at all and allowed lines to cross or not cross at will. There is no explanation under such an account for why lines do not cross—only the statement that they do not. On the other hand, if the ill-formedness of crossing association lines derives from extralinguistic factors, then UG does not have the power to allow or to require crossing lines. The only possibility is for association lines not to cross. Furthermore, there is an explanation for why they do not cross: if they did cross, a contradiction would result among the precedence and overlap relations encoded in the representation.

### References

- Archangeli, D. (1984) *Underspecification in Yawelmani Phonology and Morphology*, Doctoral dissertation, MIT, Cambridge, Massachusetts.
- Archangeli, D. and D. Pulleyblank (1986) *The Content and Structure of Phonological Representations*, ms., University of Arizona and University of Southern California.
- Clements, G. N. (1985) "The Geometry of Phonological Features," *Phonology Yearbook 2*, 225–252.
- Goldsmith, J. (1976) *Autosegmental Phonology*, Doctoral dissertation, MIT, Cambridge, Massachusetts. (Published by Garland, New York, 1979.)
- Hammond, M. (1986) "On Deriving the Well-Formedness Condition," ms., University of Wisconsin, Milwaukee. [To appear in *Linguistic Inquiry* 19.2.]
- Higginbotham, J. (1983) "A Note on Phrase Markers," *Revue Québécoise de Linguistique* 13.1. (Also published in D. Archangeli, A. Barss, and R. Sproat, eds., (1985) *MIT Working Papers in Linguistics* 6, Department of Linguistics and Philosophy, MIT, Cambridge, Massachusetts.)
- Klatt, D. H. (1976) "Linguistic Uses of Segmental Duration in English: Acoustic and Perceptual Evidence," *Journal of the Acoustical Society of America* 59:5, 1208–1221.
- Liberman, M. and J. Pierrehumbert (1984) "Intonational Invariance under Changes in Pitch Range and Length," in M. Aronoff and R. Oehrle, eds., *Language Sound Structure*, MIT Press, Cambridge, Massachusetts.
- McCarthy, J. (1986) "OCP Effects: Gemination and Antigemination," *Linguistic Inquiry* 17, 207–264.
- Pulleyblank, D. (1986) *Tone in Lexical Phonology*, Reidel, Dordrecht.

be consistent with "P(G) < P(F<sub>2</sub>)."<sup>1</sup> G will precede F<sub>2</sub> on the tier (that is, all P(G) < all P(F<sub>2</sub>)). Thus, F<sub>1</sub> and F<sub>2</sub> end up on different sides of G through fission and tier conflation alone. No metathesis is involved.

In (iiib), on the other hand, in addition to the ordering in (iv) derived by substitution, there is the ordering "F<sub>2</sub> < G" on their tier. F<sub>2</sub> precedes G because F preceded G prior to fission, and fission does not change precedence relations. (That is, prior to fission, F < G, or all P(F) < all P(G). After fission, F<sub>1</sub> < G and F<sub>2</sub> < G, or all P(F<sub>1</sub>) < all P(G) and all P(F<sub>2</sub>) < all P(G).) Thus, locating F<sub>2</sub> after G in (iiib) would require metathesis, or changing the precedence relation "F<sub>2</sub> < G" to "G < F<sub>2</sub>."