ON ANGLE BRACKETS

By David Tuggy

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1. Introduction

Angle brackets (or angled brackets) have been used in phonological rules in two different and somewhat contradictory ways. Both ways agree that a rule containing angle brackets is first to be tried with all the material in the angle brackets included in the rule, but they differ as to what should be done next. One way is to try the rule without the material in angle brackets. The crucial thing is that on the second pass you ignore whatever is inside the brackets.[1] Let us call this Skip-it application.

The second way to use angle brackets involves switching the polarity of any single feature contained in an angle bracket[2] on the second pass through the rule. Any such feature with a + marking will be read with a - marking on the second application of the rule, and vice versa. Let us call this Flip-it application.[3]

Rules using angle brackets have been proposed which fall into four classes with respect to whether they work properly when interpreted by these two conventions. Some rules will work when interpreted by either convention, some will work only under the Skip-it convention, others only under the Flip-it convention, and still others will not work properly under either convention. I will call these different classes of rules Classes I-IV. They can be quite simply charted as below.

In this paper I would like to examine a representative rule from each of these four classes.[4] After showing that neither the Skip-it nor the

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[1] Chomsky and Halle seem to propose this as the most basic interpretation of angle brackets (e.g. pp. 76-77). Harms also interprets in this way (p.66), as do Anderson (pp. 83, 103, note 8, and 126), Harris (1969, p. 101, note 31), and most others.

[2] For convenience I will refer to each pair of angle brackets (<>) as a singular "bracket"; "brackets" will refer to more than one pair.

[3] Chomsky and Halle propose this on pp. 125 and 212, and, evidently, in the appendix to Chapter 8 (pp. 394-395). It is not clear that they espouse a thorough-going Flip-it convention: in the note on p. 212 they skip the feature in an unpaired angle bracket instead of flipping it, and it is not clear to me what they would do with a set of angle brackets which each contains a single feature. Tranel (p. 363), in discussing this convention, assumes that such a pair of features would both be flipped and not skipped.

Notice that where a pair of angle brackets each contains a single feature, flipping them both is equivalent to using the Greek letter notation instead of angle brackets.

[4] I am not here concerned with critiquing the analyses embodied by these rules, but only with the formal problem of what conventions for the application of angle brackets will let the rules account for the data their proponents intended them to account for. My argument is not based on the assumption that these particular analyses are correct, but rather on the assumption that rules such as the ones given here are proper and possible in human languages; that such rules are not wrong in principle although they

		Flip-it: works	Flip-it: doesn't work
Skip-it	works	Class I	Class II
	doesn't work	Class III	Class IV

Flip-it convention can account for them all, I would like to consider a third kind of application, If-then application, which does account for rules of all four classes.

2. Skip-it Application

2.1 Fe?fe?-Bamileke (Class I)

The Skip-it convention for the application of angle brackets works fine for the rules I am grouping into Class I. An example of such a rule is a vowel lowering rule of Fe?fe?-Bamileke, posited by Hyman (p. 122).

$$\begin{bmatrix} V \\ [-lo] \\ [<-hi>] \end{bmatrix} \longrightarrow \begin{bmatrix} -hi \\ [<+lo>] \end{bmatrix} / \_\_\_ \; C \; \$$$

This rule is to account for the following facts: u becomes o, and o becomes ɔ, in closed syllables. The first pass will try the fullest expansion of the rule, including the features in the angle brackets. This will correctly turn o into ɔ. The second pass through the rule will ignore the material in the angle brackets, reading as follows:

$$\begin{bmatrix} V \\ [-lo] \end{bmatrix} \longrightarrow [-hi] / \_\_\_ \; C \; \$$$

This second pass will thus, correctly, change u to o.

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may be wrong in fact.

2.2 Seri (Class II)

Marlett has proposed the following rule for Seri, which we will use as an example of Class II rules.

$$C \longrightarrow [+lg] \;/\; \begin{matrix} V \\ [+str\ ] \\ [<-lg>] \end{matrix} \; \langle i \rangle \_\_ \; V$$

What this rule accounts for is the following: Any intervocalic consonant becomes long following any stressed vowel. Also an intervocalic consonant becomes long if it follows a short stressed vowel which is followed by an i.

The first pass through the rule, including the material in the angle brackets, will lengthen an intervocalic consonant following a stressed short vowel and an i. On the second pass, leaving out the material in angle brackets, the rule will read as follows:

$$C \longrightarrow [+lg] \;/\; \begin{matrix} V \\ [+str] \end{matrix} \; \_\_ \; V$$

This will correctly lengthen all intervocalic consonants that directly follow any stressed vowel.

Clearly Skip-it application is adequate to make this rule work correctly and to account for the data.

2.3 English (Class III)

Class III rules do not work if interpreted according to the Skip-it convention. As an example of a Class III rule we will take relevant portions of Chomsky and Halle's Auxiliary Reduction Rule I for English (p. 125).

$$V \longrightarrow \begin{matrix} [-str] \\ [-tns] \end{matrix} \;/\; \langle V\ C_o \rangle \; \_\_ \; \begin{matrix} C_o \\ [\alpha\ str\ ] \\ [<+tns>] \end{matrix} \; \begin{matrix} V \\ [\beta\ str] \end{matrix}$$

Where α is less than β.

This rule is to account for the following facts: When followed by a vowel with stronger stress, tense vowels reduce to schwa provided that they are not initial (i.e. not the first vowel in the word), whereas lax vowels do so even if they are initial.

If you interpret this rule by Skip-it application, the first pass will correctly reduce non-initial tense vowels that are followed by a vowel with higher stress. However, on the second pass the wrong results obtain. On this pass the rule reads as follows:

$$V \rightarrow \begin{matrix}[-str]\\[-tns]\end{matrix} \; / \; \overline{\begin{matrix}[\alpha\ str]\end{matrix}} \; C_0 \; V \; [\beta\ str]$$

Where α is less than β.

On this pass the rule will incorrectly reduce any vowel, tense or lax, that is followed by a vowel with higher stress. Thus the initial tense vowels that the angle brackets were intended to keep from reducing are going to reduce anyway.

2.4 Tetelcingo Aztec (Class IV)

As an example of a Class IV rule, consider the following rule from Tetelcingo Aztec (Tuggy, unpublished).

$$\begin{matrix}[\ +obs\ ]\\[\ \alpha\ cor\ ]\\[<+strid>\ ]\\[\langle +cont \rangle^{a}]\\[\langle \beta\ pal \rangle_{b}]\end{matrix} \rightarrow h \; / \; \_\_ \; \begin{matrix}[\ +obs\ ]\\[\ \alpha\ cor\ ]\\[\ -cont\ ]\\[<+strid>\ ]\\[<\beta\ pal>^{a}_{b}]\end{matrix}$$

This rule should express the following generalizations: Stops spirantize to h before any non-continuant obstruent that agrees with them in coronality. E.g. t becomes h before t, c, or č, but not before k. Affricates spirantize only before another affricate, but not before a stop. That is, c and č spirantize before each other, but not before t (nor before k or k^{w}.) A fricative will spirantize only before an affricate that agrees with it in palatality. Thus s becomes h before c but not before č, and š does it before č but not before c.

The same problem as with the English rule results if we use Skip-it application on this rule, only it is complicated by the fact that there are two pairs of angle brackets involved. On the first pass the rule correctly spirantizes s before c and š before č.[5] On the second pass the rule, omitting the lower angle bracketed material, will read as follows:

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[5] The lower angle brackets in this rule must be omitted on the second pass instead of the upper brackets. Under the Skip-it and Flip-it conventions the rule doesn't work anyway, but it works worse if the a brackets are dealt with first. The complications entailed if the a brackets are dealt with first under the If-then convention are discussed in footnote 14.

$$\begin{bmatrix} +\text{obs} \\ \alpha\,\text{cor} \\ [<+\text{strid}>] \end{bmatrix} \rightarrow h \;/\; \underline{\quad} \begin{bmatrix} +\text{obs} \\ \alpha\,\text{cor} \\ -\text{cont} \\ [<+\text{strid}>] \end{bmatrix}$$

The rule on this pass will correctly spirantize c and č before each other, but it will also incorrectly spirantize s before č and š before c. On the third pass the rule, skipping the material within the upper pair of angle brackets, will read as follows:

$$\begin{bmatrix} +\text{obs} \\ \alpha\,\text{cor} \end{bmatrix} \rightarrow h \;/\; \underline{\quad} \begin{bmatrix} +\text{obs} \\ \alpha\,\text{cor} \\ -\text{cont} \end{bmatrix}$$

The rule will now spirantize any obstruent before any non-continuant obstruent with which it agrees in coronality. This will correctly spirantize t, but it will also spirantize c and č, as well as s and š, before t, which is incorrect. The angle brackets might as well not have been written into the rule, for all they were able to accomplish.

Clearly the right results are not achieved by interpreting this rule by the Skip-it convention.

3. Flip-it Application

3.1 English (Class III)

In order to avoid the problem we saw in section 2.3, Chomsky and Halle proposed the convention of Flip-it application.[6] By this convention, on the first pass the rule is read as before, with all the material in angle brackets included. This will correctly reduce non-initial tense vowels when followed by a vowel with higher stress. However, on the second pass through the rule, instead of the feature [+tns] being skipped, it is flipped to read [-tns], and the sequence $V C_0$ at the beginning of the environment is left out.[7] This means that on the second pass the rule will read as follows:

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[6] p. 125, note 78. Their clarification of what they mean in the appendix to Chapter 8 (pp. 394-395, by my estimate) is quite beyond my poor power to add or to detract.

[7] This is accomplished by skipping. It would make sense to claim a sort of flipping whereby a segment that is in angle brackets would be not ignored but prohibited on the second pass (cf. footnote 11). This would, however, give the wrong results here, predicting that lax vowels would reduce only when they were initial. It is presumably for that reason that Chomsky and Halle decided to flip only single features, but skip any other angle bracketed material.

$$V \longrightarrow \begin{matrix}[-str]\\[-tns]\end{matrix} \Big/ \underline{\quad} \; C_0 \; V \; [\beta\,str]$$
$$[\alpha\,str]$$
$$[-tns\;]$$

Where α is less than β.

This ensures that only lax vowels will now be changed; tense vowels have had their chance to reduce, and they do not get another. Thus the Flip-it convention makes the rule work properly.

3.2 Fe?fe?-Bamileke (Class I)

The Fe?fe?-Bamileke rule posited by Hyman also works fine under Flip-it application. The first pass again, including all the angle-bracketed material, turns o into ɔ in closed syllables. On the second pass the angle-bracketed occurrence of the feature [-hi] is (presumably) flipped to read [+hi] and the feature [+lo] flipped to read [-lo]. This gives the following expansion form:

$$\begin{matrix}V\\[-lo]\\[+hi]\end{matrix} \longrightarrow \begin{matrix}[-hi]\\[-lo]\end{matrix} \Big/ \underline{\quad} \; C \; \$$$

This will correctly convert u to o (redundantly specified as [-lo]) in closed syllables.

3.3 Seri (Class II)

Marlett's Seri rule, however, will not work properly under the Flip-it convention. The first pass will correctly lengthen an intervocalic consonant after a short stressed vowel which is followed by i. On the second pass, however, the feature [-lg] will be flipped to read [+lg] and the i will be left out, giving the following form of the rule:

$$C \longrightarrow [+lg] \Big/ \begin{matrix}V\\[+str]\\[+lg\;]\end{matrix} \underline{\quad} \; V$$

This means that the second pass will confine itself to long stressed vowels. The rule cannot lengthen a consonant which follows a short stressed vowel, though such consonants lengthen in Seri.

Clearly, then, Flip-it application gives us the wrong results in this case.

3.4 Tetelcingo Aztec (Class IV)

The Tetelcingo Aztec rule cannot be properly administered by Flip-it application either. As usual, the first pass does what it should, spirantizing s before c and š before č. There is a problem as to how to flip the polarities on the lower angle brackets before the second pass.[8] Depending on how you work it you get different results, all of them wrong. You also get into trouble when you undo the upper brackets on the third pass. The rule at this point tells us (ignoring the lower brackets) that strident consonants must have a strident consonant following them if they are going to spirantize. Now if we flip the feature [+strid] in each case, we get the following form of the rule for our final pass:

$$\begin{bmatrix}+\text{obs}\\ \alpha\text{cor}\\ -\text{strid}\end{bmatrix} \rightarrow h \;/\; \underline{\quad} \begin{bmatrix}+\text{obs}\\ \alpha\text{cor}\\ -\text{cont}\\ -\text{strid}\end{bmatrix}$$

This says that non-strident obstruents must have a non-strident following them if they are to spirantize. The rule thus cannot spirantize t before c and č, although t does spirantize in those environments.

Again, the Flip-it convention clearly leads to the wrong results.

4. If-then Application

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[8] If (a) you follow Chomsky and Halle's convention of flipping F and skipping Z "where F is a feature and Z is some string other than a single specified feature" (p. 212, note 42), you must flip the [βpal] in the environmental angle bracket, and skip the bracket containing the features [+cont] and [βpal]. This will be equivalent in its results to a straight Skip-it application: all the s's and š's that were excluded on the first pass because they didn't agree in palatality with their environmental partner will go ahead and spirantize on the second pass, even though they disagree in palatality.

If (b) you assume that where two features are included in an angle bracket you should flip them both, the second pass will deal only with non-continuant stridents (i.e. affricates) as it should, but since both β's have been negativized it will still have to maintain correspondence of palatality in order to apply. This incorrectly states that c will not spirantize before č nor vice versa.

Or if (c) you assume that where two features are included in an angle bracket you should flip only one of them, there are still difficulties. If (c') you flip the feature [cont], the rule will properly look only at non-continuant stridents again, but will require that they not agree in palatality ([βpal] [-βpal]). The fact is, of course, that non-continuant stridents are not sensitive to any palatality markings; either c or č will spirantize before the other. Or, (c'') if the feature [pal] is to be flipped, you wind up with an exact repeat of the first pass, spirantizing only continuants which agree in palatality. The only difference is that you are matching -β's instead of β's.

We have seen that there is one set of rules (Classes I and II) that can be dealt with under Skip-it application, and a different set (Classes I and III) that can be dealt with under Flip-it application, and we have seen a Class IV rule which neither application convention could make work properly.

There is a third type of application of angle brackets which has occasionally been proposed in the literature as something unusual (or even something illegitimate) to be used to handle exceptional cases.[9] This type of application we will call If-then application. It differs from the Skip-it and Flip-it applications in that it does not treat angle brackets symmetrically. One bracket must be marked as the if-bracket, and its mate as the then-bracket. The results of the application of this type of marking are set forth in detail in Harms,[10] but the effect can be achieved simply by flipping the if-bracket and skipping the then-bracket. The notion is intuitively quite simple: The if-bracket states a condition and the then-bracket expresses a requirement that is dependent on that condition. If the condition in the if-bracket is fulfilled, then so must be the requirement in the then-bracket. However, if the condition in the if-bracket is not fulfilled, then it does not matter whether the requirement in the then-bracket is satisfied or not. Thus, on the first pass you check to see if the condition in the if-bracket and its corresponding requirement in the then-bracket are satisfied. If they are, you may apply the rule. If they are not, you may not apply the rule. Then, on the second pass, you check to make sure that the if-condition is not satisfied. If it is not, you may apply the rule, whether or not the then-requirement is satisfied.[11]

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[9] For instance, Harms (p. 74-75) discusses it as a formal device. Cf. also Anderson, p. 153, Tranel, p. 364, fn. 12. Harris (1974, note 21) describes a pair of such brackets (proposed by Brame and Bordelois) as 'stated in terms of "⊃" rather than "≡". Thus the $\underline{b}$ material could appear without the $\underline{a}$ material, but not conversely.' (Harris' criticism of this as unnecessary is based on the fact that a Flip-it interpretation would also work.) Actually, Chomsky and Halle's device of flipping one bracket (the one containing a single feature) and skipping its mate is in effect applying an If-then convention.

The fact that these analysts used angle brackets at all is evidence that they felt intuitively (and rightly, I think,) that these "exceptional" cases (Class IV) are really like the cases traditionally handled by angle brackets. Formally there was no reason why angles should be used instead of square brackets, parentheses, or some arbitrary new kind of brackets.

[10] Harms, pp. 74-75. In effect Harms says that, in a case $\langle\rangle_a \langle\rangle_b$, with the condition "if $\underline{a}$ then $\underline{b}$", and given that the rest of the rule's structural description is satisfied, a table like the following holds:

$\langle\rangle_a$ is present	$\langle\rangle_b$ is present	the rule applies
yes	yes	yes
yes	no	no
no	yes	yes
no	no	yes

[11] The following discussion is intended to make it more formally clear what I intend the If-then convention to do.

Let us mark the if-bracket with an arbitrary mark $<>_i$. Its mate will then be the then-bracket. Then let us test this kind of application on the four rules we have examined so far.

4.1 Fe?fe?-Bamileke (Class I)

Hyman's Fe?fe?-Bamileke rule worked with either the Skip-it or the Flip-it convention. Under the If-then convention we would mark the angle bracket in the structural description as if $(<\text{-hi}>_i)$, and the one in the structural change $(<\text{+lo}>)$ would be the then-bracket. The rule will be read on the first pass as before, with all the material in angle brackets included, and, as before, it will successfully lower o to ɔ. On the second

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Any Requirement can be opposed to either of two things: the absence of the Requirement (which we will call Permission), or the presence of an opposing Requirement (which we will call Prohibition). In other words, a "Thou shalt" can be opposed either to an "I don't care if thou.." or to a "Thou shalt not." Any pair of angle brackets should be read on the first pass as containing two Requirements. On the second pass, the Requirement in the if-bracket is changed to its corresponding Prohibition, whereas the Requirement in the then-bracket is changed to Permission.

In the formalism we have inherited, it is easy to characterize the three way distinction of Requirement, Permission, and Prohibition with respect to a feature appended to a list of features of a particular segment or class of segments. However, it is not so easy to characterize this distinction with respect to any feature, segment or sequence that holds its own place in the linear order of the SD of a rule. For example, a consonant can be easily marked [+vd] (Requirement) or marked [-vd] (the corresponding Prohibition) or simply not marked at all for the feature [vd] (Permission). However, the consonant itself can either be represented as present (represented by say the feature [-vocalic] or the symbol C) or not. If it is represented, that constitutes a Requirement. If it is not represented, it may constitute either Permission or Prohibition, depending on where in the SD it occurs. In general, non-representation of a segment or sequence of segments internal to the SD of a rule is equivalent to Prohibition: if the SD of a rule specifies kit, any sequence such as krit or kirt is prohibited. However, a segment or sequence's non-representation at the edges of the SD of a rule is equivalent to Permission: given the same SD kit, both rkit and kitr are permitted. There are of course ways to fudge around these tendencies in order to achieve the results you want, such as putting an SD internal segment or sequence in parentheses (guaranteeing Permission instead of Prohibition), or expanding the SD to include the occurrence of everything except what you want to prohibit on the periphery of the SD. When this last expedient fails to look classy (how do you characterize the class of consonants that are not a k?) analysts have fallen back on explicit statements of Prohibition, such as "C_i, where $C_i \neq k$."

I would like the If-then convention to be conceived of as giving a Prohibition when undoing the if-bracket, but Permission when undoing the then-bracket. If the then-bracket is in the SC, a universal principle of inertia or laziness could make it explicit that nothing changes unless required to. Thus Permission in the SC would not mean optionally variant outputs. If the then-bracket is in the SD, the Permission would mean that either reading would be acceptable.

pass, flipping the if-bracket and skipping the then-bracket, the rule will have the following expansion form:

$$\begin{matrix} V \\ [-lo] \\ [+hi] \end{matrix} \longrightarrow [-hi] \; / \; \underline{\quad} \; C \; \$$$

This will successfully lower u to o.

Clearly the If-then principle is adequate for this rule's application.

4.2 Seri (Class II)

Marlett's Seri rule worked with the Skip-it convention but not with the Flip-it convention. Under the If-then convention we would mark the bracket around the i as the if-bracket ($\langle i \rangle_i$), and the one around the feature [-lg] would be the then-bracket.[11] On the first pass, as before, intervocalic consonants would be lengthened after a short stressed vowel[12] and i. On the second pass, the i would be flipped to become null, and the feature [lg] on the vowel gets ignored (i.e. skipped). This gives the following expansion form:

$$C \longrightarrow [+lg] \; / \; \begin{matrix} V \\ [+str] \end{matrix} \; \emptyset \; \underline{\quad} \; V$$

This will correctly lengthen an intervocalic consonant following any stressed vowel.

The rule is thus claiming that if there is an i between the stressed vowel and the consonant to be lengthened, the stressed vowel must be short, but that if there is no i it doesn't matter whether the vowel is long or short. And that seems intuitively like the correct way to talk about the Seri data. At the least we can say that this convention is adequate for

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[12] Given the characterization of the If-then convention in terms of Requirement, Permission, and Prohibition (see last footnote) it follows naturally that the result of flipping segments or sequences of segments in if-brackets must be their absence. Perhaps one should flip the feature [+segmental] for all segments enclosed in if-brackets. What we want to say here is that if there is an i, the stressed vowel must be short, but that if there is not an i, the length of the stressed vowel does not matter.

Notice that the reason this rule worked under Skip-it application is that when you skip a segment (such as this <i>) in the middle of the SD of a rule, you demand its absence. (That, of course, is Prohibition). This contrasts with the case of segments or sequences (such as the $\langle V\ C_o \rangle$ in Chomsky and Halle's English rule) which are on the extremes of the SD: skipping them does not demand their absence, but only makes their absence not matter (i.e. gives Permission.)

this case.

4.3 English (Class III)

Chomsky and Halle's English rule worked under Flip-it application but not under Skip-it application. Under If-then application we would mark the bracket around the feature [+tns] as the if-bracket ($\langle_{+tns}\rangle_i$), and the bracket around the V C_o sequence will be the then-bracket. The first pass proceeds as usual, correctly reducing tense vowels. On the second pass, the polarity of the if-bracket flips, and the then-bracket is skipped. This will give the same expansion form as that produced by the Flip-it convention, which is given in section 3.1. And, of course, the right predictions are made: lax vowels will now reduce irrespective of whether or not they are initial.

Again, the If-then convention is clearly adequate to handle the rule. And again it seems intuitively right to say that if the vowel to be reduced is tense, then it may not be initial, but if it is not tense it doesn't matter whether it is initial or not.

4.4 Tetelcingo Aztec (Class IV)

The Tetelcingo Aztec rule didn't work under either the Skip-it or the Flip-it convention. Under the If-then convention we would mark the angle brackets under the obstruent that spirantizes as if-brackets; the corresponding brackets under the environmental obstruent are then-brackets. The first pass goes as usual, spirantizing s before c and š before č. On the second pass, the feature [cont] is flipped,[13,14] and the corresponding

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[13] Either the convention of flipping both features in an if-bracket is adopted (this is the method used in getting the expansion form given in the text), or it must be specified that a feature marked with a Greek letter is not to be flipped, or in some other way we must guarantee that [cont] gets flipped in order to exclude fricatives from further consideration.

[14] As intimated earlier, the b brackets must be treated before the a brackets to get the right results. If the a brackets are treated first, the second pass will spirantize nonstrident fricatives before stops with which they agree in palatality. Since there are no nonstrident fricatives in Tetelcingo Aztec, this pass will accomplish nothing. Then the third pass will spirantize stops correctly, but the affricates will never get a chance to spirantize.

I can see three ways to avoid this happening. (i) We could externally specify that $\langle\rangle_b$ must be treated before $\langle\rangle_a$. (ii) We could propose some (hopefully universal) convention that would make $\langle\rangle_b$ be treated before $\langle\rangle_a$. Treating angle brackets in the order that produces the maximal amount of rule application (i.e. that lets the rule make the maximum number of changes) would work here. I have no evidence that this is not ad hoc, however. (iii) We could include $\langle\rangle_b$ within $\langle\rangle_a$. This would guarantee that $\langle\rangle_b$ would be treated first, but it would have the unpleasant side effect that the $\langle\rangle_{bi}$ (the inner if-bracket) would be flipped twice. That is, the if-brackets would start out as:

$$\left\langle \left\langle \begin{matrix} +strid \\ +cont \\ \beta\ pal \end{matrix} \right\rangle_{bi} \right\rangle_{ai}$$

then-bracket is skipped. This gives the following expansion form of the rule for the second pass:

$$\begin{bmatrix} +obs \\ \alpha cor \\ \langle +strid \rangle_i \\ -cont \\ -\beta pal \end{bmatrix} \longrightarrow h \; / \; \underline{\quad} \; \begin{bmatrix} +obs \\ \alpha cor \\ -cont \\ \langle +strid \rangle \end{bmatrix}$$

This correctly excludes the continuant obstruents from further spirantizing, and correctly gets rid of the palatality restriction. On the third pass the feature [strid] is reversed in the if-bracket, and skipped in the then-bracket. This gives the following expansion form:

$$\begin{bmatrix} +obs \\ \alpha cor \\ -strid \\ -cont \\ -\beta pal \end{bmatrix} \longrightarrow h \; / \; \underline{\quad} \; \begin{bmatrix} +obs \\ \alpha cor \\ -cont \end{bmatrix}$$

This will correctly restrict spirantization to stops, and allow them to undergo it before either another stop or an affricate.

Thus the If-then convention allows this rule to be interpreted in such a way as to come up with the right results, a feat which neither of the other two conventions was able to accomplish.

4.5 Conclusion

We have seen that the If-then convention can take care of all four cases: the one which both the Skip-it and Flip-it conventions could also take care of (Class I), the two which one of them could take care of but not the other (Classes II and III), and the one that neither of them could take care of (Class IV).

On the second pass the inner bracket would flip to give

$$\left\langle \begin{matrix} +strid \\ [-cont] \\ [-\beta pal] \end{matrix} \right\rangle_i$$

Then, on the third pass, the outer bracket would flip, giving, presumably,

$$\begin{matrix} [-strid] \\ [+cont \\ [\beta pal \end{matrix}$$

This would not let the rule apply to stops (or to anything else except the non-existent nonstrident fricatives.) Some adhoc way of blocking this result would be needed. I prefer the adhocity of (i) or the hopefully less adhoc adhocity of some version of (ii).

I have not found any cases where angle brackets[15] have been proposed that cannot be taken care of by If-then application. I therefore propose that all angle brackets should be interpreted by the If-then convention, and thus that all rules using angle brackets must in principle mark which is the if- and which is the then-bracket.

5. Can We Predict Which is the If-Bracket?

It would be nice if we could discover some principled way to determine which of any set of angle brackets[16] will be the if-bracket and which will be the then-bracket.

5.1 Principle I

The majority of rules that one finds proposed which use angle brackets have one of the brackets in the structural description (SD) of the rule and the other in the structural change (SC) of the rule. Hyman's Fe?fe?-Bamileke rule is such a case. Every such rule that I know of will work if you make the the bracket in the SC the then-bracket, and the one in the SD the if-bracket.[17] Since this generalization holds true, let us propose Principle I for predicting if-brackets:

> Principle I: Where one bracket is in the SD and the other in the SC, the one in the SD is the if-bracket and the one in the SC is the then-bracket.

Principle I is almost certainly a reflection of the very nature of phonological rules: they are if-then statements where if the SD is met, then the SC is made. Since the SD is already an *if* and the SC is a *then*, it is hardly[18] surprising that the marking of angle brackets in them reflects that fact.

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[15] There may well be real cases of "discontinuous dependencies": i.e. cases where two segments or sequences in the structural description of a rule could either both appear or neither appear, but neither of which could appear without the other being there. These might call for an If-and-only-if notation. (Greek letters are traditionally used for such cases where only single features are involved). Even such cases could be taken care of by permitting reciprocal If-then brackets: i.e. $\langle\rangle_{i_1}$ $\langle\rangle_{i_2}$, or simply $\langle\rangle_i$ $\langle\rangle_i$.

[16] Until I find some examples where reciprocal if-then brackets are needed (see previous footnote), I do not see how to tell where they might be necessary, so I will confine these remarks to simple cases of angle brackets, where a bracket is either an if-bracket or a then-bracket, but not both.

[17] As far as I can tell, all such rules will also work with the if-then markings reversed, given disjunctive ordering, which is usually claimed to hold with all angle brackets (e.g. Chomsky and Halle p. 77). Perhaps we should have Principle I simply explain that when one bracket is in the SD and the other in the SC it doesn't matter which bracket is the if-bracket.

[18] As suggested in the preceding footnote, perhaps the proper generalization is that the fact that the SD is an *if* and the SC a *then* overrides and

5.2 Principle II?

Principle I tells us how to predict which angle bracket is the if-bracket if one of a pair is in the SD and the other in the SC. However, when they are both in the SD prediction is much more difficult, if not impossible. The Seri, English, and Aztec examples we have looked at are all examples of rules where both angle brackets are in the SD.

Examination of them quickly destroys several hypotheses that we might think of. It is immediately obvious that you cannot say that the bracket to the right (or to the left) is the if-bracket, because the English and Seri examples have the right one as the if-bracket, but the Aztec rule has the left one. Nor can we follow what Chomsky and Halle essentially propose,[19] that where one bracket contains a single feature and the other contains something else, like a segment or a sequence of segments, the one containing the single feature is the if-bracket. The Seri rule is a counterexample to this claim, because there the if-bracket must be the one containing a segment, whereas the then-bracket is the one containing a single feature.

Perhaps we can generalize, however, that where one bracket in the SD is associated with the part of the SD that will actually be changed by the SC and the other is in the environmental part of the SD, the non-environmental one will be the if-bracket. Let us call the part of the SD that will be changed by the SC the locus. It corresponds, in the familiar slash-dash notation, to the material to the left of the arrow or to features listed under the dash. The non-local portion of the SD we can call the environment. We might then propose Principle II:

Principle II: Where one bracket is local and the other is environmental, the local bracket is the if-bracket.

This principle predicts correctly for the English and Aztec cases which bracket is the if-bracket. And, in the rules I have been able to examine which have a local-environmental pair of angle brackets, I have found no exceptions to Principle II so far. It is, however, based on very few cases--I have not found more than 5 such rules. Also, there does not seem to be any explanation of why it should be true, as there was for Principle I. For these reasons, I would take Principle II with a large pinch of salt.

5.3 No Principle III

Neither Principle I nor Principle II can tell us about cases like the Seri example, where both brackets are environmental. I have found counterexamples to all the principles I have thought of which would predict that in the Seri rule the <i> would be the if-bracket, as it must. It does not work to say that it is the right-most bracket that is the if-bracket in these cases, nor to say that it is the bracket nearest to the local position, nor to say that it is the bracket with the segment rather than the single feature, nor anything else I can think of. Thus it seems that there

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nullifies or renders irrelevant and therefore indeterminant the if-then marking of the angle brackets.

[19] p. 212, note 42.

is no Principle III to take care of cases where both brackets are environmental. Unfortunately, this means that we cannot predict in principle which of any pair of angle brackets is the if-bracket and which is the then-bracket: in at least these cases they must be marked.

Also, people have, from time to time, proposed analyses where two features of a single segment in the SD bore an if-then relationship. They did not use angle brackets to mark this, but if it is true, as I have argued, that angle brackets should be interpreted as basically marking such a relationship, it would make sense to use angle brackets for these cases also.[20] For instance, Chomsky and Halle propose the following:

$$V \longrightarrow [+tns] \;/\; \underset{\left[\begin{smallmatrix}\alpha\,lo\\ \beta\,str\end{smallmatrix}\right]}{\underline{\quad}}\;\#$$

where β = + if α = +

This, given if-then interpretation of angle brackets, should probably be written:

$$V \longrightarrow [+tns] \;/\; \underset{\left\langle\begin{smallmatrix}+lo\\ +str\end{smallmatrix}\right\rangle_i}{\underline{\quad}}\;\#$$

If it is conceded that this is the proper way to handle such cases, we have a pair of angle brackets which are both local. Once again, neither Principle I nor Principle II can help us decide which bracket should be the if-bracket. Again, I can think of no Principle III which would give us a way to predict which of the two features should be in the if-bracket and which should be in the then-bracket.

Marlett has proposed a stress shift rule for Seri (another Class IV rule, by the way) which involves a pair of angle brackets which are both local, though they are not both enclosing features of a single segment, as in the case we just examined.[21] The rule is as follows:

$$\begin{array}{cccc} V & + & V & \\ \langle +lo\rangle & [& +hi &] \\ & [& +str &] \\ & [\langle +back\rangle_i & &] \\ 1 & & 2 & \end{array} \Longrightarrow \begin{array}{cc} 1 & 2 \\ [+str] & [-str] \end{array}$$

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[20] Relevant portions of the Tensing Rule, p. 74.

[21] This rule can actually be formulated without angle brackets, though it is not clear that that is better. The argument holds as long as rules such as that given in the text are possible and should be permitted by theory.

This rule is supposed to capture the following generalizations:

a + í ==> ái   o + í ==> ói
a + ó ==> áo   but i + ó ==> ió

(o functions as a high vowel in Seri.)

Given the existence of rules of this type, we again are not going to be able to predict by either Principle I or Principle II which of the two brackets is going to be the if-bracket and which is going to be the then-bracket. And again there is no clear way to predict by any other means: there is no Principle III to help us out.

5.4 Conclusion

I thus conclude that we probably cannot predict in every case which of a pair of angle brackets will be the if-bracket and which will be the then-bracket. Where Principle I can be invoked I think it will hold true. Where Principle II can be invoked I think it might hold true. Where neither rule can be invoked, I think the brackets will just have to be marked.

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Afterword

Much of the discussion in Section 5 has been rendered vacuous by the signal discovery of the Principle of Transposition (Law of the Contrapositive), which can be found in virtually any textbook of elementary symbolic logic (e.g. W. Gustason and D. Ulrich, 1973, Elementary Symbolic Logic, Holt, Rinehart, & Winston, N. Y., front flyleaf.) This principle states that $(a \supset b) \equiv (\sim b \supset \sim a)$. That is, a statement "a implies b", (or "if a then b",) is equivalent to one saying "not b implies not a" (i.e. "if not b then not a"). In the cases of all the rules with both brackets in the SD (those cases discussed in 5.2 and 5.3) this works out to mean that in principle either of the two brackets may be marked as the if-bracket. All that needs to be done is for the polarities to be switched (requirements changed to prohibitions) for both brackets. Thus where the Tetelcingo Aztec rule was written

$$[\langle +\text{strid}\rangle_i] \longrightarrow h \;/\; \_\_\_ \quad [\langle +\text{strid}\rangle]$$

it could have been written

$$[\langle -\text{strid}\rangle] \longrightarrow h \quad \_\_\_ \quad [\langle -\text{strid}\rangle_i]$$

The same goes for most of the other pairs of angle brackets discussed in this paper, though for many of them the formalism makes it hard to write the rule.[1] This means that there is no sense trying to predict which of a pair of angle brackets will be the if-bracket--either one can be. The question reduces to this: given that a certain one of a pair of angle brackets is chosen to be the if-bracket, can you predict whether it will have a + or a - in it? I see no hope of a yes answer to that question.

The situation where one of the angle brackets is in the SD and the other in the SC is considerably more complex. I have not figured it out to my satisfaction, but I think that there is still some validity in Principle I. I would be grateful for anyone's clarification of how those cases work.

--David Tuggy

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[1] Another principle, that of Implication, states that any statement "if a then b" is also equivalent to a statement "either not a or b". Thus the rules could also in principle be formulated in this way, but the formalism makes it almost impossible to do so in most cases. Note however that the if-then requirement in Chomsky and Halle's Tensing rule (p. 121 above) could conceivably be written

$$\begin{Bmatrix} -\text{lo} \\ +\text{str} \end{Bmatrix}$$