

Phonological Representation and Action-At-A-Distance

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0. INTRODUCTION

The formal theory of phonology may be thought of as comprising two interacting but distinct components: the theory of phonological representations and the theory of phonological rules. What is undoubtedly the greatest result obtained thus far in phonology, the theory of distinctive features, belongs to the theory of representations, but in the past twenty years it has been, for the most part, the theory of rules that has attracted the most attention. It is only in the past five years that interest in the nature of phonological representations has returned to the fore. Two major theories have been advanced: the Autosegmental theory of Goldsmith (1976) and the Metrical theory of Vergnaud & Halle (1978). These two theories propose different, though largely compatible, modifications of the theory of representations set out in Chomsky & Halle (1968). The Autosegmental theory is for the most part an enriched theory of distinctive features, obtained by relaxing the constraints on the geometry of distinctive feature representations imposed in *The Sound Pattern of English*. The Metrical theory, on the other hand, proposes the existence of additional, hierarchical structure, such as the syllable and the foot.¹

One of the classical problems in the formal theory of phonology is the proper treatment of harmony processes and related forms of action-at-a-distance, the discussion of which antedates the publication of SPE (see Lightner 1965). Although neither the Autosegmental theory nor the Metrical theory was originally conceived as a theory of harmony, claims have been made on behalf of both theories on the basis of their treatment of harmonic processes. In the present paper I shall consider the treatment

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of such processes in the two non-linear theories. In particular, I shall evaluate the claims of the Metrical theory of harmony.

1. The Autosegmental Theory

In the classical generative phonological theory of Chomsky & Halle (1968) a phonological representation consists of a linear sequence of feature matrices. Each matrix is a column-vector consisting of binary specifications of a fixed set of distinctive features, and each matrix corresponds to one quasi-temporal unit or "segment". Equivalently, we may conceive of a phonological representation as a linear sequence of segment "slots", to each of which is linked a specification for every distinctive feature. There are two implicit constraints on the relationship between the feature specifications and the segment slots. First, it is assumed that to every segment there corresponds exactly one specification for every feature, and conversely, that every feature specification corresponds to exactly one segment. This constraint is stated formally in (1).

Secondly, it is assumed that no rule can create a violation of (1). That is to say, deletion rules must affect the entire feature bundle together with the temporal slot that it occupies, and insertion rules may insert only an entire segment, not an incompletely specified segment, or an isolated feature specification. Moreover, no rule may create an association between a single unit of one sort (segment slot or feature) and more than one unit of the other sort. This constraint is stated formally in (2).

(1) *The Bijectivity Constraint*²

The mapping between every string of distinctive feature specifications and the string of segments must be bijective.

(2) *The Integrity Constraint*

No rule may operate in such a manner as to create a violation of the Bijectivity Constraint.

Over the years it has become clear that neither of these two constraints can be maintained. In particular, evidence from African tone languages led Goldsmith (1976) to reject the two constraints, thus replacing the theory of Chomsky & Halle (1968) with the Autosegmental theory of phonology.³ The violations of the two constraints may be summarized as follows.

Violation of the Integrity Constraint is exemplified by the phenomenon of melody preservation discussed by Goldsmith (1976). In these cases a vowel is deleted but its tone remains and is realized on an adjacent vowel.

Action-At-A-Distance

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$$(3) \begin{array}{cc} T^1 & T^2 \\ | & | \\ V^1 & V^2 \end{array}$$

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Melody Tier

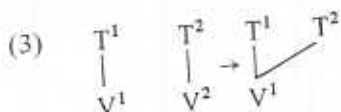
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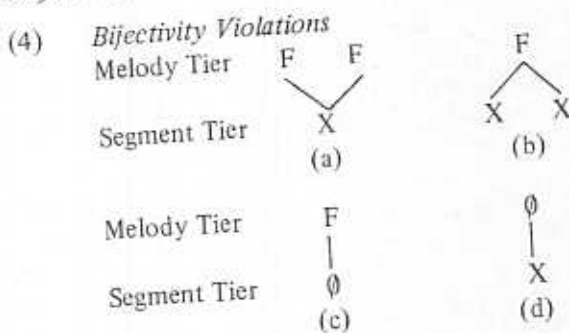
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This is illustrated schematically in (3). If the Integrity Constraint held, we would expect the tone always to be deleted along with the vowel with which it is associated.



Violations of the Bijectivity Constraint take two forms: violations of injectivity and violations of surjectivity. Violations of injectivity occur when a single unit on one tier is associated with more than one unit on another tier. Violations of surjectivity occur when a unit on one tier lacks an association with a unit on some other tier. Both types of violation can occur in two directions, i.e. in the direction from the segment-tier to the melody-tier or in the direction from the melody-tier to the segment-tier. The four possible violations are illustrated schematically below; (4)a and (4)b are violations of injectivity; (4)c and (4)d are violations of surjectivity.



Examples of all four types of bijectivity violation have been provided in the autosegmental literature. Type (4)a is exemplified by the mapping of multiple tones onto a single vowel, producing a phonetic contour tone, discussed in Goldsmith (1976). Type (4)b is exemplified by the association of a single tone to more than one vowel (Goldsmith 1976), by the association of a single set of consonant features to two consonants, yielding a geminate consonant (Schein 1981), and by the association of a single element of a consonantal or vocalic melody with multiple consonant or vowel positions in Semitic languages (McCarthy 1978, 1979, 1981, 1982).

The two types of surjectivity violation frequently occur simultaneously. For example, in many Bantu languages verb stems have no underlying tone, a violation of type (4)d. Instead, the tone pattern of the verb is determined by its tense or aspect; that is to say, the tense/aspect morphemes

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ky & Halle (1968) sequence of feature of binary specificity corresponds to the way we may conceive of segment "slots", distinctive feature. between the feature and that to every segment every feature, and ends to exactly one

iolation of (1). That are bundle together on rules may insert segment, or an isomorph create an association (structure) and more than one normally in (2).

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these two constraints in African tone languages, thus replacing the autosegmental theory of tone may be summarized

d by the phenomenon (Goldsmith 1976). In these cases a tone on an adjacent vowel.

consist exclusively of tones, a violation of type (4)c. A similar situation arises in Semitic where lexical roots consist exclusively of consonants and derivational "stems" consist of a CV-skeleton, that is to say, a sequence of segments specified only for the feature Syllabic (McCarthy 1978, 1979, 1981, 1982).

The existence of such cases as these led to the abandonment of the Bijectivity and Integrity Constraints. The theory in which these violations are permitted is the Autosegmental theory of Goldsmith (1976).

In Autosegmental phonology each distinctive feature potentially constitutes a separate tier, distinct from the segmental core. The association between each feature tier and the segmental core is governed by the Well Formedness Condition of Goldsmith (1976), given here in modified form.⁴

(5) *The Well Formedness Condition*

- a. Association lines may not cross.
- b. Every segment must be fully specified.

The two subconditions have a somewhat different status. Subcondition (5)a in effect states that the two tiers have the same ordering. It is assumed that (5)a holds at every stage of the derivation, and that no rule may create a violation of it. Subcondition (5)b on the other hand is an output condition on the phonological component.⁵ It need not be satisfied in underlying representation, or at any stage of the derivation preceding the last. Moreover, rules are free to create violations of (5)b, provided of course that such violations are eliminated in the course of the derivation.

Condition (5)b may be satisfied in two ways. First, a segment may be specified for a given feature in the segmental core. Such specifications are available for segments that do not participate in prosodic processes. A segment not specified in the segmental core must obtain its specification by association with an autosegment. Such segments are referred to as P-bearing, and the corresponding autosegments may be referred to as P-segments.⁶

Representations that do not satisfy the Well Formedness Condition must be modified so as to do so. This is accomplished by means of a set of universal association conventions.

(6) *Association Conventions* (Clements 1981; 138)

- a. Given a continuous string S consisting of one or more free P-segments and an open string T occurring in its domain, associate (free) P-segments in S to (free) P-bearing units in T in a one-to-one manner from left to right.
- b. Given an open string T remaining after the operation of

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A P-segment is said to be associated to an open string if it is associated to a P-bearing unit in the association line. A P-bearing unit in the association line could be associated to a P-segment by an association line.

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In Turkish suffixes are associated to the verb stem in backness, and if the suffix is associated to the verb stem in the case of the verb stem /di/ ha-

(7) geldim 'I came'
durdum 'I stopped'

In these cases the suffix is associated to the verb stem in the association line. In the case of the verb stem /di/ ha-

(8) -R
|
gel dIm

In some cases a suffix is associated to the verb stem in the association line. In the case of the verb stem /di/ ha-

(6)a, associate each (free) P-bearing unit in T with the P-segment in whose domain it falls (giving precedence to the P-segment associated with a P-bearing unit occurring to the left of T).⁷

A P-segment is said to be free if it is not associated to a P-bearing unit. An open string is an unbroken sequence of unassociated P-bearing units. A P-bearing unit is said to be in the domain of a P-segment if an association line could be drawn between the two without crossing an existing association line.

Although the Autosegmental theory was not originally conceived as a theory of harmony, a large class of harmonic processes fall out without further stipulation from the assumptions of the theory. In any string in which some segments are underlyingly unspecified for a feature (and this is permitted in the Autosegmental theory), the Well Formedness Condition must be fulfilled, and in the absence of language particular rules this will be accomplished by the Association Conventions. The result of application of these conventions will be the association of the unspecified segments to existing autosegmental specifications. Thus, unspecified segments will come to harmonize with fully specified segments. The application of the various clauses of the Association Conventions is illustrated by the case of Turkish vowel harmony.

In Turkish suffix vowels generally harmonize with preceding vowels in backness, and if high, in roundness as well. This is illustrated by the verb forms in (7) in which the unspecified high vowel (written I) of the past tense suffix /dI/ harmonizes with the verb stem.

(7) geldim "I came" açtım "I opened"
durdum "I stood" güldüm "I laughed"

In these cases the past tense is unspecified for the feature Round whereas the verb stem is specified. Thus, in accordance with Association Convention (6)b the autosegment associated with the vowel of the verb stem is associated to the vowel of the past tense suffix. This is illustrated in (8).

(8)
$$\begin{array}{ccc} -R & & -R \\ | & \rightarrow & | \\ \text{gel dIm} & & \text{gel dIm} \end{array}$$

In some cases a suffix vowel is specified for the harmony feature. As a result, an unspecified vowel may find itself in the domain of two autosegments, and, as required by Association Convention (6)b, it is the left-hand autosegment that takes precedence. This is illustrated by the progressive forms in (9), the derivation of which is shown in (10).

- (9) geliyorum "I am coming" atşıyorum "I am opening"
 duruyorum "I am standing" gülüyorum "I am laughing"
- (10) $\begin{array}{cc} -R & +R \\ | & | \\ \text{gel} & \text{Iyor} & \text{Im} \end{array} \rightarrow \begin{array}{cc} -R & +R \\ \diagdown & \diagup \\ \text{gel} & \text{Iyor} & \text{Im} \end{array}$

Finally, the autosegment with which unspecified segments are associated need not have any underlying association. This situation arises in the case of words that trigger irregular suffix harmony, that is to say, harmony in which the suffixes do not agree with the last vowel of the stem. These may be represented as in (11), with a floating (unassociated) autosegment at the end of the stem. In accordance with Association Convention (6)a, this floating autosegment takes precedence in associating to free P-bearing units.⁸

- (11) $\begin{array}{cc} +B & -B \\ \wedge & \\ \text{saat} & \text{I} \end{array} \rightarrow \begin{array}{cc} +B & -B \\ \wedge & | \\ \text{saat} & \text{I} \end{array}$ "hour" (definite accusative singular)
 saat I saat I saati

We see then that the existence of harmony systems of this type follows directly from the possibility of under-specification of segments in underlying representation, together with the Association Conventions. Since this theory of representations and the Association Conventions are motivated quite independently of harmony, this in itself constitutes an argument in favor of the autosegmental analysis.

A number of additional arguments for the autosegmental analysis have been presented in the literature. I will only summarize these here.⁹ First, the autosegmental analysis eliminates the arbitrariness of assigning an underlying feature specification to segments which are always in the harmonic domain of some harmony trigger and which always harmonize with it. Second, and closely related, the redundancy of lexical representations is minimized by removing from them feature specifications for segments whose specification for the harmony feature is entirely predictable. Third, the autosegmental representation provides a means of representing a variety of apparently irregular forms, such as the irregular Turkish nouns discussed above. Fourth, the theory makes the correct prediction that segments specified for the harmony feature by a rule will never undergo the harmony. If they are specified at the segmental core, they will be transparent to the harmony, while if they are specified autosegmentally they will be opaque, that is to say, not only will they fail to undergo the harmony but they will themselves be potential harmony triggers. Fifth and finally, the Autosegmental Theory allows the description of non-

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directional harmony systems such as those of Akan (Clements 1981) and Guaraní (Poser 1981b).

The fact that the autosegmental account of harmony falls out from independently motivated properties of the theory together with the manner in which this account produces the five advantages listed above provides strong motivation for this account of harmony. Consequently, the fact that there exist harmony-like processes that are not describable as purely autosegmental underspecification harmonies should not be taken to indicate that the autosegmental account must be abandoned, *contra* Anderson (1980). Linear accounts of the type proposed by Howard (1972) simply do not meet the challenge of the five arguments mentioned above, nor, for the same reasons, does the metrical account of non-directional harmony of Vergnaud and Halle (1978)¹⁰. Moreover, since the autosegmental account falls out from the theory without further stipulation, the addition of mechanisms capable of handling non-autosegmental cases, were these mechanisms extended to the autosegmental cases, since nothing would prevent the autosegmental generation of such harmonies. The conclusion is, then, that the existence of non-autosegmental harmony processes motivates the existence of mechanisms in addition to the autosegmental association conventions, not their replacement.

2. THE RESIDUE OF THE AUTOSEGMENTAL THEORY (RES(AS))

I will discuss four types of process that cannot be treated as purely autosegmental underspecification harmonies. The first of these is feature-changing harmony. In the autosegmental account of harmony outlined above only segments that are unspecified for the harmony feature undergo harmony. If it can be demonstrated that a harmonizing segment must nonetheless be underlyingly specified for the harmony feature, such a harmony cannot be attributed to autosegmental spreading. Some mechanism must be added to the theory to permit features to be changed.

The second type of harmonic process that cannot be described in purely autosegmental terms is local harmony. By local I do not mean that the harmony trigger and the undergoer need be strictly adjacent. Rather, I refer to processes in which only some fixed number of a string of potential undergoers of harmony actually undergo harmony. In typical unbounded harmonies, an unbroken string of harmonizing segments will all undergo harmony. An element will fail to harmonize only if it never harmonizes; whether or not it harmonizes in some particular environment will not depend upon its position in the string. In a local harmony, only some fixed number of potentially harmonizing elements will actually undergo

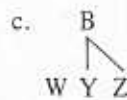
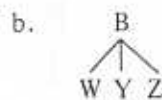
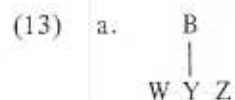
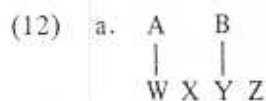
harmony, these being those elements closest to the trigger. Such a harmony cannot be described autosegmentally, since autosegmental spreading is unbounded.

A third class of case that cannot be described in purely autosegmental terms is that of unbounded dissimilation. Autosegmental spreading can produce only assimilation; an unbounded dissimilatory rule can only be described by means of a feature-changing rule.

The last class of case, and the only one that has been offered as evidence for the Metrical theory (Halle & Vergnaud 1981), is that of directional harmony. By this I mean a harmony in which the spreading of the harmonic feature is demonstrably restricted to one direction.

Emphasis must here be put on the word *demonstrably*, for there are harmony systems that are only apparently directional. Consider, for example, the case of Turkish rounding harmony, discussed briefly above. This system has been taken to be an example of a directional harmony by Halle & Vergnaud (1981) on the grounds that the harmony always spreads from left to right. However, this is not due to any explicit statement of directionality; rather, it is due to the fact that the underspecified vowels of Turkish nearly all belong to bound suffixes and hence are nearly always in the domain of an autosegment to their left.¹¹ Since, by Association Convention (6)b it is the lefthand autosegment that takes precedence when an unspecified element lies in the domain of two autosegments, unspecified vowels nearly always obtain their specification from an autosegment to their left thus giving the appearance of directionality.¹² As we have seen, and as Clements & Sezer (this vol.) document in great detail, there is nothing in Turkish that is inconsistent with the bidirectional spreading predicted by the Autosegmental theory.

It is also important to note that the priority clause of Association Convention (6)b is not equivalent to making autosegmental harmony strictly directional. Consider the underlying representations in (12)a and (13)a. The Association Conventions predict that in (12)a P-bearing unit X will be associated with autosegment A, while Z will be associated with B, as in (12)b. This case is identical to the Turkish example in (10). A directional account of Turkish would make this same prediction.



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As we have se... the right of some... rectional. In cert... break up imperr... this vowel harmo... vowel. In this ca... specified vowel, s... This indicates th... directionality con... the same vowel.

A parallel case... autosegment take... teresting system... and do not partic... segments particip... and nasal) and r... remaining segmer... vowels and nasal... (15).

- (14) a. ?okar
b. ?õkã

Consider now underlying representation (13)a. The Autosegmental theory predicts that in this case W as well as Z will be linked to B. Since there is no autosegment to the left of B the priority clause does not apply, and W will be linked to the only autosegment in whose domain it lies, which in this case is to its right. This yields the output in (13)b. In a strictly directional account, only Z would harmonize with Y. W would surface with its underlying value (in a feature-changing system) or would be provided with the default value of the harmony feature (in a feature-specifying system). In neither case would W harmonize with Y. In order to establish the existence of strictly directional harmony it is necessary to demonstrate the existence of cases like (13)c.

It is also important to observe that the addition of the priority clause to the association conventions is not an *ad hoc* way of adding directionality to the autosegmental theory. If only cases of the type described in (12) were known, we might conclude that, while there was no necessity of permitting strictly directional rules, there was also no reason to treat such cases as being non-directional. Cases like that in (13)b would however demonstrate conclusively the necessity for a priority clause in a fundamentally non-directional theory. The fact is that such cases have been documented. Clements & Sezer (this vol.) show that this is precisely what happens in Turkish.

As we have seen, almost all unspecified vowels in Turkish occur to the right of some fully specified vowel, so that harmony appears to be directional. In certain cases, however, an epenthetic vowel is inserted to break up impermissible word-initial consonant clusters, and in general this vowel harmonizes in backness and rounding with the following stem vowel. In this case the epenthetic vowel is not preceded by any fully specified vowel, so it associates perforce with an autosegment to its right. This indicates that Turkish vowel harmony is indeed non-directional; directionality comes into play only when two autosegments compete for the same vowel.

A parallel case, though with the priority clause reversed (i.e. righthand autosegment takes precedence), occurs in Guarani.¹³ Guarani has an interesting system of nasal harmony. Voiceless obstruents are always oral and do not participate in the harmony; they are transparent to it. Of the segments participating in the harmony, only stressed vowels (both oral and nasal) and nasal stops are underlyingly specified for nasality. The remaining segments obtain their nasality specifications from the stressed vowels and nasal stops. This harmony is illustrated by the pairs in (14) and (15).

- (14) a. ?okarú . "he eats"
 b. ?ókã ñ+ "it got lost"

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B
 X Y Z

B
 Y Z

- (15) a. ${}^n\text{der}+\text{v}^{\check{c}}$ "thy brother"
 b. $\text{n}\check{\text{e}}\text{p}\check{\text{e}}\text{t}^{\check{c}}$ "thy tobacco"

In (14) we see that the third person singular subject prefix /*ʔo*/ agrees in nasality with the following verb stem. In (15) the second person singular possessive prefix /*ne*/ is nasal before a nasal stem, and oral before an oral stem. (A nasal stop is prenasalized before an oral vowel.) Of these four cases, only (15)a shows any evidence of directionality, and in this case we have an unspecified element in the domain of two autosegments, a nasal autosegment on the left and an oral autosegment on the right. This demonstrates that in Guaraní the priority clause gives precedence to the righthand autosegment. The same phenomenon is illustrated by (16) and (17).

- (16) ${}^{\check{c}}\text{um}\check{\text{i}}\check{\text{s}}\text{a}\gamma^{\text{w}}\check{\text{a}}$ < / $\text{um}\check{\text{i}} + \check{\text{s}}\text{a} + \gamma^{\text{w}}\check{\text{a}}$ /
 "like those" those+like+belonging to
- (17) $\text{r}\check{\text{e}}\text{x}\check{\text{o}}\check{\text{t}}\check{\text{a}}\check{\text{r}}\check{\text{a}}\text{m}\check{\text{o}}$ < / $\text{r}\check{\text{e}} + \text{x}\check{\text{o}} + \text{t}\check{\text{a}} + \text{r}\text{am}\check{\text{o}}$ /
 "if you go" you+go+future+if

In (16) the /*a*/ of /*ʃsa*/ is in the domain of the stressed nasal vowel to its left and the stressed oral vowel to its right, and it is the righthand vowel that wins. In (17) the /*a*/ of /*ta*/ is in the domain of the stressed oral vowel to its left and the nasal stop (/m/) to its right, and it is the nasal to the right that wins.

Thus far we have a case like that of Turkish (without word-initial epenthesis) but with the priority clause reversed. If Guaraní nasal harmony were truly directional we would expect to find that no segment would ever harmonize with something to its left. This prediction is false. Consider for example the forms in (18) and (19). In the first case we have an oral verb stem, and in the second a nasal verb stem. As expected, the negative prefix /*no*/ harmonizes with the verb stem to its right. Note however that the negative suffix /*i*/ also harmonizes with the verb stem, even though the verb stem is to its left. Since the negative suffix is word-final there is no autosegment to its right and the priority clause does not apply.

- (18) ${}^n\text{doroxa}+\text{x}\check{\text{u}}\text{i}$ < / $\text{no}+\text{ro}+\text{x}\check{\text{a}}+\text{x}\check{\text{u}}+\text{i}$ /
 "I don't love you" Neg+1-2+love+Neg
- (19) $\text{n}\check{\text{o}}\check{\text{r}}\check{\text{o}}\check{\text{i}}\text{n}\check{\text{u}}\text{p}\check{\text{a}}\text{i}$ < / $\text{no}+\text{roi}+\text{nup}\check{\text{a}}+\text{i}$ /
 "I don't beat you" Neg+1-2+beat+Neg

A similar example is given in (20). In (20)a the /*a*/ of "spouse" harmonizes

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with the stressed rity clause. What the /*a*/ now harm

- (20) a. $\text{m}\check{\text{e}}^{\text{n}}$
 "wid
 b. $\text{m}\check{\text{e}}^{\text{n}}$
 "spo

Just as in Turki: nality only come P-bearing unit. T clause of Associ strictly direction:

Let us return example of direc nal harmony sy: (13)b. This is a r but it is not suf due to its being demonstrate tha that when it occo mony. To summ tional harmony i it occurs on one when it occurs o for the existence to date, and thus mony exists. I wí

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Chumash has with the limited tality; i.e. they a and (22). In (21 the third person When the stativiz this suffix. (/n/ isolation form be becomes /*ʃ*/.

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with the stressed oral vowel of the suffix /ré/, in accordance with the priority clause. What happens when this suffix is removed? As we see in (20)b the /a/ now harmonises with the nasal stop to its left.

- (20) a. $m\acute{e}^n\acute{d}ar\acute{e}$ < $/m\acute{e}^n a + r\acute{e}/$
 "widow(er)" spouse + former
 b. $m\acute{e}^n\acute{a}$ < $/m\acute{e}^n a/$
 "spouse"

Just as in Turkish, Guaraní nasal harmony is bidirectional, and directionality only comes into play when two autosegments compete for the same P-bearing unit. These two cases demonstrate the necessity for the priority clause of Association Convention (6)b, since they cannot be treated as strictly directional.

Let us return now to the question of what would constitute a real example of directional harmony. I have indicated that in a truly directional harmony system a representation like (13)a would yield (13)c, not (13)b. This is a necessary condition for a harmony to be truly directional, but it is not sufficient. The failure of W to harmonize in (13)c could be due to its being opaque, i.e. underlyingly fully specified. Thus, we must demonstrate that W is indeed susceptible to harmony, that is to say, that when it occurs to the right of a harmony trigger it does undergo harmony. To summarize, we know that we are dealing with a strictly directional harmony if some element harmonizes with a harmony trigger when it occurs on one side of the trigger, and fails to harmonize with a trigger when it occurs on the other side. To my knowledge, no explicit argument for the existence of a harmony of this type has been made in the literature to date, and thus it remains to be demonstrated that true directional harmony exists. I will present such a case below.

2.1. Directional and Feature Changing Harmony

I will demonstrate the existence of both directional and feature-changing harmony by means of the same example, that of the Ineseño dialect of Chumash, described by Applegate (1972).¹⁴

Chumash has a harmony system that makes all sibilants in the word, with the limited exception discussed in section Five below, agree in palatality; i.e. they are all /s/ or all /š/. This is illustrated by examples (21) and (22). In (21) the verb stem is /sunon/, and when it is followed by the third person singular object suffix /us/ it retains its underlying /s/. When the stativizing suffix /š/ is added, however, the /s/ harmonizes with this suffix. (/n/ becomes /t/ before /š/.) In (22) the verb "to pay" in its isolation form begins with an /s/; when the suffix /Vtš/ is added this /s/ becomes /š/.

prefix /ʔo/ agrees in second person singular, and oral before an oral vowel.) Of these directionality, and in this of two autosegments, on the right. This has precedence to the illustrated by (16)

imō/

ed nasal vowel to its the righthand vowel the stressed oral vowel it is the nasal to the

(without word-initial Guaraní nasal harmony at no segment would tion is false. Consider case we have an oral expected, the negative at. Note however that rb stem, even though is word-final there is es not apply.

+i/
+Neg

+i/
+Neg

? "spouse" harmonizes

- (21) ksunonus "I obey him" /k + sunon + us/ (290)
 kšunotš "I am obedient" /k + sunon + š/ (290)
- (22) saxtun "to pay" (255)
 šaxtunitš "to be paid" (255)

It is a straightforward matter to demonstrate that this harmony is feature-changing. Since a morpheme containing a sibilant need not be followed by any other such morpheme, it is possible to observe the isolation form of harmonizing segments. If Chumash were not feature-changing, we should expect to find that the isolation form of harmonizing segments was either /s/ in every case or /š/ in every case, since the specification for the harmony feature of underspecified segments would have to be supplied by a default rule that would necessarily assign the same default value to every harmonizing segment. Consequently, if some harmonizing segments surface as /s/ when outside the domain of another sibilant, and others surface as /š/ when outside the domain of another sibilant, we must attribute /s/ from /š/, and therefore we must conclude that the harmony process changes these underlying feature specifications. I shall now show that this is the case.

Consider first the causative prefix, whose isolation¹⁵ form is seen to be /su/ in (23). This prefix harmonizes with the verb stem /šoyin/ in (24).

- (23) suwayan "cause to hang" /su + wayan/ (151)
- (24) kšušoyin "I darken it" /k + su + šoyin/ (119)

A similar example is the third person subject prefix, whose isolation form is seen to be /s/ in (25) and (26).

- (25) saqunimak "he hides" /s + aqunimak/ (15)
 (26) sixut "it burns" /s + ixut/ (18)

When the following verb stem contains a /š/, the prefix harmonizes with it, as illustrated in (27) and (28).

- (27) šilakš "it is soft" /s + ilakš/ (7)
- (28) šammotš "they paint it" /s + am + motš/ (17)
 3 + indef.pl.subj. + paint

It is even possible to see /s/ change to /š/ in the same environment depen-

ding on what follows the isolation form; w harmonizes. Exam

(29) a. hasxin

(29) b. hašxin

(30) a. skuti
 b. škutiv

Consider now the isolation form of the prefix /š/ in (31) to be /iš/.

(31) a. pišana

(31) b. pišik

This prefix becomes /iš/ as illustrated in (32).

(32) a. sis^hil

(32) b. sistisi

A similar example is the isolation form of the third person subject prefix /s/ in (33) to be /š/.

(33) a. šapit

(33) b. sapit

ding on what follows. Thus, in (29)a the third person prefix retains its isolation form; when the past tense suffix is added in (29)b the prefix harmonizes. Example (30) is exactly parallel.

(29) a. hasxintila "his Indian name" /ha + s + xintila/ (200)
poss.+ 3 +Ind.name

(29) b. hašxintilawaš "his former Indian name" (200)

(30) a. skuti "he sees" /s + kuti/
b. škutiwaš "he saw" /s + kuti + waš (509)

Consider now the dual subject marker, whose isolation form is seen in (31) to be /iš/.

(31) a. pišanan' "don't you two go" /p + iš + al + nan'/ (109)

(31) b. piš'ik+min "you two are young" /p + iš + ?ik+min/ (417)
2 + dual+neg.imv.+go
2 + dual + be young

This prefix becomes /is/ when the rightmost sibilant in the word is /s/, as illustrated in (32).¹⁶

(32) a. sis^hiluleqpeyus "they two want to follow it" < (333)
/s + iš + sili + ulu + aq + pey + us/
3 du. desid follow 3obj

(32) b. sistisiyepus "they two show him" /s + iš + tiši + yep
3 du. show (71)
+ us/
3obj

A similar example is given below. In this case, (33)a shows that the isolation form of the stem "good" is /tš^ho/, and indeed this stem causes the subject prefix /s/ to harmonize with it. When this same stem is followed by the third person object suffix /us/ it harmonizes with it.¹⁷

(33) a. šapits^holit "I have a stroke of good luck" < (89)
/s + api + tš^ho + it/
3 quick good lobj

(33) b. šapits^holus "He has a stroke of good luck" < (118)
/s + api + tš^ho + us/
3 quick good 3obj

We have now seen four morphemes that contain sibilants, all of which undergo harmony. Two of these show /s/ in their isolation forms, while the other two show /š/. This suffices to establish that Chumash sibilant harmony is feature-changing.

Consider now the issue of directionality. In every example that we have so far examined it is the rightmost sibilant that dominates. Is this evidence of true directionality, or is this an artifact of the distribution of harmonizing and opaque segments?

Example (34) below shows that the third person object suffix /us/ harmonizes with the past tense suffix /waš/ to its right. What happens when /us/ is not followed by any sibilant, but is preceded by /š/? If Chumash sibilant harmony were non-directional, we should expect /us/ to harmonize with the sibilant to its left, yielding /uš/. As we have already seen in (33)b this is not the case; rather, it is /us/ that triggers harmony in the sibilant to its left. Notice that this behaviour cannot be attributed to the sibilant to the left of /us/ being unable to trigger harmony; example (33)a shows that /tš^ho/ does indeed trigger harmony to its left, when it is not followed by another sibilant. We conclude that Chumash sibilant harmony constitutes a genuine case of right-to-left directional harmony.

- (34) šapitš^holušwaš "he had a stroke of good luck"
 /s + api + tš^ho + us + waš/ (119)
 3 quick good 3obj past

This Chumash case is of particular interest because it is a case of unbounded harmony; we might expect that local rules would be directional and feature-changing but that unbounded rules would be feature-specifying and non-directional. In order to establish that Chumash sibilant harmony is indeed unbounded, it remains to show that it is not local cyclic.¹⁸

This may be demonstrated in two ways. First, consider again example (34). This may be bracketed in three ways,¹⁹ listed in (35). The first bracketing yields the incorrect output *šapitš^holušwaš: the second and third bracketing yield the equally incorrect *šapitš^holušwaš. Thus, no matter what the bracketing, (34) cannot be generated by cyclic application of a local rule.

- (35) a. [[[s [apitš^ho]] us] waš]
 b. [s [[[apitš^ho] us] waš]]
 c. [[s [[apitš^ho] us]] waš]

The unboundedness of this rule may also be established by considering the effect of following sibilants on single morphemes containing more than

one sibilant. If t^l able to affect on bounded rule con examples below harmonize with harmony cannot

- (36) šlušišiniw

- (37) šitš^hiwišut

cf. ts^hiwi

We conclude that feature-changing

2.2. Local Harmony

Anderson (1980) This is the case c les in (38) illust a front vowel, th

- (38) gūmə
 tōmU
 lāhI
 hūlU?
 lāgU
 tūnU?
 ótdUt
 óksU?

Notice that this it did we should failure of harmc to tense vowels; it would not be a ever, since Kens rule must be ord must precede th tion.

one sibilant. If the harmony rule were local, a following sibilant would be able to affect only the rightmost of the sibilants in the stem; only an unbounded rule could affect more than one sibilant on a single cycle. As the examples below demonstrate, in stems containing two sibilants, both harmonize with a following sibilant. Consequently, Chumash sibilant harmony cannot be local cyclic.

- (36) $\check{s}lu\check{s}i\check{s}iniwa\check{s}$ "it is all grown awry" < (291)
 /s + lu + sisin + waš/
 3 +all + grow awry + past
- (37) $\check{s}it\check{s}'iwi\check{s}ut\check{s}$ "he plays the rattle" < (99)
 /s + ts'iwis + Vtš/
 3 + rattle + verbaliser
- cf. ts'iwisun "to make a rattle" (275)

We conclude that Chumash sibilant harmony is an unbounded, directional, feature-changing harmony-rule.

2.2. Local Harmony

Anderson (1980) has already proposed one example of local harmony. This is the case of Chamorro, described by Topping (1968). As the examples in (38) illustrate, when a word is preceded by a particle containing a front vowel, the initial vowel of the word becomes front and unrounded.

- | | | | | | |
|------|-------------------------|-----------|---|-----------------------------|----------------|
| (38) | $g\acute{u}m\acute{a}$ | "house" | i | $g\acute{i}m\acute{a}$ | "the house" |
| | $t\acute{o}mU$ | "knee" | i | $t\acute{e}mU$ | "the knee" |
| | $l\acute{a}hl$ | "male" | i | $l\acute{a}hl$ | "the male" |
| | $h\acute{u}lU?$ | "up" | | $s\acute{a}n h\acute{i}lU?$ | "upward" |
| | $l\acute{a}gU$ | "north" | | $s\acute{a}n l\acute{a}gU$ | "northward" |
| | $t\acute{u}nU?$ | "to know" | | $en t\acute{i}nU?$ | "you know" |
| | $\acute{o}t\acute{d}Ut$ | "ant" | | $mi \acute{e}t\acute{d}Ut$ | "lots of ants" |
| | $\acute{o}k\acute{s}U?$ | "hill" | | $gi \acute{e}k\acute{s}U?$ | "at the hill" |

Notice that this harmony does not extend beyond the first syllable; if it did we should obtain * $i t\acute{e}mI$ and * $s\acute{a}n h\acute{i}lI?$. One might claim that this failure of harmony to affect the second syllable was due to a restriction to tense vowels; since the second vowel in the above words is always lax it would not be a candidate for harmony. This way out is not available, however, since Kenstowicz and Kisseberth (1979) show that this harmony rule must be ordered prior to stress placement, and that stress placement must precede the vowel reduction rule that creates the lax vowels in question.

In an attempt to provide an autosegmental analysis we might propose that the harmonizing vowels are unspecified for the features Back and Round, and that we are dealing with a dominant harmony. When the prefixed particle contains a front unrounded vowel these features will be spread to the underspecified vowel of the stem. Such an analysis requires that only the stem initial vowels be underspecified. This is logically possible, and it is not ruled out by any explicit principle of the Autosegmental theory. However, this is a rather bizarre distribution of specified and unspecified segments. Moreover, it has been implicitly assumed in work in the Autosegmental theory that the status of segments is a lexical property. As such, we expect either a random distribution of specified and unspecified elements, subject to such functional principles as the notion that elements that can occur freely are likely to be fully specified, whereas bound forms are likely to be incompletely specified, or a context-free generalization to the effect that every member of a given natural class, subject to lexical exceptions, will be specified or unspecified for a given feature. Context-sensitive generalizations of the type necessary in Chamorro are contrary to the spirit if not the letter of the Autosegmental theory. Nonetheless, since no explicit version of the constraints on underspecification is available, nor has any investigation of the consequences of different theories been made, it is not possible to rule out this analysis of the Chamorro facts *a priori*.

Were we to adopt this analysis we would face a further problem. When no particle precedes, why do the word-initial vowels not harmonize with the following vowel, e.g. why is the isolation form of "male" not **läh* instead of *lah*? We might suppose that only vowels in word-initial position or in particles are P-bearing, while those elsewhere are specified at the segmental level, which would prevent them from spreading their feature specifications. This would increase the bizarreness of the distribution of specification types. The alternative would be to make this harmony strictly directional, itself incompatible with a purely autosegmental account. Thus, it is possible to provide a purely autosegmental account of this harmony system, but only at the cost of a bizarre underlying distribution of specification types that ought very likely to be prohibited.

A more solid example of a local harmony is found in Lango, described by Woock and Noonan (1979)²⁰. Lango has ten vowels which fall into two harmonic sets in accordance with their ATR specification, as listed in (39).

- (39) a. i e ɔ o u [+ATR]
 b. i ɛ a ɔ u [-ATR]

[-ATR] vowels become [+ATR] when adjacent to [+ATR] vowels, as illustrated in the following examples. In (40) we see that the second person

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singular alienable possessive. In (41) we see that the suffix /wu/ has the same

- (40) lùt " " "
 màc " "
 dèk " "
 (41) bós " "
 lè " "
 jò " "

When the same suffix follows the initial vowel of the stem harmony

- (42) còŋó
 bòŋó
 (43) lèmón
 bòŋó
 ròmò

This suggests that we propose an autosegmental analysis. Specifically, we could propose that the suffix /wu/ is a vowel. Such a proposal would be problematic in many cases, but here it is not. Consider the plural forms in (44). The suffix /i/ triggers harmony in certain cases; this is shown in (46) where the suffix /i/ harmonizes with the stem vowel /a/. In (45) the suffix /i/ does not harmonize with the stem vowel /a/. Lexically opaque harmony is indeed local.

- (44) gòt
 lùt
 (45) pùnù
 (46) bòŋó
 ròmò

singular alienable possessor suffix /ni/ causes the preceding vowel to harmonise. In (41) we see that the second person plural alienable possessor suffix /wu/ has the same effect.

(40)	lüt	"stick"	lütü	"your stick"
	mác	"fire"	máccí	"your fire"
	dèk	"stew"	dèkkí	"your stew"
(41)	bò	"net"	bòwú	"your net"
	lè	"axe"	léwú	"your axe"
	jò	"people"	jòwú	"your people"

When the same suffixes are added to disyllabic stems, only the second vowel of the stem harmonises.

(42)	cò ŋò	"beer"	cò ŋóní	"your beer"
	bò ŋó	"dress"	bò ŋóní	"your dress"
(43)	lè mún	"orange"	lè múnwú	"your orange"
	bò ŋó	"dress"	bò ŋówú	"your dress"
	rò mò	"sheep"	rò mòwú	"your sheep"

This suggests that Lango ATR harmony is local. In principle we could propose an autosegmental analysis along the lines discussed for Chamorro. Specifically, we could say that only the last vowel of the word is P-bearing. Such a proposal would suffer from the same defects as in the Chamorro case, but here it is possible to rule it out empirically.

Consider the plural forms in (44). These show that the plural suffix /i/ triggers harmony in the preceding vowel. The form in (45) show that in certain cases this suffix triggers deletion of the stem final vowel. The forms in (46) show that when as a result of this deletion rule the vowels that fail to harmonize with the suffix /wu/ in (43) come to be adjacent to the suffix /i/, they undergo harmony. This should not occur if these vowels are lexically opaque. Consequently, we may conclude that Lango ATR harmony is indeed local.

(44)	gòt	"mountain"	gòdí	"mountains"
	lüt	"stick"	lütí	"sticks"
(45)	pùnù	"pig"	pùní	"pigs"
(46)	bò ŋó	"dress"	bò ŋí	"dresses"
	rò mò	"sheep"	ròmí	"sheep" (pl.)

we might propose features Back and ony. When the pre-se features will be n analysis requires is is logically pos-the Autosegmental f specified and un-assumed in work its is a lexical pro-of specified and un-s as the notion that specified, whereas , or a context-free given natural class, pecified for a given ecessary in Chamor-tosegmental theory. ints on underspeci-consequences of dif-out this analysis of

ther problem. When not harmonize with of "male" not *läh/ in word-initial posi-where are specified from spreading their nness of the distribu-) make this harmony y autosegmental ac-egmental account of irre underlying distri' be prohibited.

l in Lango, described ls which fall into two ion, as listed in (39).

ATR] vowels, as illu-at the second person

2.3. Dissimilation

Although unbounded dissimilations do not appear to be common at least one clear example has been reported from a well studied language. According to Cheng (1973) Mandarin Chinese has a rule that converts a Third toned syllable to Second tone before another Third toned syllable. This is illustrated in (47).²¹

- (47) mai^2 ma^3 "to buy a horse" $/\text{mai}^2 \text{ma}^3/$
 $\text{f}\text{a}\text{n}^2$ $\text{c}^{\text{h}}\text{a}\text{n}^3$ "flour factory" $/\text{f}\text{a}\text{n}^2 \text{c}^{\text{h}}\text{a}\text{n}^3/$

In these cases the domain of the rule is VP and NP respectively. In slow, careful speech this rule is restricted to maximal projections of lexical categories, but in more rapid, casual speech the domain of the rule becomes the entire sentence. As a result, it is possible to find such examples as (48). Here a sequence of four Third toned syllable dissimilates from the final Third toned syllable.

- (48) lau^2 li^2 mai^2 xau^2 $\text{t}\text{e}\text{iou}^3$ "Old Li buys good wine"

This rule is clearly dissimilatory, it affects an unbounded string of Third toned syllables, and inspection of the syntactic tree of (48) will show that it cannot be local cyclic.

The examples presented demonstrate the existence of directional, feature-changing, local, and dissimilatory rules.

3. The Metrical Theory

In the Metrical theory of Vergnaud & Halle (1978) and Halle & Vergnaud (1981) it is necessary to set the five parameters listed in (49), the significance of which will be explained in the course of the discussion. The harmony process proceeds in four stages, listed in (50).

- (49) *Parameters*
 (i) projection
 (ii) direction of branching
 (iii) harmony feature
 (iv) opaque elements
 (v) conditions on feature copying
- (50) *Stages*
 (i) projection

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- (ii) tree constraints
 (iii) feature c
 (iv) percolation

The operation of projection on which the harmony elements which will be determined are all those that participate in the harmony projection. The projection may be found

The second stage number of metrical uniformly left-branching of parameter (ii), as simple unbounded, it will be only one transparent element in the Designated Terminal node of the tree harmony and the right

The next step (Terminal Element Position) for the harmony may be unconditional only if the DTE is simple

Finally, the feature all of the terminal specifications.

We may illustrate harmony described

The projection to specify as [+strict] of branching is to that it is the feature discussed in section F no opaque segment conditions on feature c

Consider now the shown in (51). Its branching. As the the illustration) is nodes to produce the

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- (ii) tree construction
- (iii) feature copying
- (iv) percolation

The operation of projection consists of designating the class of segments on which the harmony tree is to be constructed, that is to say, the elements which will be the terminal nodes of the tree. The projected segments are all those that are in some way relevant to the operation of the harmony: undergoers, triggers and blockers. Segments that do not participate in the harmony are not projected. For example, in a typical vowel harmony the projected class might be all [+syll] segments. A formal definition may be found in Vergnaud (1977).

The second stage consists of the construction of the minimum possible number of metrical trees onto the projected segments. These trees are uniformly left-branching or right-branching, depending upon the setting of parameter (ii), and all are binary-branching. All such trees are in principle unbounded, so that in a word containing no opaque elements there will be only one tree. Tree construction is subject to the constraint that opaque elements may appear only in the Designated Terminal Position. The Designated Terminal Position is defined to be the most deeply embedded node of the tree, that is to say, the leftmost node in a left-to-right harmony and the rightmost node in a right-to-left harmony.²²

The next step consists of copying the specification of the Designated Terminal Element (the segment occurring in the Designated Terminal Position) for the harmony feature to the root of the tree. This copying may be unconditional, in the case of an α -harmony, or it may take place only if the DTE is specified +F or -F, in the case of a dominant harmony. Finally, the feature specification on the root of the tree percolates to all of the terminal nodes of the tree, overriding their existing feature specifications.

We may illustrate this procedure by applying it to the Chumash sibilant harmony described in section 2.1.

The projection consists of the class of sibilants, which it is sufficient to specify as [+strid]. Since this is a right-to-left harmony the direction of branching is to the right. The harmony feature is arguable; let us say that it is the feature Anterior. With the exception of the cases to be discussed in section Five, which we will ignore for the time being, there are no opaque segments. Finally, since this is an α -harmony, there are no conditions on feature copying.

Consider now example (34). The harmony tree for this example is shown in (51). Its terminal nodes are the four sibilants, and it is right branching. As the arrow shows, the specification of the DTE (circled in the illustration) is copied to the root, whence it percolates to the terminal nodes to produce the surface form.

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of the issue of directionality, the original arguments for the Metrical theory were based on what I will refer to as the geometric interpretation of the metrical tree. In this interpretation geometric properties of the harmony tree are claimed to play a crucial role. This interpretation is quite different from the interpretation that allows the description of the RES(AS).

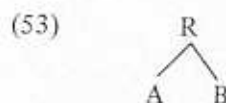
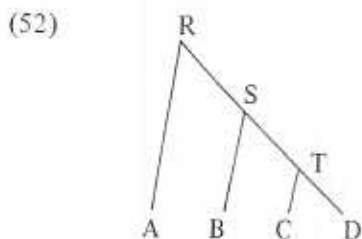
4.1. The Geometric Interpretation of the Metrical Tree

Two geometric properties of the metrical tree have been claimed to play a role in harmony processes. These are the depth of embedding and the uniform branching property.

The depth of embedding function is claimed to play two roles. First, recall that the Designated Terminal Element of the harmony tree is defined to be the most (or least, in other versions of the theory) embedded node. On this basis, Vergnaud & Halle (1978) claim that depth of embedding plays a crucial role in determining directionality. Now it is clear that they do not mean to claim that the direction of spreading can in any way be predicted by this device; the direction of branching of the harmony tree does not come from anywhere; it is simply stipulated. The claim must rather be that the depth of embedding function plays a necessary and sufficient role in the mechanism of the harmony process. This claim is false.

First, it is obvious that reference to depth of embedding is not necessary to stipulate directionality. It is more than adequate to draw a pair of brackets delimiting the harmonic domain and to designate either the leftmost position or the rightmost position as the DTE. This is no more arbitrary than stipulating construction of a left- or right-branching tree.

Nor is reference to depth of embedding sufficient to designate the DTE. Since, as Vergnaud & Halle (1978; 4.6-7) state, depth of embedding is "...measured in number of intervening nodes between the root of the tree and the affected segments", it follows that every tree has two "most embedded nodes". To see this, consider the tree in (52). The nodes intervening between the root and terminal node D are S and T. The same nodes, and no others, intervene between the root and terminal node C. Consequently, C and D are equally embedded. In any right-branching tree the rightmost node and its neighbor are equally embedded; in any left-branching tree the leftmost node and its neighbor are equally embedded. Consequently, the DTE is ill-defined if reference is made only to depth of embedding.



In some versions of the Metrical theory the DTE is defined to be the least embedded node. This definition eliminates the above problem in some cases, for in a tree with three or more terminal nodes there is a unique least embedded node. However, the problem remains whenever there are only two terminal nodes. As is obvious from figure (53) both terminal nodes are equally embedded, so the least embedded node is not unique. Such trees will arise not only in local harmonies where all trees have only two terminal nodes, but also in unbounded harmonies whenever it happens that there are only two elements on the projection, as in example (27), for example.

I conclude that reference to depth of embedding is neither necessary nor sufficient for the specification of the DTE.²³

The second claim for the role of depth of embedding in harmony is based on the existence of phonetic gradation within the harmony domain. Following the proposal of Sportiche (1977), Vergnaud & Halle (1978) claim that in Guaraní nasality spreads directionally, from right to left. Within the harmony domain there is a decrease in nasalization from right to left, as described by Gregores & Suarez (1967: 66):

With the unstressed syllables preceding a nasal consonant, N[asalization-WIP] is automatically present and is never strong. Elsewhere, nasalization occurs covering a span of varying length, in which the velum appears to be lowered increasingly from medium to strong, so that the nasal timbre is strongest toward the end of the nasal span.

Vergnaud & Halle (1978:4.6-7) observe that:

...this fact is captured directly ... if it is assumed that the degree of nasality varies inversely with the depth of embedding measured in number of intervening nodes between the root of the tree and the affected segment: the larger the number of intervening nodes, i.e. the deeper the embedding of the affected segment, the weaker its degree of nasalization. As noted by Sportiche, this phenomenon is of some theoretical significance because it suggests that there is an advantage to representing nasal harmony in Guaraní by means of left-branching trees rather than by nondirectional trees

...Since in the nondirectional tree all terminal nodes are equidistant from the root, differences in the distance from the root cannot be utilised to reflect such facts as the difference in Guaraní nasalization.

Action-At-A-Distance

Since in more recent theories of harmony the tree that represents the harmony domain has to vary in complexity,

Vergnaud & Halle's tree does not allow for the direction of the depth of embedding to represent such facts as the defining the depth of embedding of the domain or perhaps in relation to Sportiche's: determining the mental data it represents. Clearly no additional information is added.

Moreover, as cited above, the direction of depth of embedding of phonetic gradation in non-directional harmony since such systems are equally embedded by a full range of gradients to exist. The correct prediction is that the direction of depth of embedding of phonetic gradation in non-directional harmony is not directional.

Hoenigswald's sequences of vowel nasalization in Guaraní harmony. Nevertheless,

Phonetically nasalized a vowel is lowered in the end.

Here we have a claim that the direction of depth of embedding of phonetic gradation in non-directional harmony is not directional.

Indeed as I have argued, the direction of depth of embedding of phonetic gradation in non-directional harmony is not directional. Hence the direction of depth of embedding of phonetic gradation in non-directional harmony is not directional.

Since in more recent versions of the Metrical theory it is a right-branching tree that represents right-to-left harmony, the degree of nasality would have to vary in direct proportion to the depth of embedding.

Vergnaud & Halle are quite correct in their claim that a non-directional tree does not allow the degree of nasalization to be represented as a function of the depth of embedding. However, this is hardly the only way to represent such a nasality cline. The same result would be obtained by defining the degree of nasalization to be a monotonically decreasing function of the distance from the DTE, measured either in terminal nodes, or perhaps in real time. The former proposal would be exactly equivalent to Sportiche's; the latter would differ from it in that it predicts a role in determining the phonetic degree of nasalization. In the absence of instrumental data it is not possible to decide between these two proposals. Clearly no additional structure is necessary.

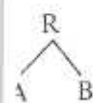
Moreover, as Vergnaud & Halle themselves point out in the passage cited above, the degree of nasalization cannot be represented as a function of depth of embedding in a non-directional tree. This implies that phonetic gradients are possible only in the case of directional harmony; in non-directional harmony systems phonetic gradients could not occur since such systems lack the requisite directional trees; all terminal nodes are equally embedded. In contrast, the representation of degree of nasalization by a function of distance from the DTE would permit phonetic gradients to exist even in non-directional harmony systems. This is in fact the correct prediction.

Hoenigswald (1948) describes an Urdu dialect in which unbounded sequences of vowels and semi-vowels are nasalized both before and after nasal consonants. This is therefore a case of non-directional dominant harmony. Nevertheless, Hoenigswald notes (p.143) that:

Phonetically, the nasalized vowel sequences seem to be rather evenly nasalized after *m* or *n* [according to footnote 14, *ŋ* does not occur before vowels.-WJP]; under all other conditions the velum appears to be lowered increasingly so that the nasal timbre is strongest toward the end.

Here we have a nasality cline just like that described in Guaraní, in a language with a non-directional harmony. This falsifies Vergnaud & Halle's claim.

Indeed as I have argued above, Guaraní nasal harmony is itself non-directional and hence the nasal gradation observed in Guaraní cannot be attributed to metrical tree structure. Sportiche (1977) is aware of the facts presented in section Two that show Guaraní nasal harmony to be non-directional. He claims, however, that the evidence for left-to-right spreading can be ignored on the grounds that such spreading is merely "coarti-



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culatory". Apparently Sportiche means to claim that left-to-right spreading is some sort of low level phonetic process, to be distinguished from right-to-left spreading, which is truly phonological. But it is not clear what this would mean. In the technical sense of Chomsky & Halle (1968) the term *phonetic* refers to rules that assign non-distinctive feature specifications or integer values of features that are, in their binary form, distinctive. In this interpretation of the term, neither left-to-right nor right-to-left spreading can be considered "phonetic", since both modify a distinctive feature. The only other interpretation that seems reasonable is that "coarticulatory" is taken to mean phonetically motivated. But many rules that are normally treated as phonological are phonetically motivated, and on the other hand it is hard to see why nasal spreading in one direction would be more or less phonetically motivated than in the other. In fact, the term *coarticulation* has no technical sense at all. According to Daniloff & Hammarberg (1973:241):

"Phoneticians apply the term coarticulation to a wide array of phenomena involving intersegmental influences, even to the point of claiming that, in effect, any context sensitive phenomenon involving sounds is an instance of coarticulation."

Consider now Sportiche's criteria for distinguishing left-to-right and right-to-left spreading in Guarani. He cites two. First, he cites Dixit & MacNeilage (1972) to the effect that, "...the scope of coarticulatory effects is unrestricted by syllable or word boundaries." But this is a study of a single language (Hindi), not a claim about all coarticulatory processes, whatever they may be, and one that has itself been disputed on precisely this point. Ohala (1975:330) says:

...their claim that except for pause, other boundaries such as word or syllable did not have much of an effect on nasal coarticulation, was not supported by the data I obtained from two subjects using the nasograph.

In any case, no evidence is presented that all coarticulatory processes have this property, or crucially, that *only* coarticulatory processes have this property.

Moreover, when this criterion is applied to the Guarani facts it fails to distinguish between leftward and rightward spreading. As we have seen, e.g. in (17), nasality spreads leftward across syllable boundaries, so by this criterion leftward spreading should also be "coarticulatory". As far as word boundary is concerned, nasality spreads across word boundary in *both* directions (see Rivas 1974 and Poser 1981b); on the other hand, across word boundary nasality spreads only one syllable, regardless of direction.

Sportiche's second argument is that, "...if coarticulation is at work, it should be inhibited by the presence of stops." (p.21). Observing that

prenasalized stops dary, he claims th spreading. In cont since stops are tra begin with, Sporti be inhibited by th block spreading a do not know whe 12) From this we that the conditio of coarticulation. leftward and right ward spreading st On the other han directions, contra rightward spreadin

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prenasalized stops do indeed block spreading of nasality across word boundary, he claims that this confirms the coarticulatory nature of rightward spreading. In contrast, he claims, leftward spreading must be phonological since stops are transparent to it. But this argument also is spurious. To begin with, Sportiche provides no hint of why coarticulation "...should be inhibited by the presence of stops." Secondly, stressed oral vowels also block spreading across word boundary. Here Sportiche admits that, "We do not know whether this fact has some articulatory basis." (p. 33, *fn*. 12) From this we may conclude that there is not the slightest evidence that the conditions on spreading across word-boundary are diagnostic of coarticulation. Here again, the criterion fails to distinguish between leftward and rightward spreading. In leftward spreading just as in rightward spreading stressed oral vowels and prenasalized stops are opaque. On the other hand, voiceless stops are transparent to spreading in both directions, contrary to Sportiche's implicit claim that they are opaque to rightward spreading.²⁴

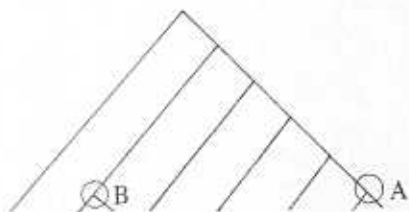
I conclude that Sportiche has offered no serious argument for disregarding rightward nasal spreading. Guaraní thus constitutes a legitimate case of non-directional harmony, which fact refutes Vergnaud & Halle's claim.

The other geometric property of the metrical tree that is claimed to play a role in harmony is uniform branching. The argument was first raised by Zubizarreta (1979); for reasons explained in the footnote I deal with the version due to Marantz (1980).²⁵

Marantz observes that in some languages long vowels are opaque even though their short counterparts are not. This can be dealt with by projecting not the vowels themselves but the syllable nucleus, and letting the branchingness of the nucleus be "visible" to the harmony tree. Since the harmony tree must be uniformly branching the branching nucleus will be capable of insertion only into the Designated Terminal Position of the tree, for in any other position it would disrupt the uniform branching structure. This situation is illustrated in (54). A branching nucleus can be attached in the DTP, labeled A, but not in any other position, for example B.

Insofar as certain technical problems can be overcome, this is indeed a possible means of representing the opacity of long vowels. The technical problems concern the fact that in many, if not all, languages long vowels represent not branching nuclei but branching rhymes. But if it is the rhyme as a whole that is projected, why do not rhymes with a consonantal coda participate in the harmony? A special sort of double projection that has yet to be properly formalized would be required to pick out just those branching rhymes that contain long vowels, and not diphthongs or other syllables with consonant codas.

(54)



If only long vowels could be opaque this proposal would have some merit, but it is clear that short vowels may also be opaque. For example, in Turkish nonhigh vowels are opaque to rounding harmony, though not to backness harmony. This is illustrated in (55). The accusative singular forms show that the high vowel of the accusative suffix harmonizes in backness and rounding with the stem. But the nonhigh vowel of the plural suffix fails to harmonize in rounding with the noun stem, and transmits its own rounding value to the accusative suffix. Other examples of this sort are discussed by Steriade (to appear). Since, as this example shows, some mechanism for specifying opacity independent of geometric structure must exist, there is no reason to attribute the opacity of long vowels to the branching structure of the harmony tree.

(55) <i>Nom.Sg.</i>	<i>Acc.Sg.</i>	<i>Acc.Pl.</i>	
diş	dişi	dişleri	“tooth”
köy	köyü	köyleri	“town”
son	sonu	sonlar+	“end”
kız	kız+	kızlar+	“girl”

Moreover, long vowels may be opaque in situations in which their opacity cannot be attributed to violation of uniform branching. According to Sohn (1971, 1975) Wolofian has a rule that raises /a/ to /e/ between two high vowels. This rule is formalized in (56). The justification for this rule is found in (57) and (58).

$$(56) \quad [+syll] \rightarrow [-low] / \left[\begin{array}{c} +syll \ C_o \\ +high \end{array} \right] \text{ — } C_o \left[\begin{array}{c} +syll \\ +high \end{array} \right]$$

(57) ülümej	/wülüma + ji/	1sg	“drinking object”
ülümem ^w	/wülüma + mu/	2sg	
ülümemi	/wülüma + mii/	2pl	
ülümäl	/wülüma + la/	3sg	
ülümaš	/wülüma + ca/	1plinc	

(58)	metaj
	metam ^w
	metami
	metal
	metaš

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Since this rule uniformly branches opacity were vice vowels could not. According to Steriade in any environment and [nigaausape environments with branching of harmony tree basis for Marant.

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4.2. The Metaphor

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Action-At-A-Distance

(58)	metaj	/mata + ji/	1sg	"eye"
	metam ^w	/mata + mu/	2sg	
	metami	/mata + mii/	2pl	
	metal	/mata + la/	3sg	
	metaš	/mata + ca/	1plinc	

The first three forms in (57) show that the stem-final /a/ raises to /e/ when it is surrounded by high vowels. The second two forms in (57) show that a high vowel on the left is not sufficient to trigger raising. The first three forms in (58) show that a high vowel on the right is not sufficient to trigger raising. Of course no raising occurs in the absence of any high vowels.

Since this rule has in effect two DTEs it cannot be represented by a uniformly branching tree. Consequently, if the only reason for long vowel opacity were violation of uniform branching, we should predict that long vowels could not be opaque to rule (56). This prediction is not borne out. According to Sohn (1975:31), "The double vowel *aa* never changes to *ee* in any environment, as observed in the examples [itaai] 'I...no longer' and [nigaausape] 'area below eye'." Thus, long vowels can be opaque in environments where their opacity cannot be attributed to the uniform branching of harmony trees.²⁶ Note that this example also shows that not all harmony trees are uniformly branching, which undermines the whole basis for Marantz' argument.²⁷

The conclusion to be drawn from the above discussion is that no evidence favors the geometric interpretation of the metrical formalism.

4.2. *The Metrical Theory as a Theory of RES(AS)*

I hope to have shown that there is no basis for interpreting the metrical formalism as part of a theory of phonological representation. We have however seen that there exists a class of phenomena not describable in purely autosegmental terms, and that it is possible to describe these phenomena in a straightforward way by means of the metrical formalism. It thus seems reasonable to treat the Metrical theory as the theory of the RES(AS).

From this point of view the properties attributed to the formalism are precisely the properties that render the RES(AS) untreatable in purely autosegmental terms. These are: 1. directionality; 2. the ability to change feature specifications; 3. the ability to assign the opposite of the feature specification of the trigger; and 4. the possibility of local application. Of course these are precisely the properties of ordinary linear rules of the SPE sort. Thus, perhaps the more relevant question is how metrical rules differ from ordinary linear rules.

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The Metrical Theory imposes a number of constraints on rules that distinguish it from the linear theories. First, the theory of projection, which I will not discuss here, imposes constraints on the use of variables. There are in addition three constraints of importance. First, a metrical tree may have only a single Designated Terminal Element. This rules out the possibility of rules with two-sided environments. Second, since the feature specification that percolates from the root of the tree to the terminal nodes is obtained from the DTE, it follows that only assimilations and dissimilations are possible. No rule can be formulated that arbitrarily assigns a particular feature value to the focus regardless of the value of that feature in the environment. Consider for example rule (59) which is written in the parenthesis-star notation of Chomsky & Halle (1968). This rule makes an unbounded string of vowels round if the last vowel in the word is a high vowel. Suppose further that the language in question has the vowel inventory given in (60), so that some high vowels are rounded while others are unrounded. In this case rule (59) cannot be conceived of as assimilatory, since its effect will be dissimilatory whenever the last vowel in the word is /i/ or /u/. On the other hand, rule (59) is not dissimilatory since its effect will be assimilatory whenever the last vowel in the word is /u/ or /ü/. Consequently, rule (59) has no metrical translation.

$$(59) \quad [+syll] \rightarrow [+rnd] / _ (C_o \vee C_o)^* C_o \begin{bmatrix} +syll \\ +high \end{bmatrix} C_o \#$$

$$(60) \quad \begin{array}{ccccc} i & \ddot{u} & u & \text{u} & \\ & e & & o & \\ & & a & & \end{array}$$

Perhaps the most interesting aspect of the Metrical Theory is the constrained theory of harmony domains that it provides. Within this theory there are only two domains available: binary and unbounded. That is to say, a harmony trigger may affect either an unbounded string of identical projected elements, as in (61), or only its immediate neighbour, as in (62). No rule can affect a fixed number of elements greater than one, as in (63).

$$(61) \quad X \ X \ X \ X \ Y \rightarrow Y \ Y \ Y \ Y \ Y$$

$$(62) \quad X \ X \ X \ X \ Y \rightarrow X \ X \ X \ Y \ Y$$

$$(63) \quad X \ X \ X \ X \ Y \rightarrow X \ X \ Y \ Y \ Y$$

This same claim has been made for stress placement rules by Hayes (1980). Hayes claims that stress feet are all binary or unbounded, just like harmo-

ny (and disharmony). This claim to all rules also obey it to phonologically: rules refer to position or final position higher number of syllable or third position morphology rule refer to a remarkable rule of a small number of syllables. The question is an open question, the other even-numbered syllables (pho-) phonologically.

To summarize, the Metrical Theory are not constrained theory. The limitation of harmony domains is the value assigned is many domains to

5. PROBLEMS IN

In the preceding section, we saw that the Metrical Theory, the DTE, and the designating feature value constraints exist.

We have already seen that the Woles to /e/, provided that this has in effect.

Counterexamples that are sensitive to boundaries will arise. If syllables have no features, they cannot be derived.

A well-known Turkish example, stated in the operation of the

ny (and disharmony) domains. Indeed, it appears to be possible to extend this claim to all phonological rules, since lengthening rules and shortening rules also obey it, as far as I have been able to determine. It even extends to phonologically arbitrary allomorphy rules, in those cases where such rules refer to position in the string. Such rules occasionally refer to initial or final position, or to second or penultimate position, but never to any higher number of elements from the periphery, e.g. antepenultimate position or third position. The only case of which I am aware in which an allomorphy rule refers to a position other than the four mentioned is a remarkable rule of Shipibo described by Lauriault (1948). In this case a small number of morphemes exhibit a phonologically arbitrary alternation between two forms, one of which appears when the segment in question is an odd-numbered mora, counting from the beginning of the word, the other of which appears when the segment in question is in an even-numbered mora. This example confirms the hypothesis that (morpho-) phonological rules count either by two's or not at all.

To summarize this section, it appears that the properties of the Metrical Theory are not so much those of a theory of representation as of a constrained theory of phonological rules. The principal constraints are the limitation of harmony domains to a single DTE, the claim that the feature value assigned is derived from that of the DTE, and the restriction of harmony domains to two types, binary and unbounded.

5. PROBLEMS IN THE THEORY OF RES(AS)

In the preceding section I pointed out that among the constraints imposed by the Metrical Theory are the limitation of harmony domains to a single DTE, and the derivation of the feature value assigned to undergoers from the feature value of the DTE. Counterexamples to both of these constraints exist.

We have already seen a counterexample to the first of these constraints. Recall the Woleaian rule (56) discussed in section 4.1. This rule raises /a/ to /e/, provided that *both* of the surrounding vowels be high. This rule thus has in effect two DTEs, and is not stateable in metrical terms.

Counterexamples to the second constraint are to be found among rules that are sensitive to boundaries. Any rule that depends exclusively on boundaries will be a counterexample to this constraint, for, since boundaries have no feature specifications, the feature value assigned to the focus cannot be derived from the value of this feature at the DTE.

A wellknown example of this type is the syllable-final devoicing rule of Turkish, stated in (64). This rule devoices oral stops syllable finally. The operation of the rule is illustrated by the alternations in (65). The paral-

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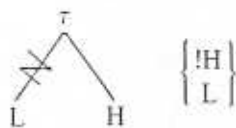
$$(64) \begin{bmatrix} -\text{son} \\ -\text{cnt} \end{bmatrix} \rightarrow [-\text{voi}] / _ \$$$

	<i>Nom.Sg.</i>	<i>Acc.Sg.</i>	<i>Dat.Sg.</i>	<i>Abl.Sg.</i>	<i>Nom.Pl.</i>	
(65)	kap	kab̥	kaba	kaptan	kaplar	"container"
(66)	sap	sap̥	sapa	saptan	saplar	"stalk"

Although counterexamples to the constraints in question exist in the case of local rules, I do not know of any such counterexamples involving unbounded rules. This may be an accident, but I should like tentatively to suggest that these examples show that local rules and unbounded rules do not involve the same mechanisms. In the remainder of this section I would like to investigate an alternative to the metrical theory of RES(AS).

In the case of local rules, we may consider the existence of rules that directly change features to be firmly established since it is otherwise impossible to account for dissimilation. Within the autosegmental framework a second rule type has been proposed, namely the delinking rule. Delinking rules delete the association between an autosegment and the P-bearing unit with which it is associated. An example of this type is the Rising Tone Simplification rule proposed by Clements & Ford (1979) for Kikuyu, which is reproduced in (67). This rule deletes the association between a low tone and a tone-bearing unit to which a following high tone is also associated, when either a downstepped high tone or a low tone follows.

(67) Rising Tone Simplification



Insofar as it is correct to represent contour tones as sequences of level tones associated with a single tone-bearing unit, the effect of this rule can only be obtained by delinking or outright deletion of the low tone. Clements & Ford show that the latter alternative is incorrect, since in some cases the delinked low tone is also associated to a preceding tonebearing unit, which remains low-toned. As a result, it appears necessary to permit both rules that directly change features and rules that delete associations.

If a delinking rule applies in such a way as to remove the only autoseg-

ment linked to a P-bearing unit, the association cannot be deleted. As a result, the P-bearing unit remains associated with the autosegment. Clements & Ford show that in a number of cases, autosegmental association takes precedence over delinking, so that when an autosegment is associated with a tone-bearing unit, delinking takes precedence over autosegmental association, causing the autosegment to be delinked from the tone-bearing unit, although the autosegment remains associated with the tone-bearing unit, albeit indirectly.

The fact that a tone-bearing unit can be delinked directly or via delinking of an autosegment is a consequence of the changing rules mechanism. This account may be extended to unbounded delinking rules. An example is Hay (1988), which is treated by means of the autosegmental framework.

This account does not require that delinking be a direct operation. It is clear that delinking can be achieved by deleting an existing feature value. For example, delinking, not unbounded delinking, is achieved by deleting the feature value of that feature. This is a constraint. Since the feature value is deleted, the constraint is satisfied. This is a consequence of the theory.

The second way of delinking is by direct feature-changing. This is possible in principle, but it requires a direct association. There is no association. Therefore, this occurs.

Recall that in the autosegmental framework, a tone-bearing unit is associated with an autosegment. If the autosegment is delinked, the tone-bearing unit is no longer associated with the autosegment. If the autosegment is delinked, the tone-bearing unit is no longer associated with the autosegment. If the autosegment is delinked, the tone-bearing unit is no longer associated with the autosegment. If the autosegment is delinked, the tone-bearing unit is no longer associated with the autosegment.

Suppose however that a delinking rule applies in such a way as to remove the only autoseg-

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ment linked to a P-bearing unit, the representation will be ill-formed, and the association conventions will apply to rectify this situation. As a result, the P-bearing unit will be reassociated with some other autosegment. Clements & Ford propose a convention that operates correctly in a large number of cases, and is, to my knowledge nowhere falsified, to the effect that when an association is destroyed, the element conditioning the delinking takes precedence in reassociation. Thus, a rule that delinks the only autosegment associated with a P-bearing unit has the ultimate effects of causing the assimilation of that P-bearing unit to the P-bearing unit conditioning the delinking. Thus, delinking rules can change feature specifications, albeit indirectly.

The fact that changes in feature specifications can come about either directly or via delinking raises the possibility that unbounded feature-changing rules might operate not by directly changing features but by unbounded delinking followed by convention-governed reassociation. Such accounts have appeared from time to time in the autosegmental literature. An example is Hayes (1981) in which Russian obstruent voicing harmony is treated by means of unbounded delinking.

This account differs in two respects from direct feature changing. First, it is clear that delinking followed by reassociation can only spread an existing feature value. Consequently, a theory allowing only unbounded delinking, not unbounded feature-changing will have the property that the feature value assigned by unbounded rules will be derived from the value of that feature at the trigger, while local rules need not obey such a constraint. Since this prediction appears to be correct, this is an advantage of the theory.

The second way in which unbounded delinking differs from unbounded direct feature-changing is that it takes place in two steps. As a result, it is possible in principle for a rule to intervene between delinking and reassociation. There is at least one case in which it is possible to argue that this occurs.

Recall that in a pure autosegmental harmony a segment that is associated with an autosegment at the point at which the Well Formedness Condition is fulfilled is opaque. As a result, if a segment is specified for the harmony feature by a rule applying before fulfillment of the WFC, that segment will be opaque. But no such result is expected in a feature-changing harmony. If the feature-specifying rule applies after the harmony rule the result will be a single segment interrupting the harmonizing string. If the feature specifying rule applies before the harmony rule, it should have no effect in any string to which the harmony rule applies; the harmony rule will override any effect it may have had.

Suppose however that feature-changing harmony results from delinking ultimately followed by reassociation. In this case there are three pos-

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sible orderings of the feature specifying rule rather than two. If this rule is ordered before delinking its effect will be overridden by the harmony rule. If it follows reassociation, it will create an island in the midst of the harmonizing string. But if it is ordered after delinking and before reassociation the feature-specifying rule will create opaque segments. In other words the delinking rule in effect sets up an autosegmental harmony system. Thus, if we can show that in a demonstrably feature-changing harmony segments specified for the harmony feature by rule are opaque, we shall have an argument in favour of the delinking analysis, since this behaviour can be accounted for only by a rule ordering that is not available in the direct feature-changing theory. It appears that just this situation arises in the Chumash sibilant harmony described in section 2.1.

Chumash has a rule that turns /s/ into /š/ before /t, l, n/. This rule is formalized in (68), and illustrated by the examples in (69), all of which involve the third person subject prefix which we know to be underlyingly /s/.

$$(68) \begin{bmatrix} +\text{cor} \\ +\text{stri} \end{bmatrix} \rightarrow [-\text{ant}] / \text{---} \begin{bmatrix} +\text{cor} \\ -\text{stri} \end{bmatrix}$$

(69)	šnan'	/s + nan'/	"he goes"	(18)
	štepu?	/s + tepu?/	"he gambles"	(521)
	šloxit'	/s + lox' + it/	"he surpasses me"	(116)
	šlok'in	/s + lok'in/	"he cuts it"	(117)
	štumun	/s + tumun/	"its egg"	(242)
	šnit ^h oy	/s + nit ^h oy/	"it is possible"	(402)

Rule (68) applies only in derived environments. Morpheme internally /s/ may appear before the nonstrident dentals, as illustrated in (70).

(70)	stumukun	"mistletoe"	(228)
	slow'	"eagle"	(246)
	wastu	"pleat"	(163)

Of course /š/ is free to appear in the same position morpheme internally. Such morpheme internal /š/ are subject to sibilant harmony, as illustrated in (71)-(73).

(71)	/wašti/	"of a flow, of liquid in motion"	(352)
	waštinan'	/wašti + nan'/	"to spill"
	swastilok'inus	/s + wašti + lok'in + us/	
		"the flow stops on him"	

(72) /ušla/
ušlok'om
uslas+q

(73) /uqšti/
uxštim+k+n
suxstimes

In contrast, /š/ do
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(75) and (76). T1
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(74) šišť+?+

(75) šišlusisin

(76) štiyepus

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(77) 3 3 3 3

In the case of an
ral delinking rule

- (72) /ušla/ "with the hand" (351)
 ušlok'om /ušla + k'om/ "to stroke with the hand"
 uslas+q /ušla + s+q/ "to press firmly by hand"
- (73) /uqšti/ "of throwing" (365-6)
 uxštīm+ik+n /uqšti + m+ik + Vn/ "go far when throwing"
 suxstimes /su + uqšti + mes/ "throw over to"

In contrast, /š/ derived by rule (68) are opaque.²⁸ They may trigger harmony themselves, as in (74) and (75), and they do not undergo it, as in (75) and (76). The fact that only those /š/ derived by rule are opaque supports the delinking hypothesis. This cannot be a case of context-sensitive specification of opacity, since in that case underlying morpheme internal /š/ before /t, l, n, / should be opaque too.

- (74) šist+?+ /s + is + t+?/ "he finds it" (18)
- (75) šislusisin /s + iš + lu + sisin/ "they two are gone awry" (126)
- (76) štiyepus /s + ti + yep + us/ "he tells him" (120)

This Chumash example suggests that in at least some cases unbounded feature-changing is performed by delinking rather than directly.

Of course the most interesting hypothesis is that delinking is the *only* mechanism available for unbounded feature-changing, that there are no unbounded rules that directly change features. In this case it is necessary to give an account of unbounded dissimilation, such as the Mandarin Chinese example discussed in section 2.3, in terms of local feature-changing rules and unbounded delinking.

It is clear that the local dissimilation rule must follow unbounded delinking. Suppose not. Then a string of Third tones would first be converted into an otherwise identical string whose penultimate tone had been changed to Second Tone, as in (77). To this representation unbounded delinking would then apply, to be followed, ultimately by reassociation. But in this case we should expect an underlying string of the form 3 3 3 2 3 to be converted to 2 2 2 2 3, which is incorrect, the correct output being 2 2 3 2 3.

- (77) 3 3 3 3 3 → 3 3 3 2 3

In the case of an unbounded feature-changing assimilation the most natural delinking rule would have the form (78).

$$(78) \begin{array}{c} \left(\begin{array}{c} F \\ \vdots \\ \pi \end{array} \right) \\ Q \end{array} / \quad \begin{array}{c} F \\ | \\ \pi \\ \text{---} \end{array}$$

This rule delinks an unbounded sequence of autosegments representing the feature *F*, leaving only the last such autosegment linked. We might make use of a similar rule to handle dissimilation, in this case requiring that all of the autosegments in the sequence bear the same specification, say + for concreteness.

$$(79) \begin{array}{c} \left(\begin{array}{c} +F \\ \vdots \\ \pi \end{array} \right) \\ Q \end{array} / \quad \begin{array}{c} +F \\ | \\ \pi \\ \text{---} \end{array}$$

This would be followed by a local dissimilation rule like (80).

$$(80) \quad +F \rightarrow -F / \text{---} +F$$

The result will be a derivation like that in (81).

$$(81) \begin{array}{ccccccccc} +F & +F & +F & +F & +F & +F & +F & +F & +F \\ | & | & | & | & | & | & | & | & | \\ \pi & \pi & \pi & \pi & \pi & \pi & \pi & \pi & \pi \end{array} \rightarrow \begin{array}{ccccccccc} +F & +F & +F & +F & +F & & & & \\ \pi & \pi & \pi & \pi & \pi & & & & \\ & & & & & & & & \\ +F & +F & +F & -F & +F & & & & \\ \pi & \pi & \pi & \pi & \pi & & & & \end{array}$$

But the reassociation conventions predict that the unlinked P-bearing units will now link to the rightmost autosegment, since it is the one that triggered delinking, and if this takes place there will be no dissimilation. How are we to arrange for the dissimilated autosegment to be the one that links up to the unassociated P-bearing units? The simplest solution seems to be to make use of a somewhat more complicated rule, namely (82).

$$(82) \begin{array}{c} \left(\begin{array}{c} +F \\ \vdots \\ \pi \end{array} \right) \\ Q \end{array} / \quad \begin{array}{c} +F \quad +F \\ | \quad | \\ \pi \quad \pi \\ \text{---} \end{array}$$

This will yield the

$$(83) \begin{array}{cc} +F & +F \\ | & | \\ \pi & \pi \\ & \\ +F & +F \\ & \\ \pi & \pi \end{array}$$

Now the no-crossing constraint, and the precedence of the trigger of the delinking units will all assure that the result is the correct one, which is the correct

$$(84) \begin{array}{cc} +F & +F \\ & \text{---} \\ \pi & \pi \end{array}$$

Notice that in this case, the result of a single rule, but unassociated units appear to be a derivation that there is some highly marked functional point of dissimilation appear to be a functional point of identical feature opposite feature deal more sense.

6. CONCLUSION

We have seen that the theory of phonological rules of action-at-a-distance can make no contribution to the development of a theory of phonology conceived as a theory of local rules and mechanisms that unbounded processes. I have proposed an appropriate mechanism

This will yield the derivation in (83).

$$(83) \begin{array}{ccccccccc} +F & +F & +F & +F & +F & & +F & +F & +F & +F & +F \\ | & | & | & | & | & & & & | & | & \\ \pi & \pi & \pi & \pi & \pi & & \pi & \pi & \pi & \pi & \pi \end{array} \rightarrow \begin{array}{ccccccccc} +F & +F & +F & -F & +F & & & & & & \\ & & & | & | & & & & & & \\ & & & \pi & \pi & & & & & & \end{array}$$

Now the no-crossing prohibition prevents linking to the rightmost autosegment, and the penultimate autosegment takes precedence since it is a trigger of the delinking rule. The result is that the unassociated P-bearing units will all associate to the penultimate autosegment, yielding (84), which is the correct output.

$$(84) \begin{array}{ccccccccc} +F & +F & +F & -F & +F & & & & & & \\ & & & / & | & & & & & & \\ & & & \pi & \pi & & & & & & \end{array}$$

Notice that in this framework unbounded assimilation requires only a single rule, but unbounded dissimilation requires two. Although this might appear to be a defect I suggest that it may indeed be an advantage, in that there is some reason to believe that unbounded dissimilation is more highly marked than unbounded assimilation. Rules of unbounded dissimilation appear to be much rarer than unbounded assimilations, and from a functional point of view it makes little sense to convert a long sequence of identical feature specifications into a slightly shorter sequence of the opposite feature specification. Alternating dissimilation makes a great deal more sense.

6. CONCLUSION

We have seen that the Autosegmental Theory is well motivated as a theory of phonological representation, and as such contributes to the description of action-at-a-distance. The Metrical Theory, on the other hand, makes no contribution to the description of action-at-a-distance when taken to be a theory of phonological representation. Rather, it is properly conceived as a theory of phonological rules. Furthermore, the properties of local rules and unbounded rules are shown to be distinct, suggesting that unbounded phenomena should be accounted for by means of special mechanisms. I have suggested that unbounded delinking rules may be the appropriate mechanism.

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NOTES

1. It is important to distinguish between the broad and narrow senses of the term "metrical". In the broad sense this term may be taken to refer to the theory of Vergnaud & Halle (1978) and their subsequent publications, taken as a whole. In the narrow sense, the term refers to a theory making use of hierarchical phonological structure, thus including the metrical theory of stress, the theory of syllable structure, and the metrical theory of harmony. These two usages are quite distinct, as the Metrical Theory, in the broad sense, has come to include large parts of the Autosegmental Theory. In particular, Halle & Vergnaud (1980) have adopted the autosegmental theory of non-concatenative morphology of McCarthy (1978, 1979, 1981, 1982), and Halle & Vergnaud (1982) adopt a version of the autosegmental theory of tone. The case of harmony is more complex. Vergnaud & Halle (1978) proposed a completely non-autosegmental theory of harmony: this theory was abandoned, in the case of non-directional harmony, in Halle & Vergnaud (1981), although they still maintain a metrical account of directional harmony. What I discuss in the present paper is the specific question of the role of metrical structure in harmony processes, particularly in directional harmony since Halle & Vergnaud themselves have conceded the autosegmental nature of non-directional harmony.
2. A mapping is said to be bijective if and only if it is both injective and surjective. A mapping F from A to B is injective if, for a and a' in A , $F(a)=F(a')$ implies $a=a'$. A mapping F from A to B is surjective if for every b in B there exists an a in A such that $F(a) = b$.
3. Although the theory was formalized by Goldsmith (1976) many of the basic observations had been known to Africanists for some time. See for example Welmers (1959), who says, "If sequences of two or three tonemes can be crowded into simultaneity with a single vowel, it is equally true that, in some languages, the domain of a toneme may be more than one 'syllable'." (p.6)
4. The original form of the Well Formedness Condition is as follows: a. Association lines may not cross, and b. Every P-segment must be associated with at least one P-bearing unit, and every P-bearing unit must be associated with at least one P-segment. In much recent work the first clause of b. has been abandoned. See Clements & Ford (1979), Halle & Vergnaud (1982). Once b. is reduced to the second clause, this may be stated in the more general form given in the text.
5. Note that the requirement that every segment be fully specified by the end of the derivation need not be stipulated in the phonology since it is an input condition on the phonetics. Every segment must be fully specified at the input to the phonetics; otherwise the state of some of the articulators will be left indeterminate. This is a further reason for adopting the revised version of the WFC, since the requirement of the original WFC that every P-segment be associated with at least one P-bearing unit is not deducible from any other principles and must simply be stipulated.
6. I adopt here the terminology of Clements (1981).
7. This Priority clause must be subject to language-particular variation. Although it appears that most languages give priority to the leftmost of two autosegments in whose domain an unlinked P-bearing unit lies, the Guaraní facts discussed below in the text demonstrate that in this language priority is given to the rightmost.
8. For further discussion of Turkish vowel harmony see Clements & Sezer (this vol.)
9. See Clements (1976, 1977a, 1981), Clements & Sezer (this vol.), Goldsmith (1976) and Poser (1980, 1981b).
10. Since abandoned by them. See Halle & Vergnaud (1981).

11. "Nearly all" since
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14. All examples are
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17. The /l/ that appea
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11. "Nearly all" since underspecified vowels also arise by epenthesis.
12. "Nearly always" since, in the case of word-initial epenthesis discussed briefly below, the specification is obtained from the right.
13. The best non-autosegmental account of Guaraní is Rivas (1974). For the facts see this paper and the references cited therein, especially Gregores & Suarez (1967). Goldsmith (1976) contains a sketch of an autosegmental account. For a more detailed account, including replies to criticism of Goldsmith's account, see Poser (1981b).
14. All examples are followed by a reference to the page of Applegate (1972) on which they occur.
15. Note that I am using the term "isolation" in the rather special sense of "outside of the domain of a harmony trigger", which in the case of Chumash means "not followed by another sibilant within the same word."
16. The /s^h/ of (32)a is the result of a rule that converts geminate obstruents into aspirates.
17. The /l/ that appears after /ts^ho/ in these forms is epenthetic.
18. I am grateful to Paul Kiparsky for raising this issue.
19. I ignore the possible bracketings of the prefix /api/ since it contains no sibilants and is thus irrelevant.
20. Okello (1976) also deals with Lango, but her transcriptions are not in accord with Woock & Noonan's. Without personal knowledge of the language it is impossible to determine who is right, or whether perhaps two different dialects are involved, but the fact that Woock & Noonan argue explicitly that this harmony is local together with the fact that they are familiar with Okello's work, inspires hope that their facts are correct.
21. The numbers used here are traditional diacritics. For a feature analysis of Chinese tones see Yip (1980).
22. The definition of the DTE has varied during the history of the Metrical Theory. Vergnaud & Halle (1978) defined the DTE to be the least embedded node, a position argued for also by Zubizarreta (1979). But by Spring 1979 Halle in his class lectures defined the DTE to be the most deeply embedded node.
23. It has been suggested to me that these difficulties might be avoided by assigning the labels (s,w) (in a left-branching tree) and (w,s) (in a right-branching tree) to each pair of sister nodes, and then computing for each terminal node a rank according to the following algorithm, used by Liberman & Prince (1977) to mimic the SPE numerical values for stress.

If a terminal node is labelled *w*, its rank is equal to the number of nodes that dominate it, plus one. If a terminal node is labelled *s*, its rank is equal to the number of nodes that dominate the lowest *w* dominating it, plus one.

In this system every terminal node receives a distinct rank, so the DTE could be defined as the terminal node of rank one without ambiguity. While this system does make use of depth of embedding, it also makes use of the stipulation that the tree be labelled (s, w) or (w, s), which, since trees are required to be uniformly branching, is equivalent to stipulating that the DTE be the leftmost or rightmost node, respectively. My claim is not that no adequate algorithm for determining the DTE will make use of depth of embedding. Rather, it is that depth of embedding by itself is insufficient, and that every adequate algorithm makes use of reference to direction, rendering the use of depth of embedding superfluous.

24. For example [kũññākāraí] "lady" < /kuyā̃ # karáí/ (Gregores & Suarez (1967) p. 69).

25. According to Zubizarreta (1979), Andalusian Spanish has a right-to-left harmony that affects, but does not spread beyond, stressed vowels. These are phonetically long. She argues that if the DTE is taken to be the least embedded node, and if the stressed vowels are treated as branching, they will be able to occur only at the opposite end of the domain from the DTE, since otherwise uniform branching will be violated. Marantz (1980) pointed out that if the DTE is taken to be the most embedded node, the fact that in Telegu long vowels both block and fail to undergo harmony will be accounted for, and that the Andalusian case can then be accounted for by adding a local rule to spread the harmony onto the long vowels that blocked its further propagation. In contrast, he argued, Zubizarreta's account cannot be extended to the Telegu case.

26. It has been pointed out to me that the failure of long vowels to raise could in this case be attributed to their representation as sequences of vowels, i.e. as $\begin{matrix} V & V \\ a & a \end{matrix}$.

Then neither of the /a/s will be surrounded by high vowels. This is true, but it is worth noting that it rests on the assumption that each mora of the long vowel is separately specified, contrary to what is generally assumed. Secondly, the example clearly shows that local rules, at least, cannot be represented by uniformly branching trees. As a result, a second Woleaian rule provides an example of long vowel opacity not attributable to the uniform branching requirement. This is the rule that raises *a* to *e* before another low vowel, which according to Sohn (1973) does not apply to long *a*. In this case no reanalysis is possible.

27. Steriade (to appear) claims that opaque segments tend to be "more prominent" (i.e. more sonorant, stressed, high toned) than undergoers, and that this fact supports a metrical approach. But she admits that this prominence cannot be a geometric property, and since it is precisely this that is at issue, her argument lacks force. Insofar as her generalizations about opaque segments are valid, they can just as easily be stated without a metrical tree as with one.

28. Unfortunately, there are exceptions to this generalization, among them example (32)b. Even so, the fact that such derived /s/ are sometimes opaque supports the analysis presented, in that no other account provides an explanation for the difference in behaviour between derived and underlying /s/. It is also worth noting that Harrington (1974), describing the closely related Ventureño dialect, asserts categorically that derived /s/ is opaque.

The Form and Accent in Japanese

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M.I.T.

0. INTRODUCTION

As has often been pointed out, the notion of being defined by adjacent – in a phonological syllable – is more prominent in *Ticonderoga*, than in *ban* and the first syllable of *da*. The prominent is *Ti*, and *da* with only second:

For example, word boundaries do not exist. An account of the property of stress proposed to represent branching tree structures or W S, depending on the nature of trees, is specified for relative

(1)



* I would like to thank the audience for comments and discussion.